AN INVESTIGATION OF THE CURRENT CHALLENGES IN THE IMPLEMENTATION OF GRADE 11 CHEMISTRY LABORATORY WORK IN THREE SELECTED SECONDARY SCHOOLS IN ERITREA

HADISH WOLDU FESSEHATSION

A mini-thesis submitted in partial fulfilment of the requirement for the degree of M.Ed. in the Faculty of Education, University of the Western Cape.

Supervisor: Mrs. Sue Davidoff September, 2003.

DECLARATION

I declare that *AN INVESTIGATION OF THE CURRENT CHALLENGES IN THE IMPLEMENTATION OF GRADE 11 CHEMISTRY LABORATORY WORK IN THREE SELECTED SECONDARY SCHOOLS IN ERITREA* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

HADISH WOLDU FESSEHATSION September 2003.

Signed:------------

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ABSTRACT

The study has attempted to investigate the current challenges in the implementation of Grade 11 chemistry laboratory work in three selected secondary schools in Eritrea. Specifically, the study has attempted to address the following questions:

- To what extent does Grade 11 chemistry laboratory work in the selected Eritrean secondary schools promote the achievement of Kerr's (1963) aims of practical work in school science, particularly in chemistry?
- How adequate are the conditions of Grade 11 chemistry laboratory work in the selected Eritrean secondary schools?
- What constraints/problems do Grade 11 chemistry teachers encounter in implementing and teaching laboratory work?
- What challenges do Grade 11 chemistry teachers encounter in implementing and teaching laboratory work?

Data were collected through two instruments: questionnaires and interviews, conducted with various stakeholders viz: teachers, laboratory assistants, students and a member of the chemistry panel. The outcome of the data was analysed in terms of appropriate qualitative and quantitative descriptions.

The results of the data revealed that there were many problems and challenges chemistry teachers encountered during the implementation of Grade 11 chemistry laboratory work. Lack of resources, unqualified laboratory assistants, large class size, teaching overload, double shift system, poor infrastructure of the laboratory rooms, poor preparation of teachers, incoherence of laboratory activities with theory, and time constraints were the main problems that hampered the implementation of laboratory work. The challenges were: the way of introducing the different teaching methods; the way of integrating stated laboratory activities, the implementation process and

the needs of students in their daily life; the struggle of how to organize the activities in the chemistry curriculum to appeal to student interest without abandoning the organized study of the discipline; the struggle to accommodate large number of students in laboratories on one hand and deal with the acute shortage of space of the building on the other hand; the setting up of an appropriate teaching load; the establishment of a proper shift system; managing students in large class size laboratory work; the need for well qualified and trained laboratory assistants as well as skilled teachers and the need to set out an appropriate laboratory timetable.

Some of the recommendations include:

- One recognized research centre and one organization body should be established at national level to carry out responsibilities for in-service training and recruiting qualified teachers and laboratory assistants.
- Scarcity of resources should be improved through the allocation of an increased proportion of the budget from the ministry of education and greater efficiency in the use of existing allocations through 'cost-saving reforms'.
- Continued methodological dialogue should be provided among the teachers in order to support and accept the use of various methods.
- The number of students should not exceed 35 students at least to have reasonable management and attention for individual students in laboratory work.
- The laboratory room must be sufficiently sized and designed to accommodate the students of one class and to support a wide diversity of teaching styles and methods.
- Major reforms are currently needed in laboratory work in order to coordinate the teaching of chemistry concepts with their applications in the laboratories as well as to produce students as critical thinkers and problem solvers.

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LIST OF ABBREVIATIONS

B.Sc.= Bachelor of Science

DDT= Dichloro-Diphenyl-Trichloroethane.

DGE = Department of General Education

EHRD = Eritrean Human Resources Development

EPLF = Eritrean Peoples' Liberation Front

MoE= Ministry of Education

Sq.Km = Square kilometres

UK= United Kingdom

UN = United Nations

UNESCO= United Nations Educational, Scientific and Culture Organization

USA= United States of America

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Eritrea is a country which is located in the so-called Horn of Africa. It has an area of approximately 123, 300sq.km and, according to the 1994 census, Eritrea has a population estimated at 3,615,050, an annual population growth of about 2.7% and an average population density of 29/sq.km (Ministry of Education, 2000/01: 8). It is bordered on the west and north-west by the Democratic Republic of Sudan, on the south by Ethiopia, on the south-east by the republic of Djibouti, and on the north-east and east by the Red Sea. It lies about 1200km along the east on the coast of the Red Sea.

Due to its strategic location, and its closeness to the sea, Eritrea has been a target of foreign invasion for many years. It was an Italian colony from 1890 to 1941 (about 50 years) until the Italians were entirely defeated by the British in 1941. The British also colonized Eritrea from 1941 to1952 (about ten years) before it annexed with Ethiopia under the so-called Federation. In 1952, Eritrea was federated with Ethiopia, by a UN resolution as an autonomous state (Cliff and Davidson, 1998). However, from 15 November 1962, by Proclamation Number 27, the Federal State of Eritrea was terminated and then it was integrated into the administration of the Ethiopian regime (Taye, 1991). After a 30-year war with Ethiopia, Eritrea was liberated in 1991 and achieved its independence from Ethiopia in May 24, 1993 with a referendum at 99.8% voting 'yes' for Eritrean Independence.

1.2 DEVELOPMENT OF EDUCATION IN ERITREA

According to Fiseha (1996: 26) Eritrea, like other African countries, inherited its educational systems from a variety of foreign sources. Historically, in many African countries, education has originated as a result of activities of religious missions of various denominations (Feiter, Vank and Akker, 1995: 22). Eritrea is not an exception. Even though the introduction of Christianity was the turning point for the development of the traditional educational system, formal science education was started with the emergence of Italian religious missions and with the establishment of the Italian colony.

During the Italian era, the education that was introduced was limited in scope. That is, it only went as far as Grade Four. One purpose of education was to ensure that Eritreans had a respect for Italian culture and civilization. The Italian culture and language was taught and promoted in schools. Italians began to design their own curriculum of education in Eritrea to meet the requirements of the colonial needs and aspirations which were based on segregation and discrimination (Taye, 1991: 22), by establishing separate schools for Italian and Eritrean children. Native Eritreans were not allowed to study beyond Grade Four. This was considered as sufficient to develop the necessary skills to enable Eritreans to become interpreters, clerks, telephone operators, and typists required by the Italian officials.

The basis for modern education was started within the ten years of British Military administration, when they took over responsibility for schools after defeating the Italians from East Africa, especially from Eritrea and Ethiopia. The number of schools became twice as many as there had been during the Italian's colonial rule. The main goals of the British educational structure were to force Eritreans into a wage economy (i.e. to force the pupils into work and to survive with a monthly salary) and to break up tribal solidarity (to break the unity of various ethnic groups) -Tigrinya for Christians in the highlands, Arabic for Muslims in the lowlands and Kunama for Kunama people (Taye, 1991). The introduction of these languages (Tigrinya, Arabic and Kunama) and the recruitment of Eritrean teachers were the main distinguishing features of British colonial rule in comparison to Italians. However, the educational system (or curriculum) included academic rather than vocational subjects. This was inadequate to meet the needs and interests of Eritreans.

Under the period of the Federation of Eritrea with Ethiopia (1952-1962), the first secondary schools were opened and the University of Asmara was officially established on 20 December 1958. Education was given increased priority on all levels. Secondary students now started to study chemistry.

During the Ethiopian colonial period, the Ethiopian regime took education as a political tool that tried to inculcate its colonial ideology into the Eritrean society. This ideology helped them to extend their rule in Eritrea for a long period. In addition, it was intended to paralyze skilled and educated human power so as to make Eritrea dependent on other countries (Department of General Education, 1997: 1) as well as to undermine the Eritrean identity. Eritrea had only one university with very limited capacity. Those Eritreans who passed matriculation but did not have the chance to attend university were forced to go to central Ethiopia (about 1800km from Asmara) in order to continue their higher education. Very few Eritreans could afford the financial expenditure. In this case, some of them remained there and some of them changed their nationality while others came back home. So the number of educated human resources declined, and shortages of human resources have still persisted in the present new nation. In addition, Amharic became the language of instruction in Eritrean schools, replacing Tigrinya and Arabic. As a consequence, the education system deteriorated both qualitatively and quantitatively (Department of General Education 1998: 8). This was because of the inadequacy of human and material resources, textbooks, libraries as well as laboratory buildings.

At the time of the struggle, the "Eritrean Peoples' Liberation Front" (EPLF) realized the importance of education in Eritrea and also foresaw the future outcomes of the colonial educational policy on the Eritrean society. Hence, the EPLF took education as part and parcel of the armed struggle and tried to design and develop its educational system based on the objective realities of Eritrea and the plans of the front (Department of General Education, 1997: 2). In 1982, the chemistry syllabus for secondary school levels was developed and implemented in areas which were under the control of the front.

Following the independence of Eritrea in 1991, the Department of Education (now the Ministry of Education) decided to adopt the syllabi as curriculum with certain modifications since the emerging new nation of Eritrea gave high priority to education. As a result, they started to revise the syllabus.

It was challenging to review the existing syllabus. The science panel (physics, biology & chemistry) organized workshops for science teachers in order to get feedback (i.e. problems, limitations and suggestions) about the syllabus. Based on the comments and suggestions forwarded by teachers, the panel made amendments to the syllabus, which later became the curriculum. A syllabus is a subsection of curriculum and contains a list of content areas which are to be assessed. Amidst many controversial definitions of curriculum given by different educators, Stenhouse (1975: 1) has defined curriculum as "an attempt to communicate the essential principles and features of an educational proposal in such a form that it is open to critical scrutiny and capable of effective translation into practice". This definition has been taken for this research study since this definition allows people to look at curriculum development critically and in a dynamic way and has also all the important learning areas (or all the curriculum values) to be communicated. In the classroom situation, curriculum activities include "the content, materials, equipment, teaching strategies, and personal interactions" (Nancy, 1986: 36).

Curriculum development is a dynamic process which, in Eritrea, has been done under a panel. A panel is an organized group of people in the department of general education who have the responsibility for curriculum development. The panel conducted a field study and also held the National Curriculum Review Conference in Asmara in 1993. According to the outcomes of the conference, a new curriculum for Eritrean Secondary Schools was designed and chemistry textbooks were prepared as trials in 1995 for all grades of secondary schools. Its main target was to improve the quality of education throughout the school system in general and chemistry teaching in particular, so that it would be relevant and more practical in order to satisfy the needs and demands of individuals, society and the country as a whole (Department of General Education, 1997: 3).

Moreover, the science panel in 1998, together with the Eritrean Chemical Society (ECS) and a core team of chemistry teachers (i.e. teachers who were selected to assist the panel) conducted a workshop entitled "Integration of Practical Activities Work in teaching Chemistry in Eritrean Secondary Schools". The workshop had the following aims:

- To create a mutual understanding among chemistry teachers about the importance and aims of practical work in teaching high school chemistry.
- To share experiences on how to overcome the existing constraints that hinder practical activities in teaching chemistry in Eritrean high schools.
- To discuss various alternatives that enhance the promotion of practical activities in teaching high school chemistry.
- To propose a work plan where the ECS can be actively involved in improving the quality of high school chemistry in general and in promoting practical activities in particular.

According to the panel, the workshop had two important sessions. In the first session, group discussions were carried out by participants. All participants were grouped into nine groups and each group was given one task in which the members of the group actively participated in the discussion. In the second session, the compiled outcomes of the discussion were presented to the audience by representatives of each group. After presentation, participants raised important questions that needed further clarification and also forwarded constructive comments and suggestions.

Based on the above, according to the Science Panel (1998) report, two groups were separately presented with *Task-One* that is "Importance and Aims of Practical Work in Teaching High School Chemistry" (p. 3). Two other groups were presented with *Task Two*, "Problems that Hinder Practical Work in Teaching High School Chemistry" (p. 6). The two other groups were presented *Task Three*, "Various Alternatives of Practical Activities in Teaching High School Chemistry" (p. 9). One other group was presented with *Task Four*, "Promotion of the Integration of Practical Work in Teaching High School

Chemistry" (p. 14). The last group was presented with the *Fifth Task*, "Duties and Responsibilities of Laboratory Technicians in Promoting Practical Activities" (p. 20). The workshop was concluded by identifying some problems that hindered the practical activities in all Eritrean secondary schools and also proposed their possible solutions.

Some of the problems identified by the participants of the workshop were:

- Not all chemicals for the syllabus are available.
- Many schools do not have basic equipment or adequate chemicals even for demonstration.
- No laboratory manuals, models, and laboratory technician.
- Insufficient laboratories.
- Demand by the syllabus does not match with the requirements of the syllabus and student numbers.
- Insufficient time in a 40-minute lesson for demonstration or practical work.
- Overload of teaching for most teachers, so insufficient time to prepare for practical work.
- Shortage of funds and lack of coordination in the laboratory activities.

Some of the possible solutions given by participants for these problems were:

- Ensure that chemicals and missing equipment should be made available.
- Classrooms of sufficient size within the school could be exchanged to cope with student numbers.
- One laboratory room per science subject.
- Improvement of infrastructure of the laboratory work.
- Double lessons need to be available.
- Reduce work-load of teachers to allow time to prepare.
- Refresher courses and further training for laboratory technicians.
- Teachers have to use locally available materials.

- The Ministry of Education has to train more qualified teachers and has to build new schools in the long run.
- The curriculum department must participate and cooperate in preparing the laboratory manuals.

The presented outcomes of the discussions were given input by facilitators. The facilitators asserted that some of the problems hindered the proper and effective utilization of the available human and material resources in the schools. To address them, they classified them into short and long-term plans that could assist in solving the problems. The short-term plan was to organize workshops so as to motivate and encourage chemistry teachers to employ practical activities, to identify practical activities that can be easily performed using locally available materials in the schools, to allocate some budget from school committees for purchasing practical materials and to prepare a teacher's guide for each grade level. The long-term plan was to develop standard practical activities as part of the curriculum, to build a standard chemistry laboratory in every school, to assure the continuous supply of consumable chemicals and replaceable items, to train academically and technically qualified laboratory assistants, to up-grade pedagogical qualifications of chemistry teachers and to establish a unit which is responsible for coordinating and monitoring activities of high school laboratories at a national level. Finally, the facilitators emphasised the fact that all chemical facts, principles and concepts are derived and verified through scientific observation and experimentation. Hence, it is very difficult to teach chemistry at high school level without using practical activities. So it becomes necessary to integrate theory and practical activities into the curriculum of high school chemistry (science panel, 1998).

Eritrea has six zones; namely, Semenawi Keih Bahri, Debubawi Keih Bahri, Anseba, Gash barka, Maekel and Debub. Within these six zones there are 44 senior secondary schools. Out of these schools, there are 38 governmental and six private schools. The educational system in Eritrea has four levels: Elementary (1-5), Junior or Middle (6-7), Senior Secondary School (8-11) and four years of University education. The main concern of this study is to investigate the current challenges in the implementation of Grade 11 chemistry laboratory work in three secondary schools, which are to be found in two out of the above six zones. However, before detailed explanations are given, it is important to provide some background to the present study.

1.3 BACKGROUND TO THE RESEARCH STUDY

Chemistry is "an active and continually growing science that has vital importance to our world, in both the realm of nature and the realm of society" (Chang, 1991: 3). "It plays a significant role in the betterment of human life and the modification of facilities that make life enjoyable" (Department of General Education, 1997: 3). But how does one get the necessary scientific knowledge and skill to teach in this way? One of the assumptions of chemistry education is that by engaging learners actively in laboratory work they can develop the ability for manipulating scientific apparatus and problem solving in a critical way. The reason for this is that teachers are told by educational authorities to create conducive environments in the teaching-learning process for the development of critical knowledge, skills and attitudes through engaging learners in hands-on experiments, demonstrations, and problem solving activities. There is sufficient empirical evidence to suggest that formal scientific study does have a direct bearing on enabling people to enter into a scientific career (Ghebremariam, 2000: 3). Consequently, it contributes either directly or indirectly to the socio-economic development of his/her society.

Chemistry has been taught for many years in Eritrean Secondary Schools. However, since independence in 1991, it has been taught from Grade 8 up to Grade 11 without formal textbooks (except for teachers' guidelines). Since 1995, chemistry has used a textbook in all grades (i.e. from Grade 8 up to Grade 11). Out of these grades, the Grade 11 textbook has a large volume that includes mainly organic parts of chemistry, such as crystal chemistry, hydrocarbon, aromatic, agricultural chemistry, pesticides, and pollution. Many teachers need to use laboratory work to enhance the students' understanding of these concepts and principles, many of which have reactions that need experiments.

When laboratory work is implemented properly, it enhances some students' learning of the scientific concepts (or principles) and the methods of science, helps in the development of skills that may benefit some students throughout their lives and improve motivation and scientific attitudes in some students. Laboratory work is also important to use along with a variety of other methods to ensure that the maximum number of students receive the advantage of learning. This is because learning characteristics of the students in the laboratory cannot be divorced from learning characteristics in other classes. Thus, overall functions of laboratory work are to develop hands-on as well as minds-on skills of the learners. Ensuring that learners are active both mentally as well as gaining first-hand experience in laboratory work.

1.4 STATEMENT OF THE PROBLEM

The predominant teaching-learning process in Eritrea is the lecture method (i.e. teacher dominated or "chalk and talk", focusing on facts, concepts, etc,) rather than - as the national curriculum recommends - a learner–centred approach (i.e. active participation of students with process-based learning) and practice. According to Ghebremariam (2000: 7), practical activities are almost non-existent and where they exist, theoretical lessons are almost completely divorced from practical work. He further explains that the actual teaching-learning process is still content-based (i.e. focused on facts and knowledge) and mainly teacher centred (i.e. the lessons are dominated by teachers in "chalk and talk" mode with passive participation of students).

Theory-based lessons are boring for learners in Eritrea because the learners' understanding is limited to the concepts of the textbook. The contents of the chemistry textbook of Grade 11 are dominated by many abstract concepts, principles and reactions that need to be memorized. If this is so, learners can't have a full understanding of so many concepts unless they observe and see them through laboratory work. They also remain without skills. In addition, teachers rush their lessons in order to cover the given portion in each year for the sake of matriculation but this has its own consequences. Many of the learners remain without developing psychomotor skills (i.e. manipulative skills, investigative skills, communicative skills, etc), cognitive skills (such as critical thinking, creativity) and also have less understanding of concepts and principles of chemistry that lead to more failure in this grade in comparison with the other grades. This was also confirmed through my six years of teaching experience.

Although a few teachers attempt to build into their teaching some demonstration experiments in normal classes or laboratories, very little teacher-student interaction actually takes place. Thus, students remain passive listeners and dependent on their teachers. The result is that students mostly leave high schools without having done a single experiment or investigation (Yosief, 1999 cited in Ghebremariam, 2000: 7).

Out of the 38 government senior secondary schools in Eritrea, 18 have no laboratories while 20 have only a single laboratory that serves for biology, physics and chemistry. The existing laboratories are not well equipped with the basic facilities such as electrical supply, water pipes, gas supply, safety equipment, chairs (seating materials), tables, boards. Moreover, there is low skill of laboratory assistants (laboratory technicians) who have had only a very short training (about three months) and teaching using textbooks only in large classes is common for every teacher. This might lead them to give more emphasis on imparting factual knowledge, which encourages rote learning (Yosief, 1999: 2-5).

1.5 THEORETICAL FRAMEWORK OF THE STUDY

The study attempts to document and analyse the challenges of chemistry laboratory work in the three selected Grade 11 Eritrean Secondary Schools. This will be done within the framework of critical debates and findings surrounding chemistry and its practice in laboratory work. The following are highlights of the relevant literature.

Chemistry is the study of matter and the change that matter undergoes (Chang, 2000) in general. It provides the students with knowledge of chemical facts needed for many trades and professions that make happy and useful lives (Newbury, 1960). Chemistry is also fascinating to study since it overlaps with so many different sciences (such as biology, physics, geology, medicine), which require the knowledge of chemistry (for more details, see Early and Wilford, 2001; Holman, 1995; Garnett and Garnett, 1995 and others). However, chemistry is also a challenging subject, and as a result it lends itself to some criticisms.

Fong (1998: 253) argues that chemistry is being overloaded, complicatedly structured and lacks modern topics. Similar arguments were given by Muth and Guzman (2000). They argue that chemistry is a complex, abstract subject that leads to many misconceptions. Newbury (1960: 17) contends that chemistry has a lack of correlation with other subjects (see Chang, 2002; Wellington, 1990; Fong, 1998; Chastrette and Rao, 1992; Newbury, 1960 and Deboer, 1991).

Anderson, cited by Atlay and Edwards (1993: 82) defines laboratory work as "a place where a person or group of persons engages in a human enterprise of examining and explaining natural phenomena". There are numerous studies that indicate the definition of laboratory work. (See Hegarty-Hazel cited by Lazarowitz and Tamir, 1994; Kerr, 1963; Yager, 1991; Lloyd, 1992, Hodson 1990; Wellington, 1998; Jenkins; 1992).

Laboratory work has multiple functions. Shulman and Tamir, cited by Okebukola and Ogunniyi (1984) have identified the goals of laboratory instruction as to: 1) arouse and maintain interests, attitude, satisfaction, open-mindedness, and curiosity in science; 2) develop creative thinking and problem solving ability; 3) promote aspects of scientific thinking and scientific methods; 4) develop conceptual understanding and intellectual ability, and 5) develop practical abilities. Many studies have identified the main goals of laboratory work (see Garnett and Garnett, 1999; Woolnough, 1991; Muth and Guzman, 2000; Hodson, 1992; Klopfer, 1971; Brinkwork, 1968; Beatty and Woonough, 1982; and Humphreys 1992). Their studied objectives/goals are versions of Kerr's aim, which are the main motives in this study.

In 1963, Kerr organized a survey of 701 science teachers from 151 schools in the United Kingdom (UK), particularly in England and Wales, in order to find out the roles of practical work. Kerr provided a list of ten aims of practical work in science ranked by teachers in terms of their scientific relevance. These aims had been derived from published reports on science teaching approaches and he made a few modifications to them. His aims were proposed to give response to the critics, at that time, regarding the relevance of laboratory work in the secondary schools. The ten suggested aims are as follows:

1) to encourage accurate observation and careful recording;
2) to promote a logical reasoning method of thought;
3) to develop manipulative skills;
4) to give training in problem-solving;
5) to fit the requirement of practical examination regulations;
6) to elucidate theoretical work so as to aid comprehension;
7) to verify facts and principles already taught;
8) to be an integral part of the process of finding facts by investigation and arriving at principles;
9) to arouse and maintain interest in the subject;
10) to make biological, chemical and physical phenomena more real through actual experience.

These aims were used by different educators such as Ghebremariam (2000), to evaluate Grade 10 practical work in Eritrea, and Swain et al (1999) to study attitudes towards the aims of practical work in science education in Egypt, Korea and the UK. It is still relevant for today's study. The different objectives produce different types of laboratory work.

There are different types of laboratory work that are suggested by various educators (such as Parkinson, 1994; Domin, 1999; Dugan and Gott, 1995; Bekalo and Welford; 1999; Wellington, 1994; Woonough and Allsop, 1985; Garnett and Garnett, 1999) to coincide with the numerous goals stated by them. Demonstration, individual experiments performed by students, small group work experiments and investigation were taken as the types of laboratory work for the purpose of this research study (see Wellington, 1994; Humphreys, 1992; Linington, 1992; Garnett and Garnett, 1995). However, within the practical activities in the laboratory there have been certain constraints/problems that hinder the implementation of laboratory work. Kerr (1963) points out that insufficient laboratory facilities, overuse of laboratories, shortage of qualified teachers, lack of laboratory assistants, and large classes impair the effectiveness of laboratory work. More of these problems are presented in Chapter Two (see Jenkins 1992; Ogunniyi, 1977; Thompson, 1975; Ware, 1992; Hodson, 1990; Okebukola, 1986).

The most familiar criticisms often presented against laboratory work related to over-emphasis on conceptual learning, negligence in combining the way of delivering knowledge and methodology and of doing laboratory work, routine procedures, and lack of attention to the investigation skills.

Lazarowitz and Tamir (1993) contend that laboratory activities do not increase students' understanding, whereas Hofstein and Lunetta (1982) argue that laboratory activities are effective in promoting intellectual development as well as investigation skills. Hodson (1990: 33) has also criticized much practical/laboratory as being "ill-conceived, confused and unproductive" because it has been used uncritically (see also Ruben, 1996; Wellington, 1998; Hegarty-Hazel, 1990; Domim, 1999).

There are problems between theory and practice that affect the implementation of the laboratory work. Woonough and Allsop (1985: 8) have argued that a "tight coupling of practical and theory can have a detrimental effect both on the quality of practical work and on the theoretical understanding gained by the students". This is a warning to avoid careless mixing between methodology and the knowledge that is developed through laboratory work. There are some arguments that go on the recipe-style procedure of laboratory work. For instance, German (1996) contends that recipe-like activities often short cut opportunities of stimulating students' thinking (see such as Bekalo and Welford, 1999; Lloyd, 1992; Hodson, 1990). Humphreys (1992: 31) points out that "chemistry experiments using a cookbook approach is generally less stimulating to students than an integrated laboratory". An integrated laboratory is where both academic lecture as well as practice go hand in hand in the teaching learning process. To her, an integrated laboratory gives the students a sense of unity and coherence in dealing with chemical concepts.

The other criticism that has been leveled at laboratory work is the lack of attention to investigation skill. DeBoer (1991) argues that inquiry activities help the students to generate their own views. Tamir (1990) criticizes most laboratory activities for affording a low level of inquiry. Further arguments can be found from Garnett and Garnett (1999); Wellington (1998); Merritt, Schneider and Darlinton (1993). The final argument addresses the value of motivation. According to Arce and Betancourt (1997), students were more motivated while designing their own experiments. On the contrary, Hodson (1990) has argued that laboratory work has little motivational value. These criticisms were derived from their research studies.

Empirical findings about laboratory work are presented in Chapter Two with full descriptions. These include the finding of Kerr (1963), Bekalo and Welford (1999), Roth and Roychoudhury (1993), and Okebukola and Ogunniyi (1984).

1.6 RATIONALE OF THE STUDY

Chemistry is a practical subject. It is best learned when it is presented in a practical way. However, laboratory work in Eritrea, particularly for Grade 11, was almost forgotten because teachers emphasised the lecture method which mainly focused on recalling scientific facts, concepts and principles of chemistry. The teaching process remained "chalk and talk" and did not engage students in learning in laboratory work by doing. In such cases, students remained passive. It is believed that "there is no single method of teaching which brings a complete behavioural change (i.e. cognitive, psychomotor and affective domains of learning)" (Department of General Education, 1997: 1) during the implementation of the chemistry curriculum. So laboratory work should support and coincide with the theoretical lessons in order to achieve the desired goal in accordance with the demands of the curriculum. This was because the Grade 11 chemistry textbook contains some applications of agricultural use (such as fertilizers, soil analysis), health use (such as manufacturing of soap, oil, aspirin and chemical additives that can be added into food like acetic acid), environmental use (effects of chemical pollution on the climate like DDT) and industrial use (career opportunities in the chemical industry and others such as production of alcohol, acetone, oxygen-acetylene). All these indicate the industrial applications of the study of chemistry and the need to practice them through laboratory work. According to Thompson (1975), laboratory work may be designed to emphasise the practical applications of the subject in familiar or useful situations, and thus to indicate the wider relevance of the subject. In these situations, the aims of laboratory work concern an awareness of technological, social, ecological and economic implications. All these are very important in the daily life of the students as life skill learning since they use them either directly or indirectly in their daily life.

Millar (1987) states that students must understand the how and why of science since the outcome of science provides a greater role of understanding in our society. According to him, the need is to train (in laboratory) students to fulfill their role in our society and to prepare students for our scientifically based world (i.e. to attain scientific skills) through laboratory work. Moreover, laboratory work helps students to be aware of the particular safety hazards with each experiment, to learn scientific concepts and a method of discovering data for them, to develop manipulative skills, and to help in the development of skills that may benefit some students throughout their lives. Thus, the students need to practise them in the laboratory work in order to understand and handle them carefully in their daily life use. The researcher is concerned as to why teachers do not use laboratory work appropriately in teaching chemistry as the curriculum demands, what challenges teachers encounter in the implementation process of laboratory work to achieve the above implication; and what the future careers of the students are as they leave secondary school, if they fail to succeed in matriculation? These are researcher's motives to investigate the challenges that exist in laboratory work.

1.7 AIMS OF THE STUDY

The aim of the study is to investigate the current challenges in the implementation of Grade 11 chemistry laboratory work in the selected Eritrean secondary schools. In pursuance of this aim, answers are sought to the following research questions:

1. What challenges do Grade 11 chemistry teachers encounter in implementing and teaching laboratory work?
2. How adequate are the conditions of Grade 11 chemistry laboratory work in the selected Eritrean secondary schools?
3. What constraints/problems do Grade 11 chemistry teachers encounter in implementing and teaching laboratory work?
4. To what extent does Grade 11 chemistry laboratory work in the selected Eritrean secondary schools promote the achievement of Kerr's aims of practical work in school science, particularly in chemistry?
5. What are the weak and strong aspects of Grade 11 chemistry laboratory work in the selected secondary schools?
6. What types of laboratory work do chemistry teachers perform to promote the aims of chemistry laboratory work?
7. What are the views of teachers, students and curriculum developers about the aims of laboratory work?

8. How do the schools/ministry solve the problem related to equipment that is out of use/date and the lack of qualified laboratory assistants?

1.8 SIGNIFICANCE OF THE STUDY

The researcher is not aware of any study in Eritrea, specifically concerned with investigation of the current challenges in the implementation of Grade 11 chemistry laboratory work.

The study is of importance for Grade 11 chemistry teachers to know their weaknesses and strengths with regard to chemistry laboratory work and further will help them to relate theories to laboratory work in order to enhance students' understanding and manipulative skills. It is of importance for curriculum developers to use as a base for further revisions of the curriculum because effective laboratory work incorporated into the curriculum offers an effective teaching-learning process. It can also be used as a base for further planning for what the Ministry of Education has to do in relation to the resources of chemistry laboratory work. It will also be important for students to understand the relationships between what scientific principles and theories are, and their applications to their daily life. Moreover, it is hoped that this study will provide useful information for researchers interested in investigating challenges in the laboratory work and it would give some picture to teachers about the value of practice in laboratory work.

1.9 SCOPE OF THE INVESTIGATION

The present investigation attempts to determine the current challenges in the implementation of Grade 11 chemistry laboratory work in the selected Eritrean secondary schools.

The data for analysis was collected from questionnaires and interviews. Likewise, the administration of the various instruments used in this study was limited to three secondary schools located in Asmara, Tsaedachristean and

Adi-quala. This was due to financial constraints and time limitation that allowed only for three months for data collection. Hence this study cannot provide conclusions for all schools in Eritrea. In addition, the interviews were conducted only with male teachers due to the non-existence of female chemistry teachers in the concerned schools. Despite these limitations, an effort was made to collect the necessary data based as far as possible, on the following criteria:

- The school must have a laboratory and should offer chemistry as a subject.
- The school must have Grade 11 chemistry teachers

These criteria were considered to be important because the researcher was expecting that in such schools, laboratory work would be an important part of the teaching-learning process. It was assumed that the teachers would know the availability of other facilities and how they had carried out laboratory work in spite of the constraints.

Interviews were carried out to seek the views of Grade 11 chemistry teachers, students, and laboratory assistants from the three selected schools and the chemistry curriculum developer from the panel. The administration of the instruments was limited to three governmental schools. One was in a semi-rural area, the other one was in rural area and the last one was in an urban area. Two of the three schools were located in Zoba Maekel while the third one was in Zoba Debub (Debub zone). There was only one Grade 11 class in each of the two schools in which the concerned population was involved in this study and the third school had three classes in which only one out of the three was involved in this study. In other words, the study was limited to three Grade 11 classes.

1.10 DEFINITION OF TERMS

To understand the reading of this document key terms and concepts, which match with this study, are defined as follows:

- ***Eritrea*** is a country located in the so-called Horn of Africa. Eritrea has an area about 123,300 sq. Km (Ministry of Education 2001: 8).
- ***Science*** is a body of knowledge comprising ideas, skills, information, attitudes, concepts and generalizations about the world and its nature (Ango, 1990:1).
- ***Chemistry*** is defined as the branch of science that deals with the composition, structure, properties, and transformations of matter (Boikess and Edelson, 1981:3).
- ***Laboratory work*** is a form of practical work taking place in a purposely assigned environment where students engage in planned learning experiences…interact with materials to observe and understand phenomena (Hegarty-Hazel's, 1990b: 4).
- ***Skill*** is a specific activity through which a student can be trained to do particular activities (Parkinson, 1994: 8).
- ***Experiments*** are activities in which students learn best by doing (science panel, 1998: 16).
- ***Demonstration*** is a practical display or exhibition of a process and serves to show or point out clearly the fundamental principles or actions involved (Science panel, 1998: 16).
- ***Investigations*** are the "specific types of problem solving which allow pupils a varying degree of autonomy and which are problems to which the solution is not obvious" (Gott and Dugan, 1995: 20).

1.11 OVERVIEW OF THE STUDY

Chapter One has given a general introduction to the whole study about the Grade 11 chemistry laboratory work at the secondary school level in Eritrea. Chapter Two reviews the extant literature with regard specifically to the nature and challenges of teaching chemistry laboratory work and also the debates and critiques presented in it. Chapter Three presents details of the design of the study, consisting of the process utilized for developing the instruments. The aim of Chapter Four is to analyse the findings of the study - not only in terms of the research questions raised in Chapter One but also in terms of the literature dealing with the nature and challenges of chemistry laboratory work used in chemistry. Chapter Five consists of the conclusion, implications and recommendations.

CHAPTER TWO

REVIEW OF THE LITERATURE

2.1 INTRODUCTION

The central focus of this study is to investigate the current challenges in the implementation of chemistry laboratory work in the three selected secondary schools in Eritrea. An attempt is made in this chapter to appropriate the laboratory work in the extant literature pertaining to definition of chemistry, criticisms and importance of chemistry, definition of laboratory work, aims of laboratory work, types of laboratory work, role and rationales of laboratory work, constraints/problems of laboratory work, criticisms, empirical findings and finally, conclusion. The underlying assumption is that the investigated challenges contribute to teachers' awareness of the problems in the implementation of chemistry laboratory work.

As Kerr (1963: 9) points out, science (particularly chemistry in this study) has a unique value as a means of education and also offers knowledge through experiments, observations and problem-solving. It has emphasised direct experience for more than half a century in British science education. In the early sixties there was an over-emphasis on the learning of facts and principles in science. This has always been criticized and the experimental approach encountered doubts about the methods used in the laboratories (Kerr, 1963: 9). This was the first initiative and motive for Kerr to give response to the criticisms provided by many scholars with regard to the use of laboratory work. Similar situations now prevail for the use of laboratory work in Eritrea as existed in the early sixties in Britain education.

Kerr (1963: 20) posed some fundamental questions in connection with the purpose of practical work viz: "what are the unique values which are supposed to arise from practical work? What kinds of experiments give the greatest educational returns in proportion to the time spent on them? In particular, how far is the time given to what is usually called 'practical work' justified by its contribution to educational values?" These questions are important to investigate the experimental (laboratory) aspects of science, particularly chemistry. These questions (and the ten aims given in Chapter One) helped him to identify the main obstacles of laboratory work (see section 2.7), the inconsistency between kinds of experiments which teachers had done, the main role of laboratory work and finally, he proposed how to improve laboratory work. He also underlined the need to expose learners sufficiently to experimental activities. The researcher believes that Kerr's study is enough to use as a frame of reference (Wellington, 1994) for this study especially to find and evaluate laboratory work in terms of promoting the aims of science practical work proposed by Kerr (1963). But this study is not intended to repeat Kerr's work as it is. Just as other scholars (for example, Thompson, 1975, Ogunniyi, 1997, Wellington, 1994) did, the researcher uses it as partial versions and modified form of Kerr's aims to fit with the capacity of the respondents. In each portion endeavours will be made to review what researchers have claimed about chemistry laboratory work. Finally, this chapter will provide justification for the present study.

2.2. DEFINITIONS OF CHEMISTRY

According to Earl and Wilford (2001: 1), "Chemistry is about what matter is like and how it behaves, and our explanations and predictions of its behaviour". Holman (1995: 2) also defines chemistry as about what things are made of, and how we can change them. Science tries to "describe and explain natural phenomena; interaction with the phenomena of the natural world is vital to science" (Swain, et al, 1999: 1311), particularly chemistry. Like the other natural sciences, chemistry is concerned with "studying and interpreting the natural world" (Garnett and Garnett, 1995: 3).

In addition, chemistry is often called the central science, because a basic knowledge of chemistry is essential for students of biology, physics, geology, ecology, and many other subjects (Chang, 2002: 2). According to Chastrette and Rao (1992: 9), chemistry is said to be the central science, linked to most of the other sciences and to numerous areas of importance to human beings. In conclusion, Jacobsen (1999) defines chemistry as "the science of the structure, properties, and reactions of matter. It is a basic science, fundamental to an understanding of the world we live in, and a practical science with an enormous variety of important applications". When he speaks about its relation with the other sciences, he makes it clear that knowledge of chemistry is fundamental to an understanding of biology and biochemistry and of certain aspects of geology, astronomy, physics, and engineering. Thus, chemistry gives "a special window on the world" (Hill and Holman, 2000: x). However, it has some criticisms that have existed throughout the history of chemistry as a discipline.

2.3 THE IMPORTANCE OF TEACHING CHEMISTRY AND SOME CRITICISMS

Although chemistry is an ancient science, its modern foundation was laid in the nineteenth century, when intellectual and technological advances enabled scientists to break down substances into ever smaller components and consequently to explain many of their physical and chemical characteristics (Chang, 2002). Especially during the 20^{th} century, the subject matter and technique of teaching chemistry was highly criticized by educationalists. For instance, separation of the skills and processes in science from its knowledge and content has gone too far (Wellington, 1990). This means that the content of the knowledge is divorced from the laboratory work.

According to Newbury (1960: 16-19), the following criticisms of chemistry were outlined:

- The majority of school science (particularly chemistry) syllabuses are designed for a comparatively small number of brighter students who pass from school to higher educations. The majority of students thus get little benefit, because the courses are incomplete or unsuitable;

- Chemistry certainly loses some of its effectiveness if there is no correlation with the other subjects,
- Chemistry is difficult to learn because of its extensive new vocabulary and its highly specialized language.

In many European countries, chemistry education faces a number of important difficulties. According to Fong (1998: 253), the main problems are categorized into three. These are: first, the problems concern the observed decline in the number of students studying chemistry, and the reduction in the time duration in the school curriculum devoted to chemistry; the second problem concerns the chemistry curriculum, which was described as being overloaded, vaguely structured and short of dealing with modern topics. Furthermore, the connection between the chemistry curriculum at secondary and tertiary levels is rather weak; and the final problem concerns the reality that motivation and the urge to become a chemistry teacher is not high, at least not high enough to satisfy the forthcoming need for new chemistry teachers. In Fong's conclusion, the problems are categorized into three main areas: the classroom, curriculum and teacher training. Similar problems still prevail in the Eritrean Secondary School chemistry context.

Despite the above criticisms and problems, chemistry has many important roles. Chastrette and Rao (1992: 9) state that chemistry provides the basic understanding required to deal with a large variety of needs of our society (such as feeding, clothing, tapping new energy sources, improving health). They further point out that it is also important to keep a constant vigil so as not to miss opportunities to contribute to new directions and to apply chemical knowledge to answer newer challenges and to attain better solutions to problems. According to Newbury (1960: 11-12), studying chemistry should provide a lot of advantages and benefits, such as:

- Chemistry gives an essential background of knowledge for cultural development - it expands the student's knowledge of the universe and of his/her position in it; it helps in the appreciation and enjoyment of nature and life, etc.

- Chemistry gives many opportunities to foster the scientific method and disciplines, since it trains the student to observe and think clearly and carefully.
- Chemistry stresses the need to appreciate the meaning of scientific life, endeavours to create open-mindedness, intellectual honesty, self-sacrifice and devotion - which ought to serve as ideals to future citizens.
- Chemistry acquaints the students with knowledge of chemical facts needed not only for many trades and professions, but also by all citizens, to enable them to lead happy, well-balanced and useful lives.

It should be clearly understood that chemistry, as a branch of science, is a method and a habit of thought; and that subject-matter, training in skills, and teaching techniques should be selected accordingly, and should be well and closely linked with the students' emotions and common interests (Newbury, 1960: 16-19).

In conclusion, students in high school chemistry courses should develop better understandings of those fundamental concepts, major ideals, laws, and principles of chemistry that will enable them better to interpret natural phenomena, common application of chemical principles, and industrial applications and uses of the principles of chemistry (National Society for the Study of Education cited by Deboer, 1991: 106). Furthermore, according to the general chemistry laboratory series, the university of Notre Dame (2000) describes chemistry in its 'preface' in the following way:

> Chemistry is not dead; creative experiments are still being done, and new theory is being built and restructured to explain more accurately our observations of chemical phenomena. Chemistry remains a living experimental science.

2.4. DEFINITION AND ROLES OF LABORATORY WORK

According to Hegarty-Hazel, cited by Lazarawit and Tamir (1994: 94), "laboratory work is a form of practical work taking place in a purposely assigned environment where students engage in planned learning experiences ... interact with materials to observe and understand phenomena". For Kerr (1963: 21), laboratory/practical work means "experiments performed by the teachers as demonstrations, co-operative demonstrations by groups, as well as experiments and observational exercises carried out by pupils". Yager (1991: 22), also points out that laboratory work is the place "where students encounter ideas and principles at first hand. To some it merely means hands-on". Hodson (1992) expressed his belief that students learn best by direct experience, which for him means laboratory work. Woolnough (1979) and Newton (1979) also suggest that the laboratory is a place for providing pupils with an opportunity for investigations and for carrying out experiments and inquiries.

Lloyd (1992: 866) contends that the chemistry laboratory is so intimately connected with the science of chemistry, that, without experimentation, the true spirit of the science cannot possibly be acquired. Swain et al (1999: 1311) also state that practical laboratory work is the key component of science education that provides students of science with access to the behaviour of the natural world. In addition, practical work is often presented to students as an unproblematic process of explaining the material world in terms of true knowledge.

Practical work in school science has a history dating back at least to 1882 (Hodson, 1990). At that time it was declared that "the instruction of scholars in science subjects ... shall be given mainly by experiments" (Hodson, 1990: 1) Since this time, almost all the major science curriculum developments have promoted practical work as an enjoyable, effective form of learning (Hodson, 1990). Similarly, Wellington (1998: I) wrote in his preface that practical work has been used for just over 100 years as an essential and exciting part of understanding this discipline. He further stated that although it can be costly and sometimes messy, it simply has to be done if students and teachers are to progress in their understanding.

Griff (1998) points out that practical work has become an integral component of primary and secondary science in Australia, as in many other countries. Over the years, however, the term practical work has come to mean little more than hands-on activity. As Jenkins (1998: 33) explains, the rationale of practical chemistry in the early nineteenth century when it was seen as a "vehicle for 'training the mind' and developing the skills of observing, reasoning and so on was deemed to be of general value". According to Woolnough (1991), hands-on activities, experiments, and laboratory work are all the same concept referring to the performance of experiments or practical work with chemistry apparatus, usually in a laboratory setting. According to Jenkins (1992: 199), the laboratory is one of the key features of chemistry education that requires direct engagement of students with materials, apparatus and techniques in order to develop the knowledge and skill that constitutes chemical understanding.

Hodson (1990) also proposed five major functional categories of laboratory work. These are: (1) to motivate, by stimulating interest and enjoyment; (2) to teach laboratory skills; (3) to enhance the learning of scientific knowledge; (4) to give insight in to scientific methods and develop expertise in using it; and (5) to develop certain scientific attitudes, such as open-mindedness, objectivity and willingness to suspend judgment. In addition, Anderson (1976) cited by Atlay and Edwards (1993: 82) focuses particularly on laboratory teaching in his book 'The Experience of Science' and proposes four main roles of laboratory work:

a. The laboratory is a place where a person or group of persons engages in a human enterprise of examining and explaining natural phenomena.
b. The laboratory provides an opportunity to learn generalized systematic ways of thinking that should transfer to other problem situations.

c. The laboratory experience should allow each student to appreciate and in part emulate the role of the scientist in inquiry.
d. The outcomes of laboratory work should provide adequate understanding of the natural world and associated nature with its theories.

Simpson and Anderson (1981: 110-113) categorized the major functions of laboratory work into five with respect to important goals in science education and demonstrate how teaching science in the laboratory is congruent with the enterprises of science and technology. These are: 1) learning about the nature of science and technology; 2) learning problem-solving skills; 3) learning manipulative skills; 4) learning major concepts and principles; and finally, 5) developing interests, attitudes and values. In the last concept (especially referring to attitude), Haney, cited by Simpson and Anderson (1981: 113) has proposed that there are eight aspects of scientific attitude such as (1) curiosity, (2) open-mindedness, (3) objectivity, (4) intellectual honesty, (5) rationality, (6) willingness to suspend judgment, (7) humility, and (8) reverence for life. These attitudes and values foster the human enterprise of science and can be nurtured when students are placed in a stimulating and challenging laboratory environment.

Practical work does have a place in teaching about the nature of science, because "it can be designed to draw students' attention to epistemological issues about data and knowledge claims" (Leach cited by Wellington, 1998: 63). Moreover, laboratory work should be part of the curriculum that "mirrors, reinforces and augments the rest of the course" (Gott and Duggan 1995: 25). It has many roles for "exciting pupils, giving first hand knowledge and supporting theory" (Wellington, 1994: 129). However, Lunetta and Hofstein cited by Woolnough (1991: 125) underline that to conduct practical activities well requires energy, time and resources. Having these in mind, "teachers need to be aware of the goals, potential, merits and difficulties of the school laboratory" (Tamir cited in Wellington, 1994: 128) when they intend to conduct laboratory work.

2.5. AIMS OF LABORATORY WORK

In tracing the history of practical science education, Nott (1997: 49) argues that by 1897 the laboratory had already been identified as an essential item for school science education (Wellington, 1998: 7). Millar (1998: 30) asserts that the outcomes of laboratory work can produce some support for the accepted scientific account of phenomena because through phenomena done it is difficult to produce reasonable knowledge. So laboratory work makes it as acceptable and valid as the knowledge that predicted them.

Numerous attempts have been made to articulate the objective of laboratory work (Boun, Dunn and Hegarty-Hazel, 1986; Hodson, 1998 and Woolnough, 1991). Garnett and Garnett (1995) point out that these laboratory objectives can be grouped into four major categories:

1. ***Conceptual learning***. Laboratory work is used extensively to develop students' conceptual learning and understanding of science;
2. ***Techniques and manipulative skills***. Laboratory work recognizes the importance of practical skills and techniques;
3. ***Investigative skills***. In the context of laboratory work, investigation skills include: planning an investigation, the ability to conduct the investigation, processing and interpreting data, and evaluating findings; and
4. ***Affective outcomes***. Affective objectives of laboratory work can be divided into two main categories (Gardner and Gauld, 1990): attitudes to science and scientific attitudes. Attitudes to science refer to students' feelings about liking and disliking science, and include interest, enjoyment, confidence and motivation whereas scientific attitude relates to the thinking faculty such as critical-mindedness and willingness to consider the evidence (Garnett and Garnett, 1995).

These can be achieved if the laboratory work is implemented properly and creatively.

Lunetta and Hofstein, cited by Woolnough (1991: 125-126) assert that 'experiments', 'laboratories' or 'practicals' have had a central place in science teaching. Further, they state that its purpose is that such experiences will enable students better to understand the nature of the scientific enterprise as well as to develop problem-solving skills, to grow in understanding of scientific concepts, and to experience connections between theory and practice. In addition, experience with real materials is an essential element in cognitive development.

Muth and Guzman (2000) suggest that the importance of the laboratory component to undergraduate science education could be inferred by the large number of goals ascribed to it: in comprehensive reviews of laboratory instruction, Boud, Dunn, and Hegarty-Hazel (1986) identified 1547 distinct objectives of the science laboratory, which could be broadly grouped into the following five goals. These are: conceptualization and illustrative goals, cognitive goals, psychomotor goals, processing goals and lastly, affective goals.

A review of literature reveals that in South Africa experimentally-based or laboratory–based high school science teaching has strong support from science teachers and various other educators. All science syllabi explicitly state the importance of laboratory-based teaching in their preamble, and also advocate its implementation wherever possible (Naik, 1994: 1). According to a preamble to the physical science syllabus for matriculation level (grades 10,11 and 12) issued by the ex-House of Delegates in South Africa, the following aims/objectives are stated concerning practical work:

a. To help students understand the fundamental role played by experiments and observation in establishing and extending the body of knowledge;
b. To facilitate the learning and understanding of facts and principles;

c. To give students opportunities of making simple discoveries of their own;
d. To provide experience of elementary measuring techniques, and acquaintance with some of the measuring instruments in common use; and
e. To give practice in the recording and treating of observations, the drawing of appropriate conclusions and the presentation of results (Naik, 1994: 120-121).

Hodson (1992: 77) in his summary suggests that a major goal of practical work should be the engagement of students in holistic investigations in which they use the processes of science both to explore and develop their conceptual understanding of (and increased expertise in) scientific practice. Parkinson (1994: 105), in his article "The Nature of School-Based Practical Work", proposes the following major aims: they should motivate the students to do science and students should learn something from the experience.

According to Klopfer (1971) cited by Atlay, and Edwards (1993: 79), the broad aims of laboratory courses have been identified as: (1) knowledge and comprehension; (2) processes of scientific inquiry; (3) observing and measuring; (4) seeing a problem and seeking ways to solve it; (5) interpreting data and formulating generalizations; (6) building, testing and revising a theoretical model; (7) application of scientific knowledge and methods; (8) manual skills; (9) attitudes and interests; (10) orientations and (11) literature skills.

According to Brinkwork, (1968: 3), the purposes of experimentation (which mean laboratory) as a subject in the curriculum are manifold, but perhaps the most important ones are to provide opportunities for the student to: (a) reinforce his/her understanding of material in the theoretical part of the course, through verification of laws and principles; (b) become familiar with methods of measurement, and with the machinery, apparatus and instrumentation appropriate to the subject studied; (c) organize his/her own work and carry it through systematically and carefully; (d) help to organize the work of a team; (e) analyse data, assess their reliability and draw conclusions from them; (f) report the work lucidly, and (g) learn how to judge the reliability of experimentation reported by others.

Humphreys cited in UNESCO (1992: 31) points out that the overall purpose of the laboratory experience is "to model good science by allowing students the opportunity to predict, infer, explain, control and problem-solve". She further mentions some possible purposes for experimental work (now referred to as 'laboratory work') as follows:

1. To give the student an opportunity to recognize and identify practical examples of the material discussed in lectures (or an important purpose of the laboratory is to give the student actual experience of the properties and reactions of substances).
2. To apply the content of the lectures so that students gain experience using information in new situations.
3. To develop skills in techniques and procedures such as operating an instrument, observing phenomena and recording data.
4. To develop skills in designing experiments and developing appropriate viable experimental setups to test theoretical ideas.
5. To learn the process and interpret chemical data.

Beatty and Woolnough (1982) cited by Bently and Watts (1993: 21) surveyed 11-13 year old youngsters in England and Wales, and found that youngsters spent between 40% and 80% of their time doing practical work. For the teachers in the Beatty and Woolnough survey, practical/laboratory work has many aims, but the five most important aims are to:

- Encourage accurate observation and description;
- Promote a logical reasoning method of thought;
- Make phenomena more real through experience;
- Be able to comprehend and carry out instructions; and
- Arouse and maintain interest.

All the above aims, which are given by different scholars, are placed within the frameworks of Kerr's aim (see Chapter One). Kirchner and Huisman cited by Hodson (1998) support Kerr's suggestion by saying that in reality theory and experiment are interdependent and therefore, nourish each other. They further state that practice is usually subservient to theory, is poorly related to course objectives, and consists of exercises for developing manipulative skills rather than assignments for learning to think systematically. Wellington (1994) argues that even in the present period the motives suggested by Kerr (nearly four decades ago) for doing practical work are still relevant.

2.6. TYPES OF LABORATORY WORK

Different practical activities can be appropriate for the different aims and lessons. So far, various attempts have been made to classify the types of chemistry laboratory work even though "the nature of the type of practical tasks undertaken varies from classroom to classroom" (Parkinson, 1994: 105). Parkinson classified practical/laboratory work into four categories: learning basic practical skills, illustrating a theory or concept, proving a theory, and investigative work, in accordance with the relevance of aims.

There are four distinct styles of laboratory instruction that have been prevalent throughout the history of chemistry education: expository, inquiry, discovery, and problem-based (Domin, 1999: 543). Domin has further differentiated them by three descriptors: "outcome, approach and procedure" (see Table 1). The outcome of any laboratory activity is either predetermined or undetermined.

Table 1: Descriptors of the laboratory instruction styles.

	Description		
Style	Outcome	Approach	Procedure
Expository	Predetermined	Deductive	Given
Inquiry	Undetermined	Inductive	Student generated
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student generated

Bekalo and Welford (1999: 1295-6) give more descriptions for the types of laboratory work that were developed by Gott et al (1988) in their survey of pre-service teachers in Ethiopia. They are as follows:

- **Basic skills**: measurement, selecting and use of appropriate instruments, following instructions and the construction of tables, charts and graphs from data generated from students' experiments or drawn from other sources.
- **Observation**: observing similarities or differences and changes between objects and/or events, generating classifications of patterns.
- **Illustration**: showing (often through teachers' demonstration) given phenomena, concepts, laws or principles in action.
- **Enquiry**: 'discovering' a concept in a series of more or less structured activities, usually designed for students to carry out investigations following instructions to find out, confirm or 'see' a concept in action.
- **Investigation**: designing and carrying out an entire investigation, which includes examining the data of the investigation and drawing conclusions from them.

Woolnough and Allsop (1985) suggest that laboratory work in science can be usefully classified into three types of activities: *experience* - intended to give students a feel for phenomena and to facilitate conceptual learning; *exercises* - intended to develop practical skills and techniques; and *investigations* - intended to develop problem-solving and investigation skills. According to Beatty and Woolnough, cited by Bentley and Watts (1982), there are four types of activity described: 'standard exercises' – emphasizing particular procedures and developing skills in using them, 'teacher-directed discovery experiments', 'demonstrations', and 'project work'. Of these, the first two are the most common and the last the least common. Finally, they conclude that practical activities in lower-school science appear to have two purposes: to develop practical skills and to develop particular attitudes (Bentley and Watts, 1982). Furthermore, Parkinson (1994: 104) identifies the main functions of laboratory work. Laboratory work:

a. motivates students to do science and helps to keep them interested;
b. teaches skills to students (the ability to make accurate observations, manipulation skills; helps to promote logical thinking);
c. provides an opportunity for students to develop communication skills; and
d. provides an opportunity for team work.

Extending the Woolnough and Allson (1985) scheme, Garnett and Garnett (1995: 2-3) propose that chemistry laboratory work be classified into five types of activity:

- *Laboratory work that facilitates conceptual learning.* This type of laboratory work is used because it provides concrete experiences, which may help students to understand some of these rather abstract chemistry concepts.
- *Laboratory work that develops practical skills and techniques.* This type is intended to develop specific skills or techniques such as using a balance, burette or pH meter.
- *Laboratory work that examines relationships between variables.* These are well suited to the traditional investigation of relationships between variables (for instance pressure, volume, freezing point) under controlled conditions.
- *Laboratory work that involves chemical synthesis.* Examples of synthesis include making gases such as carbon dioxide, oxygen, nylon, etc.
- *Laboratory work that involves chemical analysis.* Qualitatively, it can involve the identification of unknown chemicals; the testing of products such as chloride ions in mineral water and so on while quantitative analyses involve specific techniques such as performing titration and using separation and gravimetric techniques.

According to Wellington (1994: 132), there are at least six possibilities for organizing and carrying out practical work in the average school situation with its usual constraints. Of those six types of practical work, four are the most common. These are: demonstration, individual work by the students, small group experiments and investigation.

Demonstration is a practical display or exhibition of a process and serves to show or point out clearly the fundamental principles or actions involved (Science panel, 1998: 16). Demonstrations are particularly important if students are to see "chemistry as a practical, relevant and interesting subject, where theoretical principles are used primarily to explain observations and reactions" (Humphreys, 1992: 34). According to Humphreys, much of the interest in chemistry for the students is in actually observing chemical changes. Demonstration can be used to show and indicate "events or phenomena, such as chemical reactions, especially if those events are too expensive, dangerous, difficult or time-consuming to be done by all" (Wellington, 1994: 132). The other type of laboratory work is individual students' experiment (work). According to Linington (1992: 193), individual students' experiments may be useful "for learning and developing skills. It can enable students to work at their own pace and to organize their own learning". However, it is more expensive in terms of apparatus and chemicals than demonstrations are. And it does not allow for interactions and discussions among the students.

The third type of laboratory work is investigation. Investigations are the "specific types of problem solving which allow students a varying degree of autonomy and which are problems to which the solution is not obvious" (Gott and Dugan, 1995: 20). They further state that investigations are aimed at the students to use and apply concepts and cognitive processes (such as understandings, generalization), as well as practical skills. Investigation is regarded as a "scientific problem which requires the students to plan a course of action, carry out the activity and collect the necessary data, organize and interpret the data, and reach a conclusion which is communicated in some form" (Garnett and Garnett, 1995: 4). Laboratory investigations in chemistry should, therefore, include a wider range of approaches than the narrowly focused controlled experiment (Gott and Murphy cited in Garnett and Garnett, 1995). The last type of laboratory work is small group work. This "encourages collaborative work enabling students to explore their preconceptions and to discuss their results with their peers"' (Linington, 1992: 194). Groups of students can tackle the same investigation in different ways and organize and discuss their result findings from laboratory work.

Wellington (1998: 6) grouped the reasons and rationales for doing practical work into three main areas: one relating to knowledge and understanding (the cognitive domain); one relating to skill and processes (psychomotor domain), often deemed to be transferable; and a third relating to attitudes, enjoyment and motivation (the affective domain). The summary of his arguments in each area and counter arguments is given below:

1. Cognitive arguments. It is argued that practical work can improve students' understanding of science and promote their conceptual development by allowing them to visualize the laws and theories of science. The counter argument is that practical work can confuse as easily as it can clarify or aid understanding (especially if it goes wrong) and hence the counter slogan was "I do, I become confused", particularly in the 1980s.

2. Affective arguments. Practical work, it has been argued, is motivating and exciting - it generates interest and enthusiasm. The counter argument is that some of the students are turned off by it, especially when it goes wrong or they cannot see the point of doing it.

3. Skill arguments. It is argued that practical work develops not only manipulative or manual dexterity skills, but also promotes higher-level, transferable skills such as observation, measurement, prediction and inference. The counter argument is that there is little evidence that skills learnt in science are indeed general and transferable or that they are of vocational value.

There are research studies that address the issue of motivation. One of the most challenging areas of teaching is that of motivating students. Laboratory work is promoted in chemistry education as an effective motivational method. Laboratory work generates motivation, curiosity, enthusiasm, and confidence in learning (Hannon, 1994) through chemistry (science). Similar conclusions were made by Arce and Betancourt (1997). There is no universal agreement in this case. Hodson (1994) states that students find laboratory/practical work less boring rather than something to be enjoyed. From his point of view, laboratory work is not so important per se, but rather better than the lecture. The problem he observed is more relevant where there has been insufficient preparation for activities by teachers. This leads to low motivational impact of practical/laboratory work. Research by Windschitle and Andre (1998) indicates that practical work gives more motivation only with more mature students because they might have the intention of becoming a scientist and they can relate to their environment, whereas less mature students seem to gain from the traditional teaching styles since they have less ability to relate or associate with nature.

The researcher argues that laboratory work is intended to provide an opportunity to learn general laboratory skills, concrete examples of material covered in lectures, and exposure to topics not covered due to time constraints. Students come to the laboratory for several obvious reasons. According to this researcher, laboratory work helps the students to be aware of the particular safety hazards with each experiment, to learn scientific concepts and a method of discovering data for themselves, to develop manipulative skills, and to help in the development of skills that may benefit some students throughout their lives, thereby making them more responsible citizens. It also has the ability to increase motivational power if students are allowed to pursue their own investigations in their own work. The students can acquire all these if laboratory work has been implemented correctly and properly.

The above detailed discussions reveal that chemistry laboratory work has a significant role in the teaching and learning process of chemistry. The different types of laboratory work that have been done by different educators have their own specific aims.

2. 7 CONSTRAINTS/PROBLEMS OF LABORATORY WORK

It is important to be aware of the limitations of any teaching approach, and laboratory work is no exception. Jenkins (1992: 199) points out that practical work in a laboratory is "expensive in terms of equipment, apparatus and materials, and makes heavy demands on the time of pupils, technical staff and teachers". In addition, the allotted time in the laboratory provides constraints on a school timetable. According to Lunetta and Hofstein (1991: 126), laboratory activities are generally constrained by "school realities such as 40-minute laboratory periods, safety, budgets and resources. The teacher controls laboratory equipment, space, materials, and even the amount of measurement error that can be tolerated". After all, laboratories "cost a lot of money for special furniture and extensive plumbing and electrical services" (While, 1991: 78). A recent World Bank (1988) report concludes: "quality education is just not possible in laboratories and workshops that have no electricity or water because wiring, fuses and plumbing have deteriorated and where equipment does not operate because spare parts and consumables are lacking" (Allsop, 1991: 34).

Because of poor socio-economic conditions and their negative consequences for the conditions of teaching, the state of science education, particularly chemistry, has deteriorated in the last decades in most African countries (Ogunniyi cited by Feiter, Vonk and Akker, 1995: 22). Ogunniyi (1977) asserts that the types of methods used in the teaching and learning of science are the main barriers in achieving the fruits of learning science through practical work. He further mentions that efficiency of practical work in science is hampered among other factors by: (a) inadequate laboratory facilities in most of the schools; (b) inadequate supply of laboratory assistants; (c) lack of funds; (d) the uses of laboratories as form rooms; (e) an overloaded laboratory timetable; and (f) the extremely large classes even at the matric or ordinary level stage.

Moreover, Thompson (1975: 24), in an inquiry into the aims and methods of teaching practical working sixth-form science, points out that the major obstacles to practical work were: the supply of competent laboratory technicians, provision of laboratory facilities, loading of laboratory timetables, requirements of practical examinations and size of classes. Ogunniyi (1996) argues that teachers face the uphill task of coping with virtually bare laboratories, workshops and resource centres. He further points out that they lack supportive technical personnel and have to battle with such problems as the shortage of essential textbooks, teachers' guides, chemicals, audio-visual materials, teaching overload, large classes, and congested syllabi. It is his view that teachers lack confidence in their teaching ability because of inadequate training, lack of knowledge and skills, as well as inadequate opportunities for self-improvement.

According to Ware (1992: iv), laboratory instruction is still considered an essential component of secondary science classes in developed and developing countries. It is easy to suggest that problems associated with implementing the laboratory component of science classes result solely from inadequate facilities, and a lack of equipment and supplies, etc. If these were true, then simply providing facilities, equipment and materials would solve these problems. However, too often, laboratories are used only as regular (expensive) classrooms; equipment remains on the shelf unused to prevent breakage, or broken equipment remains without being repaired; consumables are not re-supplied; and teachers are not shown how to use and repair equipment. Ogunniyi (1986) points out the problems confronting science teaching in Africa. Some of the identified problems are poor preparation of teachers, poor implementation procedures, an overwhelming number of activities demanded by the new curricula and shortage of qualified teachers.

Simpson and Anderson (1981: 135-136) contend that although the innovative science teacher can find ways to do laboratory investigations in a poorly equipped room, facilities and equipment are often the limiting factors on how much laboratory work gets done. Thus, the availability of adequate facilities and equipment is highly desirable, and every effort should be made to obtain at least the essential items such as facilities for laboratory work, flat table surface, sources for water, electrical outlets, gas outlets or source of heat, storage areas, ventilation and safety features.

Hofstein and Lunetta (1982) cited by Hodson (1990: 39) point out that most studies of the efficacy of practical work have been flawed by poor experimental design - especially small group size, inadequate control of variables and use of inappropriate test instruments. Moreover, despite the very obvious differences between experiments to illustrate and develop manipulative skills, and inquiries that enable students to conduct their own investigations, there is a tendency for researchers to combine them under the collective title of "practical work".

According to Okebukola (1986), one of the most common problems existing in most countries of the world is that of large classes. This problem is mostly associated with budgetary constraints that limit catering for adequate facilities for the appropriate teaching of science. In addition, the ratio of qualified science teachers to students gets lower every year. He further points out that the West African countries have suffered with large classes, and that hinders the teaching process of chemistry in laboratory work. In Nigeria, for instance, this ratio of qualified teachers to students in secondary schools is in the ratio of 1: 105.

The problems of large classes may remain in most developing countries of the world for a long time. For instance, in Taiwan, the average class sizes are 50 to 60 students; in Thailand, 40-45 students (Klainin, 1988: 175); in Eritrea by 2000/01, it was 1: 56 (Ministry of Education, 2001: 31). To resolve such problems, cooperative learning techniques were devised. This technique involves allowing students to work in small cooperative groups instead of exposing them to whole-class instruction (Ghebremariam, 2000).

2.8 CRITICISMS OF IMPLEMENTATION OF LABORATORY WORK

The teaching of chemistry in laboratories has been a controversial issue, which is accompanied by many criticisms and debates. Criticisms of the current laboratory work include ineffectiveness of laboratory work, unrelatedness of scientific knowledge and methods of science, the predominance of rote-style laboratory work, a lack of attention to the development of investigation skills, low motivation and over-emphasis on information overload.

Surprisingly, little quantitative or qualitative research studies have evaluated the effectiveness of learning in the laboratory. However, from the available literature, Lazarowitz and Tamir (1993: 120) conclude that laboratory activities, as they are currently taught, do not enhance students' learning or increase conceptual understanding of science. Students retain little of what they learn in the laboratory and have difficulty applying what they know.

Furthermore, Kirchner et al (1988) argue that the laboratory is an ineffective method of promoting students' learning and that skills acquired through laboratory work might be better acquired in other arenas. Ruben (1996) also suggests that laboratory experiences do not develop process and higher order cognitive skills. On the contrary, Lunetta and Hofstein (1991: 16) argue that it is "an essential element in cognitive development". Leach and Scott, 1995, cited by Wellington (1998: 7) contend that in the context of the 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. Therefore, laboratory/practical work allows students to change the abstract to the concrete, helping them understand concepts (Arce and Betancourt, 1997). Similarly, laboratory work enables students to obtain ownership of the science concepts (Solomon, 1988). Hegarty-Hazel (1990: 55) concludes that science education without some laboratory experience is unthinkable, but equally, that student's laboratory practice is not a general panacea, the "universal end to a multiplicity of means."

In the undergraduate science laboratory, Domin (1999) cited in Ruth and Guzman (2000) proposes two reasons for the ineffectiveness of the chemistry laboratory: (a) Students spend more time trying to get correct results than thinking about how the science principles are being applied in the laboratory; (b) Most of the experiments stress lower-order skills such as rote learning, memorization, and algorithmic learning. Others argue that much school laboratory/practical work is teacher-directed busy work, which is often poorly planned and ill considered (Nott, 1996; White, 1996). Ruth and Guzman (2000) point out that the main problems facing the chemistry laboratory would seem to lie in the laboratory curriculum, which has alternatively been criticized as either too trivial or too complex and abstract.

Layton (1973) argues that the curriculum developers of the 1960s took too little notice of the problems involved in teaching these aspects of science - its knowledge and its methodology - simultaneously. Woolnough and Allsop (1985) have also warned that by negligence, the knowledge and methodology aspects of science may be mixed and, at this time, laboratory work loses its relationship with theory. Likewise, Fensham (1988) believes that modern science courses have "reduced the role of laboratory work to the enhancement of conceptual learning and have neglected opportunities for students to develop confidence and skills in applying scientific knowledge to solve real societal problems" (Garnett and Garnett, 1995: 3). Mulopo and Fowler (1987) conclude that the method of instruction made no significant difference in learning.

Woolnough and Allsop (1985) discuss various aims of practical laboratory work in more detail. They point out that practical work is abused when activities do not coincide with aims. More recently, Hodson (1990, 1992, 1993a,b) has criticized the fact that laboratory work does not necessarily engage the students' thinking. He argues that students need to have a clear knowledge of the purpose of an experiment in order to extract any benefit. In this regard, the researcher argues that sometimes the theories given in the textbook and the experiments that are listed in the manual mismatch each other. This creates a challenge to teachers in terms of how they implement them.

Criticism has also been leveled at the emphasis on rote-style laboratory work. Reports from the USA (Tamir and Lunetta, 1981) and Australia (Tobin, 1986) both indicate a predominance of recipe style laboratory work that is at the lowest level of openness to student planning. Bekalo and Welford (1999), from their studies in Ethiopian universities and colleges, claim that the aim of practical/ laboratory activities seems to be to get the 'right answer' by following detailed routine instructions, rather than on the development of investigative approaches.

Furthermore, in a review of the '20th century general chemistry laboratory', Lloyd (1992) indicates that a structured or 'cookbook' approach is still the overwhelming choice in laboratory manuals. These lead to providing few opportunities to identify problems, formulate hypotheses and to design experiments or problems; insufficient discussion of limitations and underlying assumptions; and inadequate provisions for discussion, analysis and consolidation. Hodson (1990), states that laboratory/practical work, as done by educators, only allows students to 'rediscover' information already known. Therefore, students do not learn the true method of doing science, i.e. investigation. The researcher argues that even if the laboratory manual allows for investigation purposes, teachers traditionally use rote-style learning because they taught in the way they had learned. This implies that the problem here is in the implementation process.

Tamir (1990) criticizes the low level of inquiry in most laboratory activities. DeBoer (1991) argues that inquiry-based activities are inductive, which have an undetermined outcome, and require the students to generate their own procedure. Merritt, Schneider and Darlington (1993) also question the nature of many general chemistry laboratory experiments as 'unrealistic portrayal' of chemistry experimentation. They propose a change in emphasis with greater involvement of students in planning their experiments. Hodson (1998) has also proposed that more attention be placed on "affective outcomes and a recognition of the role of laboratory work in developing students' self-esteem and confidence in their ability to solve problems" (Garnett and Garnett, 1999: 4).

Johnstone and El-Banna (1986) found that when students had to deal with large amounts of information in a chemistry laboratory session, the reporting of their observations was purely descriptive and lacked evidence of appropriate levels of interpretation and understanding. Johnstone and Letton (1991) claim that a reduction in the amount of information presented leads to improvements in students' learning. They recommend careful matching of laboratory manual descriptions with the actual requirements; improving laboratory manuals - prior to the laboratory session; and structuring laboratory activities so that an open-ended investigation follows earlier sessions, which introduce necessary prior knowledge (Garnett and Garnett, 1999).

It has been suggested by Hodson (1990: 65) that practical work in school science is both over-used and under-used. It is over-used in the sense that teachers engage in practical work as a matter of course, expecting it to assist in the attainment of all learning goals. It is under-used in the sense that its real potential is only rarely fully exploited. He further explained that there are people who believe students simply become more confused when forced to do practical science, particularly chemistry. This is due to uncritical thinking:

> Not because they are unthinking people, but because they have been subject to the powerful, myth-making rhetoric of the profession that sees hands-on practical work as the universal panacea, the educational solution to all problems (p. 34).

Hence, educators are "still faced with the problems of defending laboratory activities as an essential component of the science curriculum" (Blosser, 1983: 168). They continuously "seek for valid research evidence to support their belief in the significant and unique contribution of students' work in the laboratory" (Lazarowitz and Tamir, 1994: 94).

2.9 EMPIRICAL FINDINGS ABOUT LABORATORY WORK

Kerr (1963) carried out a survey concerned with the role of practical work in school science. The study reveals that teachers agreed on the significance of laboratory work for the development of educational values. However, there was inconsistency between the kinds of experiments which teachers had done. Verification experiments were very frequently used although teachers thought their educational value to be limited (Kerr, 1993: 95). Theory and practice were not adequately integrated. And although teachers were doing plenty of practical work, the educational value often claimed for it was not achieved. In addition, demonstration work was neglected. The investigation also found that two main obstacles prevented full achievement of the possible rewards of learning science through practical/laboratory work. Accordingly, Kerr (1963) proposed: (1) the need to improve the conditions for practical activities with respect to class size, laboratory facilities, and laboratory technicians; (2) the need to concentrate on the development of practical skills rather than meeting examination requirements; and (3) the need for greater integration between stated objectives and actual practice. The challenge was how to conduct laboratory work in relation to constraints.

Bekalo and Welford, (1999: 1294) point out that practical work was meant only for laboratory work with relatively sophisticated, and imported, expensive apparatus. Practical/laboratory work taught in Ethiopia frequently remains rote learning of factual knowledge and the passing of examinations predominantly valuing recall knowledge (Bekalo and Welford, 1999). From the study of various schools in different regions of the country, Bekalo (1997) concludes that science educators had difficulty in understanding the practical, problem-solving approach advocated in the new education policy, let alone in implementing it. As Bekalo and Welford (1999) have pointed out in their survey, small classes, basic apparatus in the laboratory and a laboratory assistant were not adequately available. Teachers employed lecture-methods that verify knowledge rather than the demonstration experiments recommended by the syllabus. It is reasonable to suppose that the 'chalk and talk' and 'routinized guided experiment approach' were common and affect teachers to carry out practical work confidently and independently. The interviews with teachers revealed that practical/laboratory work hardly took place in Ethiopian secondary school classrooms (Bekalo and Welford, 1999) - only one practical demonstration during 80 science lessons observed in four secondary schools.

However, a suggestion from their report, is given about a broad interpretation of practical work which promotes active learner participation in their own practical laboratory work. According to Bekalo and Welford (1999), this sometimes means hands-on experiments, but also encompasses a range of other ways of working, including teacher demonstration, group discussions of problems and their solutions, interaction between student and student, student and teacher, or student-teacher and students, student-teacher and trainer. It also includes individual activities, e.g. measurement, observation and investigation (Bekalo and Welford 1999: 1294). They underline that the main challenge that faced the Ministry of Education in Ethiopia was "how to implement its objectives" in secondary science education.

Roth and Roychoudhury (1993) investigated whether student-centred, open-inquiry laboratory work facilitated the learning of high order process skills and whether these skills developed holistically within a problem-solving context without being taught explicitly. In a study with year eight science and year 11 and 12 physics classes they found that open-ended inquiry laboratories resulted in considerably improved skills of identifying variables, hypothesizing, planning and carrying-out experiments, and interpreting data. In this study these cognitive skills seemed to develop gradually and holistically without being taught explicitly (Garnett and Garnett, 1999). This study also reflected how to develop cognitive skills through inquiry.

Okebukola and Ogunniyi (1984) studied the performance of students in the science laboratory in the cooperative, competitive and individualistic groups. From the study they found that: (1) science teachers could enhance the cognitive achievement of students in science through the use of cooperative laboratory work; (2) encouraging high ability students to work together in a group appears to be a good approach to improving their achievement levels; (3) allowing low ability students to work together in a group with some average and high ability students in a fixed ability group tends to enhance the performance of the low ability students; (4) mixed and heterogeneous ability grouping for cooperative work in the laboratory has a more facilitative effect on the achievement of low achievers than the competitive goal structure; and (5) competitive laboratory instructions appear to promote the development of laboratory skills.

Mulopo and Fowler (1987) tested 120 Grade 11 males (taking chemistry in Zambia). The purpose of their study was to compare the effectivessness of traditional and discovery (practical/laboratory work) methods of instruction. The students were categorized into four groups of males. Group one were concrete reasoners receiving traditional instruction, group two were concrete reasoners receiving discovery instruction, group three were abstract reasoners receiving traditional instruction and group four were abstract reasoners receiving discovery instruction. After assessing student understanding of the chemistry concepts involved, they concluded the method of instruction made no significant difference in learning.

Swain, Monk and Johnson (1999) carried out a "comparative study of attitudes to the aims of practical work in science education in Egypt, Korea and the UK". The teachers were asked to rate each of the 20 aims used by Beatty and Woolnough. The details of their outcome in the three countries are as follows.

The Korean teachers as compared to their counterparts in the UK appeared to provide 'content focused' practical work. The emphasis was strongly on facts: findings, verifying and remembering facts. Among this set of aims, elucidating theoretical work as an aid to comprehension showed the large difference from the UK teachers. The UK teachers appeared to be offering a view that is 'more investigationally focused'. The seeing and solving of problems, critical attitudes and logical reasoning all emphasized the manufacture of new knowledge rather than the rehearsals of existing knowledge. The Egyptian teachers in comparison with the UK focused on the combination of 'creativity' and 'self-reliance' rather than investigation. As with the comparison between Korean and UK teachers, the Korean teachers showed a strong tendency towards a positivistic approach to science.

The Egyptian teachers work in conditions of large classes and virtually no resources, and most of the teaching is through question and answer routines (Swain et al, 1999). The Korean teachers work in relatively opulent conditions compared with their Egyptian colleagues (Fair-Brother, 1999); they have laboratories that are dedicated rooms and well resourced. On the other hand, the UK teachers work in comparatively well-equipped schools with laboratory facilities guaranteed in comparison to Egyptian and Korean teachers. This finding indicates that resources were the main challenges for Egyptian teachers in implementing chemistry laboratory work.

In a seminal inquiry into the nature of practical work (including laboratory work) in school science, Kerr (1963) cited by Hodson (1998: 629) identified ten motives for deploying them in school (see Chapter One; 'theoretical framework'). He suggests that in the intervening 35 years, these motives have remained largely unchanged, although relative priorities may have shifted somewhat (Thompson, 1975; Beatty and Woolnough, 1982; Hegarty-Hazel, 1990; Tamir, 1991). However, while the educational goals for practical work are common across many schools, the practice employed to achieve them is not. According to Hodson (1998), research findings on the efficacy of practical work/laboratory work are confusing and generally inconclusive (Tabin, 1991; Hodson, 1993; Lazarowitz and Tamir, 1994). Furthermore, he points out that many newcomers to the profession are unsure about how best to design and implement hands-on work. This finding also shows the challenges in the implementation of laboratory work.

2.10 CONCLUSION

In this chapter definitions and advantages of chemistry, definitions of laboratory work, aims and rationales of laboratory work, types of laboratory work, problems of laboratory work, criticisms and empirical findings of laboratory work have been described. Chemistry is an experimental and growing discipline. It is necessary to use laboratory work in the teaching process of chemistry because chemistry has many functions (such as to be aware of hazardous chemicals and to take care of them for example DDT, to analyze the best agricultural fertilizers etc. In Kerr's (1963) view there are certain functions of science that can be best accomplished through laboratory work. However, Millar (1991: 20) suggested that teaching in the laboratory requires "a special approach to science, special instructional skills, special management skills, and special attitudes". The literature presented in this study deals with such cases.

Kerr's aims (see Chapter One) are the most influential work used throughout the history of science practical work. These aims are the motives in this study. The challenge here seems to be how to match aims with practice. The research study reveals that there are some problems (such as class size, inadequate facilities, inadequate laboratory assistants, teaching overload) that hinder the teaching process in laboratory work in African countries, including Eritrea. In conclusion, many scholars have proved the fact that chemistry is one of the most important subject areas, which has many applications for the improvement of human life. Such applications have been carried out in the laboratory in spite of the barriers encountered during its implementation process.

The next chapter will discuss the research methodology which has been employed in this study.

CHAPTER THREE

METHODOLOGY

3.1 INTRODUCTION

This study falls primarily within the descriptive and primary research paradigm. It is descriptive, in that it describes conditions that exist and events and processes as they occur. It is also primary research in the sense that the data has been gathered from primary sources, namely: chemistry teachers, Grade 11 students and laboratory assistants. These research methods were used in this study to investigate the current challenges in the implementation of Grade 11 chemistry laboratory work in three selected Eritrean secondary schools.

The study was limited to the three schools: two were in the central zone, 'Zoba Maekel', and the other one was in the southern zone, 'Zoba Debub'. This was because the available time was only three months (which included semester holidays) for the collection of data in Eritrea. Under such circumstances, more accessible schools were selected. The two schools were Tsaedachristian and Harnet Secondary Schools from Zoba Maekel while the third school was Adi-quala Secondary School from Zoba Debub, which is 86km from Asmara. Harnet Secondary School is located in an urban setting, Adi-quala Secondary School is in a semi-urban location and Tsaedachristian Secondary School is in a rural setting.

Before the researcher started the study, a letter was requested from the Eritrean Human Resource Development Project (EHRD), University of Asmara. The researcher's sponsor handed them the title of the study before the researcher arrived there and the EHRD office was fully aware of the study. It was processed without any obstacles. It was easy because the researcher was one of those students placed by EHRD at the University of the Western Cape to do a Masters degree in Education.

At the beginning of this study, the researcher handed a letter to the Directors (or head of the schools) of each secondary school requesting cooperation in conducting the study in their schools (see appendices I, II and III). After being granted permission, the researcher introduced himself and briefed the directors on the aim of the research. They recommended to the researcher the teachers and students who would be able to participate in the study. Some of the teachers who gave their responses wished to remain anonymous. This enabled them to be more open in their responses to items on the questionnaires and interviews. Therefore, in accordance with the research ethics the respondents' anonymity was respected.

3.2 BACKGROUND OF THE RESEARCH METHOD

Research methods are theory-laden tools. As such they impose certain theoretical perspectives on reality. When different methods are employed to study some aspects of human behaviour, each of them reveals a slightly different facet of the same social and symbolic reality (Berg, 1989; Cohen and Manion, 1989). Looking at the phenomena from these different vantage points provides researchers with a better chance of explaining the richness of complex human behaviour in more detail (Cohen and Manion, 1989). According to Berg (1989: 4), combining several research methods helps researchers to "... obtain a better, more substantive picture of reality, a richer, more complete array of symbols and theoretical concepts; and a means of verifying these elements".

Reviews of studies on the life of the classroom reveal that researchers tend to differ in their focus, approaches to data collection and the nature of the data collected. Furlong and Edwards (1993) suggest the facts that the researchers record and the interpretations they make of such facts are to a large extent a product of the theoretical assumptions they make regarding data. The use of two or more methods of collecting data enables the researcher to make use of quantitative and qualitative data (Cohen and Manion, 1989).

A definition of qualitative research is more complicated. Lincoln and Denzin (1994: 576) state that qualitative research is "drawn to a broad, interpretative, postmodern, feminist, and critical sensibility. On the other hand, it can also be drawn to more narrowly defined positivist, post positivist, humanistic, and naturalistic conceptions of human experience and its analysis". Guba and Lincoln (1994) describe the various views of the positivist, critical theorist, and the constructivist. According to them, the purpose of research from the positivist view is to explain, predict and control the human variables; from the view of the critical theorist is to critique and transform the social, political, or other cultural status that hinder and explain human beings; and from the view of the constructivist is to understand and reconstruct individuals' views under study in a particular social context.

Furthermore, "qualitative research is a field of inquiry in its own right. It crosscuts disciplines, fields, and subject matter" (Lincoln and Denzin, 1994: 1). This method also involves emphasizing "process and meanings that are not rigorously examined, or measured in terms of quantity ... and frequency" (Lincoln and Denzin, 1994: 4). It has high validity in terms of its appropriateness, meaningfulness and usefulness of inferences made by the researchers, based upon the data which they collect (Fraenkel and Wallen, 1994).

Despite its limitations in using primarily small samples and being time-consuming, qualitative research has a number of advantages. According to Crowely (1994/5), the following are identified as advantages of qualitative research. These are: 1. it can provide data that inform about appropriate solution alternatives in the study; 2. it can help to develop deep understanding of a problem that cannot be understood in terms of numbers and objectivity in the study; 3. it is appropriate to study individuals' perceptions, beliefs, and interpretations that explain their experience of life; 4. it also enables the researcher to be aware of various interviewees' voices and the researcher will ask them how, in what way and for what purposes to enrich the data in the study. Data from this study helps to enrich understanding of respondents' thinking. This method can be used side by side with the quantitative method.

In contrast to qualitative, quantitative research is research that measures or quantifies (either ordinal or interval) the level of intelligence (such as beliefs, awareness, perceptions) of individuals in a systematic manner (Mori, 2002). Quantitative research designs tend to be more predetermined than qualitative ones. One of the aims of quantitative research is to set up facts and statistically describe phenomena. The data from such studies are often described as empirical and statistical (Bogden and Biklen, 1992) in terms of "quantity, amount, intensity, or frequency" (Denzin and Lincoln, 1994: 4). These data are expressed as numbers, and interpretations are made in terms of comparisons and categorizing of those numbers (Wiersma, 1980). In this case, extraneous factors are carefully controlled to keep their validity and reliability.

Both qualitative and quantitative research methods can and have been used during the particular research study. Howe (1988: 10) suggests "such a combination is not only encouraged, but often required". Jackson (1968: vii-viii) states:

> Classroom life, in my judgment, is too complex an affair to be viewed or talked about from any single perspective. Accordingly, as we try to grasp the meaning of what school is like for students and teachers we must not hesitate to use all the ways of knowing at our disposal. This means we must read, and look, and listen, and count things, and talk to people, and even muse introspectively over our memories of our own childhood.

By crosschecking the results of quantitative and qualitative data, subjectivity is controlled and the validity of the results is increased. Exclusive reliance on one method, therefore, may bias or distort the researcher's picture of the particular reality under investigation and hence methodological triangulation in which different methods are used on the same subject of the study (Cohen and Manion, 1989) was practised in this study.

According to Cohen and Manion (1989: 75), "triangulation may be defined as the use of two or more methods of data collection in the study of some aspect of human behavior". It can also "take many forms, but its basic feature will be the combination of two or more different research strategies in the study of the same empirical units" (Denzin, 1978: 308).

This triangulation method stems from the single method approach, which yields only limited and sometimes misleading data; while the multiple methods in triangulation improve the limitation and deficiency of such data and focus on the object of the study (Cohen and Manion, 1989). In spite of the fact that it is difficult to both select and manage different kinds of research methodologies, Cohen and Manion maintain that the triangulation method has the following advantages:

a. it is suitable when a more holistic view of educational outcomes is sought;
b. it has a special relevance where a complex phenomenon requires elucidation;
c. it is also appropriate when different methods of teaching are to be evaluated;
d. it is suitable where controversial aspects of education need to be evaluated more fully; and
e. it is useful when an established approach yields a limited and frequently distorted picture.

Triangulation is concerned with establishing whether or not there is convergence in the data collected. It purports to establish whether or not the data collected are sufficient. Data that are inconsistent and non-convergent are regarded as insufficient (Berg, 1989). Thus, the triangulation method was used in this study in order to overcome the deficiencies that flow from a single method. It was also considered the best way to enhance validity and reliability of the research study through crosschecking. The instruments for this triangulation will be discussed in the following section.

3.3 INSTRUMENT

Interviews and questionnaires were the instruments used to investigate the current challenges in the implementation of Grade 11 chemistry laboratory work in Eritrea. According to Tuckman (1978), questionnaires and interviews are used by researchers to convert into data the information directly given by a person (or subject). He further points out that "by providing access to what is 'inside a person's head,' these approaches make it possible to measure what a person knows (knowledge or information), what a person likes and dislikes (values and preferences), and what a person thinks (attitude and beliefs)" (p.196). Questionnaires and interviews are a way of getting data about persons by asking them rather than watching them behave or by sampling a bit of their behaviour (Tuckman, 1978).

The clarity and validity of the questionnaire and interview questions were checked before the start of the study. The research instruments were first distributed to five experts to determine whether the questions were set correctly or not. On the basis of their comments and suggestions necessary amendments were made to ensure that the research instruments were capable of measuring what they were supposed to measure. Details of the development of each instrument are presented in the following sections.

3.4 INTERVIEWS

An "interview is a face-to-face confrontation, an oral exchange, between an interviewer and an individual or a group of individuals" (Wiersma, 1980: 142). Interviewing is "one of the most powerful ways of collecting data about human beings" (Patton, 1990 cited in Crowley, 1994/5: 60). Powney and Watts (1987: 6) state that the interview "provides both the interviewer and interviewee the opportunity to meet in a face-to-face encounter and assess each other. It can be used to provide an opening to build confidence and mutual trust between the interviewer and interviewee". In an interview, the response may be limited to a single word (for example, yes or no), or it may require a rather lengthy oral discussion (Wiersma, 1980).

There are three major forms of interviews: structured, unstructured and semi-structured. In the structured interview the content and procedures are organized in advance. This means that the sequence and wording of the questions are determined by means of a schedule and the interviewer has little freedom to make modifications. On the other hand, the unstructured interview is open-ended, having greater flexibility and freedom (Ogunniyi, 1992) whereas the semi-structured interview is in between the two.

Gay (1981: 166-7) has also suggested the following advantages and disadvantages of an interview.

Advantages:

a. When properly used the interview can produce in-depth data not possible with a questionnaire.
b. It is appropriate for asking questions that cannot be effectively structured in a multiple-choice format.
c. It is flexible, so that the interviewer can adapt the situation to each subject.
d. By establishing rapport and a trust relationship, the interview can obtain information that subjects would not give on a questionnaire.
e. More accurate and honest responses can be obtained since the interviewer can explain and clarify the questions.
f. An interviewer can follow up on the incomplete or unclear responses (Gay, 1981).

Disadvantages:

a. It is expensive and time consuming.
b. It generally involves small samples.

c. The response given by a subject may be biased and affected by her/his reaction to the interview.
d. Conducting an interview requires a level of skill usually beyond that of a beginning researcher.
e. The respondent is restricted by the interviewer to a specific time and place for the interview.
f. Lacks anonymity, especially when the topic or some of the questions are of a sensitive nature (Gay, 1981)

The interview in this study was of the semi-structured type allowing the respondents to express their ideas or experiences freely to a certain extent. Mostly, the questions were open-ended in order to put a minimum of restraints on answers given by the respondents but there were also a few closed questions. Teachers, students, laboratory assistants and the member of the chemistry panel were interviewed face-to-face and individually so that they could feel confident and express their feelings freely and what they believed about the role, aim, problems and challenges in the implementation of laboratory work. The interviews were conducted in the laboratories since there were no extra rooms that were appropriate for the interview. After being granted permission from interviewees, a tape recorder was used to record the answers for the interview questions. They were then transcribed and analyzed. The interviews enabled the researcher to find out about the perceptions of teachers, students, laboratory assistants and the chemistry panel on the conditions, roles, aims, and problems that could challenge them while practising laboratory work. The interviews were considered a useful technique in the investigation of challenges in the implementation of Grade 11 chemistry laboratory work and also complementary to the questionnaires. The semi-structured interview schedule or format for teachers, students, laboratory assistants and chemistry panel can be found in appendix IV, appendix V, appendix VI and appendix VII respectively.

3.4.1 TEACHERS' INTERVIEWS

Three chemistry teachers from the selected secondary schools were interviewed. In the three schools there was only one Grade 11 chemistry teacher each and these three were interviewed after getting agreement from them. All the teachers interviewed had a bachelor degree and their teaching experience ranged from four to 18 years. The interviews were conducted in the laboratory room during their break time in the afternoon. This was because all Grade 11 classes in the concerned schools were in the morning shift. Teachers had a larger teaching load in the morning while they had less of a load in the afternoon shift even though they taught in both shifts (including other grades). The interviewees were asked if they objected to the researcher using a tape recorder. A semi-structured interview was developed to explore the teachers' beliefs, metaphors, ideas and perceptions about the challenges that existed and the constraints they experienced in laboratory work. The interview questions were used to complement the facts and opinions that were given in the questionnaires. After the researcher ensured that the teachers were relaxed enough, the researcher conducted the interviews with their biography as an introductory part. The interview then went on to explore the conditions, aims/types, problems and challenges of chemistry laboratory work. Finally, it was hoped that the interview questions would enable the researcher to gain insight in to how teachers deal with the challenges of laboratory work.

3.4.2 STUDENTS' INTERVIEWS

The researcher requested teachers to help in choosing average students who had enough knowledge about laboratory work. This was because the average students would give the researcher reasonable information about the concerned issue. With the assistance of teachers in each school, one average student each was chosen for interviews from the selected three secondary schools. A total of three students were interviewed from the three schools. A semi-structured interview was developed for the interviews. This aimed to get some freedom in changing the mode of questioning if the occasion demanded. The students were told of the aims of the study and the nature of the interview prior to the starting of the interviews. The interview was conducted in the English language in the laboratory rooms because the chosen students had a good command of English. The interview was tape-recorded. The outcomes of the interviews were transcribed and more detailed discussions will be presented in Chapter Four.

3.4.3 LABORATORY ASSISTANTS' INTERVIEWS

Interviews were conducted with three chemistry laboratory assistants from the concerned secondary schools. The researcher held the view that the laboratory assistants were the key players for effective teaching in chemistry laboratory work. They are supporters of teachers when they conduct laboratory work. Similar to the other interviews which had been done, it was a semi-structured interview. This was done to have some flexibility while asking questions. It was hoped that the interview would enable the researcher to gain optimum information regarding the conditions, aims and types of laboratory work, and problems encountered in laboratory work. The interviews were conducted in the laboratory rooms, which were the main offices of the assistants since they did not have any separate room for office purposes. At the same time they were also rooms used for the laboratory experiments. More details of the discussion will be found in Chapter Four.

3.4.4 MEMBER OF THE CHEMISTRY PANEL INTERVIEW

The Chemistry Panel is a group of people in the Department of Education who have the responsibility for the development of the chemistry curriculum process. One person was interviewed from the chemistry panel because the panel was only left with one member as the others had been assigned to other institutes. Having assured him of anonymity, he was quite willing to participate in the interview. The time for the interview was scheduled to meet the needs of the interviewee. It was in his office during break time so that a more relaxed atmosphere could be created, and to build a certain confidence while answering the interview questions. He was interviewed concerning the laboratory manual, the general conditions of laboratory work, constraints in teaching laboratory work, what the ministry had done and what needs to be done for the future of laboratory work in Eritrean secondary schools. More information about the outcomes of this will be found in Chapter Four.

3.4.5 SUMMARY OF THE INTERVIEWEE PROFILES

From the three secondary schools where interviews were conducted:

- The three chemistry teachers were males and all had Bachelor of Science (B.Sc.) degrees in chemistry.
- The three laboratory assistants each had a three-month training certificate. Of these, two were males and one female.
- The member of the chemistry panel had a Master of Education degree focused on the development of curriculum
- All had teaching experience ranging from four to 18 years.
- The three students were Grade 11 students and had a good command of the English language.

3.5 QUESTIONNAIRES

A "questionnaire is a list of questions or statements to which the individual is asked to respond in writing; the response may range from a checkmark to an extensive written statement" (Wiersma, 1980: 142). The questionnaire is " the only convenient technique whereby information may be obtained from a large number of people, especially when they are spread over a wide geographical area". However, there is no perfect technique and they must be used with care.

In social science, particularly education, the questionnaire is probably the most commonly used method of gathering information. Nachmias and

Nachmias (1981) have suggested the followings advantages and disadvantages of using a questionnaire.

Advantages:

Using a questionnaire is cheaper than using an interview. A questionnaire does not require a trained staff of interviewers. The processing and analysis of data is also simpler and cheaper than that of interviews.

a. It reduces biasing errors that might result from the personality of interviewers and from variability in their skills.
b. It assures anonymity of respondents especially when dealing with sensitive issues
c. It gives the chance for subjects to consult documents.
d. it permits wider geographic contact with minimal cost, whereas interviewing often requires expensive travel costs and time for the interviews.

Disadvantages:

a. A questionnaire can be used as an instrument for data collection only when the questions are straightforward enough to be comprehended without verbal explanation.
b. There is no opportunity to probe beyond the given answer to clarify and elaborate ambiguous items once they are presented, nor can the response be verbally directed by the researcher.
c. Researchers have no control over the respondents' environment; thus they cannot be sure that the right person completes the questionnaire
d. The final disadvantage is that the questionnaire has some obvious poor return rate.

The first visit to the schools was done to acquaint the teachers with the purpose of the study and to appropriate the space for the next procedures. Questionnaires were distributed during the second visit after four days. There were 148 questionnaires dispatched to the students in the three selected secondary schools within two zones of Eritrea, Maekel and Debub. These were 28 students (24 males and 4 females) in Harnet Secondary, 48 students (26 males and 22 females) in Tsaedachristian and 72 students (62 males and 10 females) in Adi-quala Secondary School (see appendix XI). The researcher allowed the students to complete their questionnaires within two periods. This was because the researcher was afraid that the students might fill the questionnaires carelessly (as is usually expected from some immature students in any school). Finally, the researcher personally collected the questionnaires after the students had completed them. The return rate was thus 100%.

3.5.1 STUDENTS' QUESTIONNAIRES

Questionnaires were only given to the students. The items on the students' questionnaire (see appendix VIII) used in this study were partly derived from the version of Kerr's aim of practical work. A lot of literature on laboratory work tends to emphasise the perspectives of the researchers and teachers rather than those of the students. This study recognizes the central part played by the students in terms of the challenges in the implementation of laboratory work. The student questionnaire was developed by the researcher to capture the students' perceptions of chemistry laboratory work. The focus of the questionnaire includes the rating of aims of laboratory work; the conditions of chemistry laboratory work and writing of problems in teaching chemistry laboratory work. The students' questionnaire contained both closed and open-ended types of questions. Closed questions were included for easy use, because they are easy to answer and analyze (Cohen and Manion, 1989). Open-ended questions were also included in the questionnaire in order to provide the respondents with an opportunity to express their opinions and ideas without being limited to predetermined responses. This enabled the researcher to obtain additional relevant information. Open-ended questionnaires are effective when used for a relatively small group of people who can express themselves in writing (Nachmias and Nachmias, 1981).

Hence, this instrument consisted of four sections for students to respond to in an attempt to describe the nature of laboratory work. The themes across the instrument ranged from general information, conditions of laboratory work, aims/types of laboratory work, to the sections concerning the problems of chemistry laboratory work. To respond to this instrument, the students had to fill the blank spaces, to make ticks for the five scale items from 'excellent' to 'very poor' and for the 'Yes' or 'No' items, and finally to circle for the choice questions.

Section 'A' contained items, which the students were expected to fill in the space provided about the general information of the respondents. Section 'B' consisted of items about aims of laboratory work, which the students were expected to tick for the 'Yes,' 'No' and 'Not decided'. Section 'C' contained four types of laboratory work which students were asked to rate according to the practice they learnt and their teachers employed in terms of "frequently used", "occasionally used" and "never used" whereas section 'D' contained items about the conditions of chemistry laboratory work. The students were required to rate each item under the headings on 5-point scale. The response choices were "very much", "much", "satisfactory", "little" and "very little" in the case of this data. In addition, this section contained open-ended questions to which the students were expected to express their opinions (see appendix VIII). The data obtained from the questionnaires are analyzed using interpretation of percentages accompanied by a bar graph. The percentages are given in terms of less than 50% or greater than 50% of the responses, whereas the bar graph is used to visualize the highest recorded percentages of response. By integrating the information acquired from questionnaires and interviews, the final analysis is provided in the next chapter.

3.6 CONCLUSION

As previously stated, the intention of this study is to investigate the challenges in the implementation of Grade 11 chemistry laboratory work in Eritrean

Secondary Schools. Interest is centred on the fundamental reasons for the practical approach, and the study was therefore directed solely at chemistry laboratory work. However, laboratory work should form an integral part of the science of chemistry, and therefore its aims should not be divorced from that of science teaching in general (Kerr, 1963).

However, many modifications have been done by other researchers (e.g. Thompson, 1975, Ogunniyi, 1977) for Kerr's aims. The researcher of this study has also made partial changes to Kerr's aims to adapt to the Eritrean context. Kerr's survey covered a large number of schools whereas this survey involves only three secondary schools in Eritrea. Kerr's study used only questionnaires to get information from teachers by ranking the items of the questionnaire whereas this study includes both questionnaires and interviews to obtain reasonable data and ensure their validity by crosschecking one to the other. Kerr's respondents were only teachers while the respondents of this study are students (both for questionnaires and interviews), teachers, laboratory technician and the member of the chemistry curriculum panel. These interview and questionnaires were conducted to elucidate the opinions of various groups in order to gain holistic views about the Grade 11 chemistry laboratory work in the three selected secondary schools in Eritrea. The next chapter will report on and discuss the findings based on the data derived from the various instruments used in the study.

CHAPTER FOUR

ANALYSIS AND DISCUSSIONS

4.1 INTRODUCTION

The previous chapter dealt with the methodology which the researcher employed in carrying out the study. The two research techniques, the questionnaire and interview, were discussed. This chapter will be concerned with an analysis of the data collected. The data will be analysed in the light of the literature review developed in Chapter Two. This analysis cannot, however, claim to be comprehensive, as chemistry teaching in laboratory work is dynamic. That means new innovations in laboratory teaching will always be emerging for the new generations so that investigating the problems in the implementation of laboratory work can help to shape and develop such ongoing innovations. The analysis will hopefully provide some reflections on the present challenges in the implementation of laboratory practice in Eritrean Grade 11 classes.

The outcomes of the study are presented under the main subheadings: an analysis of the interviews of all interviewees and an analysis of the students' responses to the questionnaire. Finally, the main findings of the study are discussed.

4.2. ANALYSIS OF INTERVIEWS

4.2.1 OVERVIEW OF THE INTERVIEWS

As mentioned in Chapter Three, the interviews were conducted with teachers, students, laboratory assistants and the chemistry panel member. Most of the questions were directed at the teachers and the chemistry panel since they carry most of the responsibility for the implementation of laboratory work. Almost all of the questions were commonly presented to all the interviewees and these aimed to check the validity of the data using cross checking from the different groups of respondents. At the same time, all the analysis of the interviews was given under similar themes. The overall issues which the researcher intended to address in this study were categorized into five parts so as to give answers to the research questions. The first part of the interview dealt with the importance and aims of laboratory work. Secondly, it describes whether Kerr's aims of practical work are promoted in Eritrean schools, or not. Thirdly, it describes the types of laboratory work. The fourth and fifth parts were jointly presented under one theme that deals with the problems and challenges in the implementation of laboratory work.

For sake of anonymity throughout the discussions, numbers 1 to 3 are used to represent the respondents who were interviewed: T_1 is 'teacher one', T_2 is 'teacher two' and T_3 is 'teacher three'; LA_1 for 'Laboratory Assistant one', LA_2 for 'Laboratory Assistant two' and LA_3 for 'Laboratory Assistant three'; S_1 for 'student one', S_2 for 'student two' and S_3 for 'student three'; CP represents 'Chemistry Panel'. The analysis of the interviewees will be presented in the next sections.

4.2.2 IMPORTANCE AND AIMS OF LABORATORY WORK

In terms of the importance of laboratory activities in the daily lives of the students, all the teachers interviewed agreed that laboratory work is important to relate the actual experience with students' daily lives and to understand the physical phenomena more thoroughly through it. They further pointed out that it is also important to remember what is going on in the activities, to motivate the students towards the subject and to present concrete examples. The question posed to them was: Are all these applicable in the current situation in Eritrea? To this the teachers said that they were implemented to some extent, as demonstration type of laboratory work was used. The same idea was obtained during interviews with students and the chemistry panel. The chemistry panel member said that the teaching and learning process is totally incomplete if it does not include laboratory work, without laboratory work the study of chemistry becomes like 'History and Geography'.

In this connection, the teachers were also interviewed about whether Kerr's aims are promoted in their schools or not. Two teachers (T_2 and T_3) responded that Kerr's aims were partially promoted as they did demonstration work. However, teacher one (T_1) said that Kerr's aims were not promoted and the reason he provided was that due to shortage of facilities and large class sizes, he didn't apply them.

4.2.3 TYPE OF LABORATORY WORK

In response to the question on what criteria they used to decide whether or not to do demonstration or other types of laboratory work, all teachers described that the availability of equipment and chemicals, a reasonable working load and knowledge of the background of the target group were the most important criteria. The following points are described as a conclusion from T_1 in preferring to do particular kinds of laboratory work:

- A reasonable working atmosphere is preferable so that we can have reduced time and I can have a creative mind, that is, in case some equipment is not available, a means can be made to identify and prepare experiments using available resources/materials.
- A lighter working load is preferable to avoid constraints so that laboratory activities can be conducted in a more leisurely fashion.
- Knowledge of the background of the target groups is also helpful to conduct smooth laboratory work, because when we are doing experiments, they should follow me. If they cannot, it is meaningless to do any experimental work concerning demonstration, student-centred experiments, small group work or investigations.

In relation to what types of laboratory work are mostly used, most of the interviewees had common views and said that they occasionally used demonstration but no other types were conducted. But there was a contrary idea that came from one student, S_1, who said that there was no experiment, which had been done by his teacher. This was against the panels' demands. The panel recommended that teachers should use a variety of laboratory work, and laboratory activities should be done by the students themselves, either independently or group hands-on experiments under teachers' supervision. The reasons they provided for not doing laboratory work were that there were inadequate facilities for laboratory work. The conditions of facilities will be analysed in the following section.

4.2.4 GENERAL CONDITIONS OF LABORATORY WORK

The other questions in the interview dealt with the conditions of laboratory work. All teachers indicated that they had access to a few chemicals, materials and equipments even though the availability of such things varied from one school to another. The CP member indicated that the laboratories had shortages of resources and some schools lacked laboratories, where buildings being used for classes, were turned temporarily to laboratory rooms. In this case, as CP indicated, "you can imagine a room without sufficient facilities". All of the assistants (LA_1, LA_2 and LA_3) and the students (S_1, S_2 and S_3) who were interviewed had negative views towards the facilities in their schools. According to the laboratory assistants, even the basic equipment was not available in their schools, such as water pipe and supply, electricity, heater, safety materials and supply of gas like buta-gas. In addition, T_1 said:

> Let alone the laboratory equipment, the building itself is not properly set up and we can't say that the laboratory is full and we don't have any proper equipment in this lab.

Lack of chemistry charts and periodic tables were the main problems for LA_1 and LA_3, whereas LA_2 did not have such barriers in his laboratory. However, LA_2 said that there were unopened boxes of chemicals and apparatus that had remained unused for a long time. The presence of separate rooms (for storage of chemicals and materials, and for use as an experimental room) was not a problem for LA_2 and LA_3, but it was a main problem for LA_1 because the laboratory room in his case was for both purposes, i.e. a storage room and at the same time an experimental room. According to the CP member, the panel usually advised teachers to try their best to use whatever materials and rooms were available to do experiments for students, even if the conditions of the laboratory were deteriorating and lacked many of the necessary materials.

Regarding the replacement of broken or out-of-use materials, all teachers indicated that there was not enough replacement of the broken equipment and chemicals. The reasons they provided were that the schools did not have a sufficient budget in order to buy or import such materials. Further, they claimed that the schools had nominal budgets that could be collected from students' fees during the opening year of the schools and this was mainly used for stationery. Moreover, they mentioned that there was nobody who could repair the broken equipment and follow up the maintenance of such equipment. Thus, all the interviewees had a common concern, which was that there was no adequate provision of facilities by the school administrators for students to perform experiments.

With regard to the provision of facilities by the Ministry of Education, the teachers who were interviewed said that there was insufficient provision by the Ministry of Education. The reason they provided was that they thought the Ministry might have budget constraints. According to the teachers who were interviewed, the Ministry of Education occasionally distributed a few chemicals which had been stored for a long time. Other than that almost nothing was provided. This was also confirmed by the chemistry panel member. Such problems and challenges will be addressed in the following section.

4.2.5. PROBLEMS AND CHALLENGES IN THE IMPLEMENTATIONS OF LABORATORY WORK

All the interviewees described the problems and challenges in the implementation of laboratory work. The CP member explained how the panel considered the constraints or problems of implementing the laboratory work. He suggested that the panel could not prepare a laboratory manual outside of the curriculum or textbook. They needed to stick to practical activities which were related to what the students learnt in class as well as what students encountered in their daily lives, despite the scarcity of resources. The CP member described it in the following way:

> The main problem is the scarcity of resources. Because of such scarcities, we can't modify the manual whatever it can fit to the limitation of resources we have. We have to make a manual, which can reflect the reality of the chemical concepts as the curriculum demanded. On the other hand, we have the scarcity of resources inside the schools, which can impede all the implementation of manual into practice.

With regard to qualifications of laboratory technicians, all the teachers remarked that they were under-qualified and that they had only taken short training courses for not more than three months. In this regard the laboratory assistants said that they were not all trained in chemistry, that is, two of them trained in Biology (LA_1 and LA_2) whereas the third (LA_3) took a short training course in chemistry. All the assistants indicated that they had been teachers in Primary Schools before they came to the present job. Teacher one (T_1) spoke about the skill of laboratory assistants in the following way:

> Sometimes he doesn't even know the names of equipment that is available in the laboratory and in a course of time he might have attended certain workshops.

The CP member also agreed with the above view and responded in the following way: "it is the basic issue which has arisen now" because the laboratory assistants were the most essential or the 'engine' element in the implementation of laboratory work and should assist the teachers to make it work well. Furthermore, the panel member also said that "a teacher who is teaching 7-8 sections with an average of about 50 students per class and with about 400 students a week, cannot let students do practical work, unless the teacher is assisted by the laboratory assistant". Thus, in the CP's view, " we are trying to make some improvement by training some laboratory assistants in collaboration with the University of Asmara". The interviews reflected that the unskilled and unqualified laboratory assistants were a significant factor in hindering the implementation of laboratory work. The CP member further stated that though teachers did their best to implement it, they were not motivated and so the outcomes were not satisfactory. In addition, S_1 said that the teacher was not willing to show them any experiment with the available materials. Teachers also pointed out that the challenge seemed to be how to prepare and organize laboratory work with such laboratory assistants and how to train them continuously.

As far as teaching overload of teachers is concerned, two of the teachers, T_2 and T_3, taught both Grade 10 and Grade 11, having between 30-32 periods per week. This reality was also recognized by the panel member at the time of being interviewed. Teachers T_2 and T_3 said that these heavy loads allowed insufficient time for preparation for laboratory work. However, T_1 had a lighter teaching load (i.e. 24 periods per week), which was reasonable compared to the other two teachers. Yet T_1 explained that he did not do laboratory activities due to the other factors facing him, such as lack of resources. For the two of the teachers interviewed, the problem was time constraints for preparing and implementing laboratory work and, coping with it was challenging.

The response by the CP member to the question of whether they had scheduled a timetable for the laboratory work, was that the timetable was left to the schools to establish for themselves. The reason he gave was that the schools needed to have a flexible timetable either by combining two additional periods per week or by introducing laboratory work in any other possible way. He further stated: "If we had set it ourselves, it would have been in terms of one and half hours and this would really have an impact on the timetable of the school, which has only 40 minutes per period". Further, the chemistry panel member asserted that this formed a mismatch between two managerial systems and it has not worked up to now. According to the teachers, adjusting the time to ensure sufficient time for laboratory work, was an important challenge in the implementation of the intended activities in laboratory work.

All of the teachers pointed out that class size was another problem in the implementation of laboratory work. Two of the teachers (T_2 and T_3) who were interviewed pointed out that they had a class size ranging from 48 to 72 students per section. The response given by the chemistry panel was no different. In this regard, most of the teachers said that it was hard to manage and to do experiments under such circumstances and that the space of the laboratory was not adequate to hold all the students. On the other hand, T_1 indicated that his class consisted of only 28 students, but that he still had a problem doing laboratory work. The reason he gave was that it was his first experience in teaching this grade. The interviewed teachers concluded that it was a challenge to manage and give attention to individual students during the implementation of the laboratory work with the existing large class size.

As indicated by all interviewees, the double shift was the other main problem. According to the CP, it was introduced only for reasons of maximizing the utilization of manpower to avoid the effect of the crippling shortages of teachers in the country. The CP member indicated that teachers were required to work double shifts so that they could teach more students; however, the double shift was not working in terms of quality of teaching. T_1 said:

> It puts pressure on the teacher, so that I can't prepare the activities in cooperation with the laboratory technician. Had it been one shift system, it would have been very helpful. As long as we are working in the two-shift system, we have overloads and this creates great problems in meeting ... the laboratory experiments.

T_2 added:

> The double shift system makes it hard to prepare the laboratory and also it is boring for teachers in the teaching and learning process.

As the CP described, teachers who teach in the morning shift could have taught the theoretical aspects of chemistry in the morning and could have called their students to the laboratory room for the afternoon shift. However, in the CP's view, this double shift system did not allow the teachers to get sufficient space (i.e. the school was occupied in both, morning and afternoon, shift with different groups) or time. Finally, the CP member concluded that "it has not only affected the laboratory work but also the whole of our education system". According to the teachers, the challenge was how to implement the laboratory work within the existing shift system.

With respect to the strong and weak side of laboratory work, the CP member's view was that the weak side was more pronounced because schools had many shortages of all the resources. Moreover, the CP member said that another weakness was that the textbooks themselves did not include many practical activities, as one would expect. The reason the chemistry panel member offered was that most of the time the activities were focused on abstract chemical knowledge rather than dealing with the actual situation in the daily lives of the students. On the other hand, in the view of the CP, a strength was that the MoE has prepared the textbook and laboratory manual even though the panel needs to make some amendments on them now and then so that they can become as practical and realistic as possible.

The CP member stated that laboratory work was needed to enhance teaching and learning. He went on to say that in order to meet such aims, teachers were given orientations, and workshops on how to do laboratory work and discussed its advantages in the teaching and learning process. Furthermore, it was clear to him that teachers were free to select activities and experiments based on the equipment available in the laboratory. Most of the time, he stated, the laboratory manual was in the hands of teachers whereas the students did not have a chance to see the procedures prior to the laboratory work being conducted. Thus, the CP now has a plan to prepare a text, which includes both the theoretical concepts and the practical procedures for students to follow. According to the CP member, they were working to give priority to schools which do not yet have laboratories. In this regard, the challenge is how to give workshops for teachers and how to construct equipped laboratories with the obvious scarcity of budgets and resources. The other challenge seems to be how to incorporate practical activities with theoretical aspects of chemistry in one text that could satisfy the needs of the students.

Finally, a recommendation was given by the CP member that they are dealing with science micro-teaching in collaboration with some South Africa research centre to import valuable materials so that they can use them for a longer time as well as to reach a larger number of students. The second initiative, according to the CP, was that they have formed a core team, which is working to assist the panel in gathering what local resources can be found across the country. As the CP pointed out, these materials can be used as low cost resources and can be designed with a certain local consultancy office in Asmara. These two, science micro-teaching and low cost resources from local sources, together will be able to help the schools much more than before.

4.3 STUDENTS' QUESTIONNAIRE

4.3.1 OVERVIEW OF THE QUESTIONNAIRE

The main issues intended to be addressed in this questionnaire, were to investigate the challenges in the implementation of laboratory work, to describe the most dominant type of the laboratory work and to assess whether Kerr's (1963) aims are promoted in the Eritrean schools, or not. In addition, parts of the students' questionnaire dealt with the general biographical data of the respondents. The last section contained an open-ended space, which was intended to get some more information that was not included in the questionnaire. The data also would help to describe weak and strong aspects of laboratory work.

This study investigated many challenges that were mentioned in the questionnaires. Moreover, students also stated some other challenges in the open-ended space provided. The study also addressed the types of laboratory work used by teachers. Even though there was inconsistency in terms of the types of laboratory work engaged in, students' responses indicated that the most dominant type of laboratory work was teacher demonstration and even this was used only occasionally in some schools. According to the data given by students, Kerr's (1963) aims were partially promoted in Eritrean secondary schools.

In order to gather such data, 148 questionnaires were distributed to a sample of the three schools which were involved in this study. Out of these, all (100%) were returned (see appendix XI). 112 (or 75,68%)of the respondents were male students and 36 (or 24,32%) were females. The number of females declined as grades increased up to Grade 11 and this caused an imbalance in gender. This was because of girl students having to do house work to support their mothers in the family, and also due to early marriages (which contributed to them leaving school early). The ages of the respondents ranged from 16 to 25 years. In the subsequent sections the findings with respect to specific aspects of the questionnaire, will be discussed.

4.3.2 STUDENTS' BIOGRAPHICAL DATA

As mentioned above, the students' biographical data were collected from the questionnaire. The researcher categorized the ages of students into three parts. There were ages 16-18, ages 19-21 and ages 22-25 years. This was intended to check their coincidence with the age categories given by the Ministry of Education. The majority (about 67,57%) of the ages of the respondents fell in the normal age categories (see appendix XI). According to the school system, the ages of the students who expect to attend secondary schools (from Grade 8 to 11) are from 14-17/18 (Ministry of Education, 2000/2001). The schools still retain students beyond the given formal age levels. The responses of the student questionnaires also confirmed that all the respondents were in Grade 11 and had five chemistry periods per week in theoretical lectures while there was no chemistry laboratory time allotted. So teachers were supposed to use some of these lectures as laboratory periods in order to achieve the listed aims in the curriculum.

4.3.3 AIMS OF LABORATORY WORK

The portion of the students' questionnaire that aimed at identifying students' opinions concerning the purpose of laboratory work, listed ten aims in section 'B' (see appendix VIII). As noticed earlier, the lists of aims were adapted from Kerr's (1963: 21) aims that had been done in a British survey of schools. The ten aims are presented in Chapter One. The students were asked to rate the aims by saying either 'Yes', 'No' or 'Not yet decided'.

The analysis would have been too complex and detailed if all the items had been analysed. Thus, the analyses have only included the most significant (or influential) percentages in the study. As can be seen in Table 2, with regard to the aim (of laboratory teaching) 'to encourage accurate observation and careful recording', about 38.5% of the students said 'No' while 46% of the students were in doubt whether to say either 'Yes' or 'No', and thus said 'Not yet decided'.

As far as the aim (of practical/laboratory work) 'to promote a logical reasoning method of thought' is concerned, about 46% of the students accepted the statement by saying 'Yes', about 32.4% of the students were not yet decided to say 'Yes' or 'No'. With respect to the aim 'to develop manipulative skills', about 49.3% of the students responded 'Yes' and 25.7% of the students responded against this aim. In the same vein, about 52.7% of the students responded to 'Yes' and about 23% of the students did not believe this was an

Table 2. Students rating on the ten aims of laboratory work.

Aims of practical work	yes	No	Not-decided	Missed response
1. To encourage accurate observation and careful recording	22(14,86)	57(38,51)	68(45,95)	1(0,68)
2. To promote a logical reasoning methods of thought	68(45,95)	28(18,92)	48(32,43)	4(2,70)
3. To develop manipulative skills	73(49,32)	38(25,68)	36(24,32)	1(0,68)
4. To give training in problem-solving	78(52,70)	34(22,97)	34(22,97)	2(1,30)
5.To fit the requirement of practical work	59(39,86)	34(22,97)	54(36,49)	1(0,68)
6. To elucidate theoretical work so as to aid comprehensive	65(43,92)	35(23,65)	46(31,08)	2(1,35)
7. To verify facts and principles already taught	94(63,51)	16(10,81)	36(24,32)	2(1,35)
8. To be an integral part of the process of finding facts by investigation and arriving at principles	14(09,46)	44(29,73)	89(60,14)	1(0,68)
9. To arouse and maintain interest in the subject	89(60,14)	19(12,84)	40(27,03)	-(--,--)
10. to make biological, chemical and physical phenomena more real through actual experience	91(61,49)	22(14,86)	34(22,97)	1(0,68)
Total response	653(441,12)	327(220,94)	485(327,70)	15(10,15)

(Key: The numbers in the front sides of the brackets indicate the number of respondents. The numbers inside the brackets indicate the percentage converted.)

aim and said 'No' whereas 23% of the students responded 'not yet decided' to the aim of laboratory work 'to give training in problem solving using scientific methods'. In terms of the aim 'to fit the requirements of practical examination regulations', about 30.4% of the students responded with 'Yes'. Around 23% of the students said 'No' and about 45.9% of the students were undecided as to whether to say 'Yes' or 'No'.

As far as the aim (of practical/laboratory work) 'to elucidate theoretical work so as to aid comprehension' is concerned, about 43.9% of the students rated this question 'Yes'. About 23.7% of the students responded against this aim and rated 'No'. About 31.1% of the students did not decide their position in relation to this aim. As far as the aim 'to verify facts and principles already taught' is concerned, the majority of the students, about 63.5%, rated 'Yes', about 10.8% of the students opposed this aim by saying 'No', and around 24.3% of the students were undecided.

In terms of the aim 'to be an integral part of the process of finding facts by investigation and arriving at principles', around 29.7% of the students opposed this aim and said 'No' in response whereas about 60.1% of the students were unable to say either 'Yes' or 'No'. An analysis of Table 2 shows that about 60.1% of the students rated 'Yes' to the aim 'to arouse and maintain interest in the subject' and about 27% of the students refused to say either 'Yes' or 'No' but said 'not yet decided'. The students also responded to the last aim 'to make biological, chemical and physical phenomena more real through actual experience'. In the following way: about 61.5% of the students responded with 'Yes', about 14.9% of the students denied its role in the present situation of the laboratory work and about 23% of the students were 'Not yet decided'.

4.3.4 TYPES OF LABORATORY WORK USED BY TEACHERS AS RATED BY STUDENTS

In section 'C' of the questionnaire the students were asked to rate the types of laboratory work they experienced in the teaching of Grade 11 chemistry. They were asked to rate 1 to 3 for each of the four listed types of laboratory activities. The data obtained in this respect are given in the subsequent section.

In terms of demonstration, Table 3 shows that about 52.7% of the students occasionally observed demonstration, whereas about 47.3% of the students rarely or never observed demonstration. The response to the 'individual work' concerned, about 97.3% of the students considered that teachers 'never used' individual work in practice in this Grade.

Table 3. Students' rating on the types of laboratory work used by teachers.

Type of laboratory work used by teachers.	Frequently used	Occasionally used	Never used
Demonstration	-	78 (52,7%)	70 (47,3%)
Individual experiment	-	4 (2,70%)	144 (97,30%)
Small group experiment	-	20 (13,50%)	128 (84,50%)
Investigation work	-	3 (2,00%)	145 (98,00%)

(**Note**: the number in front of the bracket indicates the number of respondent while the number inside the bracket indicates the percentage of respondents).

As far as small group experiments are concerned, about 84.5% of the students responded that teachers 'never used' such experiments. With regard to investigation work, about 98% of the students rated it as 'never used'. To assess whether the types of laboratory work are practised or not, the conditions of laboratory work need to be investigated. This will be explained in the next section.

4.3.5 BARRIERS TO LABORATORY WORK

In this case, the questionnaires addressed the issue of problems. In section 'D' of the questionnaire (see appendix VIII), the students were asked to rate the problems with respect to the implementation of the laboratory work in their schools. They were asked to rate 1 to 5 in terms of each of the seven items listed below as: '5' for very much/high, '4' much/high, '3' satisfactory, '2' little/low and '1' very little/low. The seven items considered in this regard are: time allotment, provision of laboratory facilities, applicability in every day life, supply of competent laboratory technician, coherence with theories and principles of chemistry and skills of teachers.

Table 4 below, indicates students' perceptions with regard to time allotment for doing chemistry laboratory work in their secondary schools. As can be seen in the Table 4, about 20.9% of the respondents responded "little used" (or low) and 75% of the respondents considered the time allotment as "very little used" (or very low) which indicated that the time given for laboratory work was almost none because three-quarters of the respondents selected "very little" and were unsatisfied with the time allotted to laboratory work.

In terms of the provision of laboratory facilities or equipment by either the school administration or Ministry of Education, 56.8% of the respondents suggested "none" (or very little) and 25% of them said little facilities. In terms of the provision of facilities and equipment in the concerned schools, over 50% of the respondents admitted to insufficient (very little) supply of equipment and laboratory facilities.

As far as the contribution of the laboratory activities to the everyday life of the sample students is concerned, 57.4% of the respondents felt it had no (or very little) contribution and 10.8% of them said little. These data indicated that

Table 4. Students' ratings about the general conditions of laboratory work in chemistry.

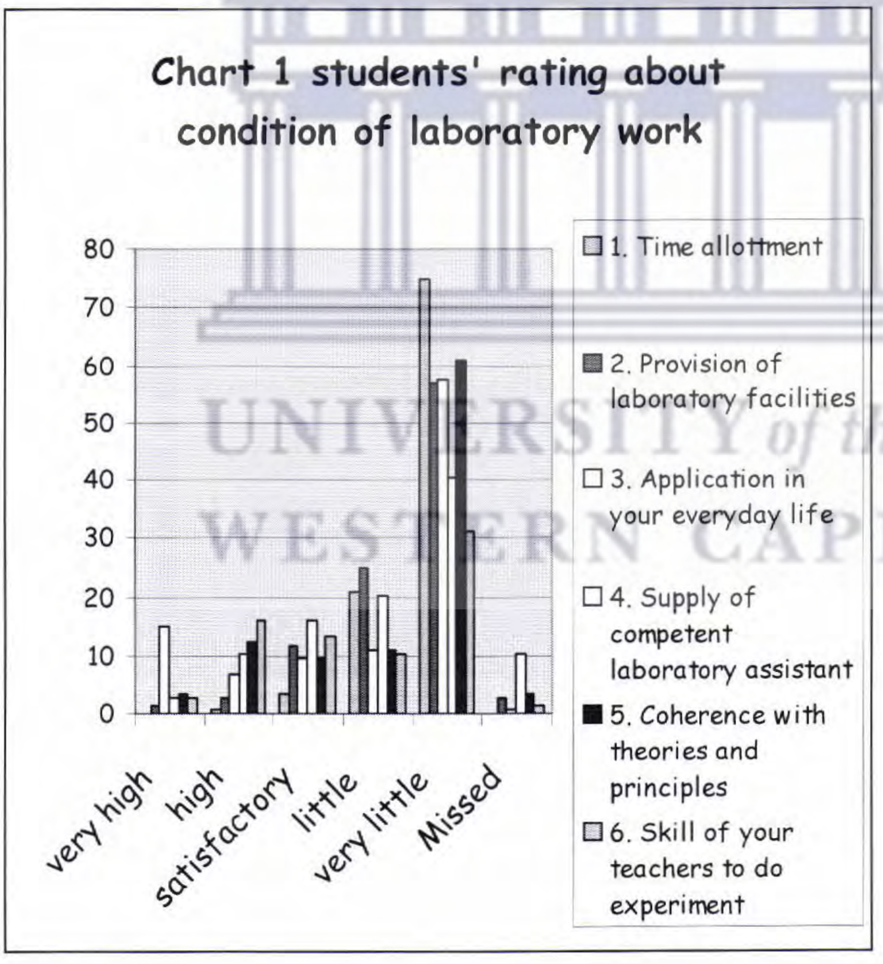
Factors		5	4	3	2	1	Missed resp.
		N (%)	N (%)	N (%)	N (%)	N (%)	N(%)
1	Time allotment	-	1(00,7)	5(03,4)	31(20.9)	111(75)	-
2	Provision of laboratory facilities	2(01,4)	4(02,7)	17(11,5)	37(25,0)	84(56,8)	4(02,7)
3	Application in your every day life.	22(14,9)	10(06,8)	14(09,5)	16(10,8)	85(57,4)	1(00,7)
4	Supply of competent laboratory assistant	4(02,7)	15(10,1)	24(16,2)	30(20,3)	60(40,5)	15(10,1)
5	Coherence with theories &principles of your textbooks	5(03,4)	18(12,2)	14(09,5)	16(10,8)	90(60,8)	5(03,4)
6	Skill of teachers to do experiments	4(02,7)	24(16,2)	20(13,5)	15(10,1)	46(31,1)	2(01,4)

(**Key**: N=number of respondent, %=percentages rounded off to one decimal place, comma between the number indicate decimal place after the number, 5=very much/high, 4=much/high, 3=satisfactory, 2=little/low, 1=very little/low and missed resp.=missed response).

more than half of the students felt the laboratory activities have very little (or almost no) role in the every day life of the students. In terms of the supply of competent laboratory technician concerned, 40.5% of the students suggested very low/little supply of competent laboratory assistants in preparing the needed experimental activities and procedures, 20.3% of them said low/little whereas 16.2% of them concluded that there was a satisfactory supply of competent laboratory assistants.

To identify the highest percentage responses of very little, little, satisfactory, high and very high to the conditions of laboratory work in the selected three secondary schools, these are indicated in bar graph form (see Chart 1 above).

Chart-1: Bar graph for the barriers of laboratory work



The students also responded to the question about coherence of laboratory activities with theories provided in the textbooks as follows: 60.8% of the students said it was very little/low, 10.8% of them suggested little/low and 12.2% of them accepted it as high. Again, with regard to the skills of teachers in the concerned schools, 31.1% of the students judged their teachers as having very low/little skill, 10.1% of them agreed that teachers had low/little skill, 13.5% of the students suggested their teachers were satisfactory in performing laboratory works, 16.2% of them said they had high skill and 27.7% of the students considered their teachers as having very high skill. And finally, 1.4% of the students abstained from responding to the teachers' skill issue.

Comments offered in the open-ended space made it clear that the conditions of laboratory work for Grade 11 chemistry in the three selected schools were insufficient and unsatisfactory. The large class size with an average of 49 students per class (see appendix XI) was mentioned. They pointed out that teachers were too exhausted to do laboratory work due to work overload and lack of encouragement given by the government and society.

4.4. DISCUSSION OF THE MAIN FINDINGS OF THE STUDY

4.4.1 AIMS OF PRACTICAL LABORATORY WORK

The researcher believes that the aims stated in Kerr are important to identify the aims of laboratory work in Eritrea. Based on this belief, the five most significant aims were identified. Whether or not similar situations have been found in any other country, some comparative analysis of the finding will certainly provide some clues about the necessary criteria or conditions that make practical work what it ought to be. The following data are used for comparisons. The most frequently mentioned aims of laboratory work, in a descending order, are as follows:

- To verify facts and principles already taught (63,5%);

- To make biological, chemical and physical phenomena more real through actual experience (61,5%);
- To arouse and maintain interest in the subject (60,1%);
- To give training in problem-solving (52,7%);
- To develop manipulative skills (49.3%).

Similar data about science practical work was also obtained by Kerr (1963), Ghebremariam (2000), Swain et al (1999) and Beatty and Woolnough (1982). For instance, Kerr (1963) pointed out the five most common aims for the same items rated by science teachers in Britain, in descending order are:

- To encourage accurate observation and careful recording;
- To elucidate the theoretical work so as to aid comprehension;
- To be an integral part of the process of finding facts by investigating and arriving at principles;
- To promote a logical reasoning method of thought;
- To verify facts and principles already taught.

A similar study had been done by Beatty and Woolnough (1982) using a modified version of Kerr's aims in England and Wales in which teachers had to be asked to rank such aims. From the five topmost, two aims such as 'to make phenomena more real through experience' and ' to arouse and maintain interest', coincided with this study. Other similar studies had also been done by Swain et al (1999) with science teachers Egypt, Korea and UK. Such studies have also shown three similarities with the present study, though in the reversed order.

In the studies mentioned above, data in the various countries reflect differences in rating and ranking of the aims. These differences have occurred due to social and material differences in the different countries. In addition, students and science teachers have different level of knowledge and capacities in rating and ranking the aims given and hence it becomes clear that the different sets of respondents have prioritised different sets of aims. On the other hand, the set of aims which are common to these countries, "combine both epistemological features - in making new knowledge – and pedagogical features – in helping students to learn science" (Swain et al, 1999: 1318).

For the overall aims discussed above, Kerr's aims were partially promoted in the more privileged schools as well as those who did demonstrations in Eritrea. Nevertheless, there is a challenge as to how to devise strategies that can help teachers in Eritrea to promote Kerr's aims of practical work. Kerr's aims could be promoted in using different types of laboratory work.

4.4.2 TYPES OF LABORATORY WORK

The findings of the data indicate that there was irregular use of different types of laboratory work in the concerned schools. The type of laboratory work used by Eritrean chemistry teachers in the concerned schools was demonstration, which was occasionally used, whereas other types of laboratory works were never observed in the sample schools. A number of other studies have also reached similar conclusions. For example, Kerr (1963) asserts that there was inconsistency between the kinds of experiments which science teachers in UK had done. His findings indicate that verification experiments were very frequently used, whereas demonstration work was neglected, and investigation was not fully achieved. Even in the study of various Ethiopian secondary schools, which had been studied by Bekalo and Welford (1999) in different regions of the country, out of 80 lessons observed, only one teacher did demonstrations. They concluded that science educators have difficulty in understanding the practice let alone in implementing it. This was due to deteriorating conditions of laboratory work.

4.4.3 CONDITIONS OF LABORATORY WORK

The findings of the study indicated that the building of the laboratory in itself is not properly set up, had inadequate infrastructures (like water supply, electric supply). These situations made it almost impossible to do laboratory work.

Such conditions are not unique to Eritrea. A number of studies have indicated problems in other countries. According to Ware (1992), in laboratory instruction, it is easy to suggest that problems associated with implementing the laboratory component of science classes results solely from inadequate facilities and a lack of equipment and supplies. Simpson and Anderson (1981) found out that facilities and equipment were often the limiting factors for science teachers, in terms of how much laboratory work gets done. In their view, the availability of adequate facilities and equipment is highly desirable, and every effort should be made to obtain at least the essential items. Therefore, from this study, it is evident that the way of dispatching the facilities and improving the infrastructure of laboratory rooms, were the challenges of the schools as well as the Ministry of Education.

4.4.4 PROBLEMS AND CHALLENGES IN THE IMPLEMENTATION OF LABORATORY WORK

The findings of this study provide some insights into the struggles experienced by teachers as they try to address the problems in the implementation of laboratory work in the concerned schools. Most of the time challenges are related to the way teachers tackle problems encountered during the implementation of laboratory work. As mentioned in the above analysis, respondents and interviewees saw inappropriate laboratory work as a major problem. This was also confirmed by the students who gave their responses on the open-ended blank space in the questionnaires. More detailed discussions follow below.

The problem noticed by all of the respondents on the questionnaires and the interviews, was insufficient material resources or facilities. Even resources which were available in some of the privileged schools, were poorly organized and also effectively unusable. This made it difficult for teachers to do laboratory work in the sample schools. The researcher found the lack of available resources problematic, despite the attempts of the schools to ensure there were some resources. Nevertheless, such problems do not necessarily mean that laboratory work cannot be done. Bekalo and Welford (1999), from their observations in Ethiopian secondary schools, suggested that lack of equipment and resources are not always the cause of failure to do practical work. They went on to say that there was a school which had fewer than 20 students per class and reasonable resources yet teachers were never observed teaching using practical work.

Moreover, there was a problem for the teacher as to how to do laboratory work with the existing chemicals and equipment at their disposal. According to Bekalo (1997) cited in Bekalo and Welford (1999), science educators in Ethiopia had difficult in understanding the practical let alone implementing it. The situation in Eritrea at the time of the study seemed to be similar to that of Ethiopia. The researcher found that there was a gap between the understanding of teachers in using laboratory work with the existing (or available) materials and the implementation process. Bridging this gap is a challenge in the implementation of laboratory work.

The buildings of laboratories themselves created another barrier in implementing laboratory work, as teachers had mentioned during interviews. The results of the data revealed that the buildings were constructed without proper planning and design and some laboratory rooms were initially constructed as teaching classrooms. Thus, the laboratory room was often too small to hold all the students at one time. The researcher also observed this limitation during interviewing. This could have hindered the implementation of laboratory work. Teachers were struggling to accommodate large numbers of students in laboratories while at the same time dealing with the acute space limitations of the building.

The data indicated that Grade 11 chemistry teachers, in the sample secondary schools, dominated their teaching process using lectures – explanations and theory discussions. This made a lesser contribution to the overall development of students and many of the students who were involved in this study are victims of one teaching method, i.e. the lecture. Similar findings were found in the study of Bekalo and Welford (1999) in Ethiopian secondary schools. They found that teachers employed lecture-methods that verify knowledge rather than the demonstrations recommended by the syllabus. It is reasonable to suppose that the 'chalk and talk' method is common and this approach influences teachers' ability to carry out practical work confidently and independently in Ethiopia. In a similar case, Woolnough and Allsop (1985: 80) stated: " most science teachers have themselves been brought up on a diet of content dominated cookery book-type practical work and may have got in the habit of propagating it themselves". The fact is that most teachers at present in the study in Eritrea were ill-prepared to do laboratory work.

There was poor preparation of teachers in the implementation of laboratory work, which could be considered a problem. The finding of this study showed that teachers were not well-skilled in manipulative work, they would need intensive laboratory workshops to implement the laboratory work correctly with the resources they have. The findings obtained by Ogunniyi (1996) point out that teachers lack confidence in their teaching ability because of inadequate training, lack of skills as well as inadequate opportunities for self-improvement. According to Swain et al (1999), most Egyptian science teachers used laboratory work infrequently because teachers were not particularly skilled in laboratory and manipulative techniques over and above poorly-equipped and maintained laboratory facilities. Ware (1992) asserted that science teachers in secondary school may have a science degree, especially in developing countries, but may miss how to utilize their knowledge in the teaching and learning situation. In this study, there was a challenge in terms of introducing the different teaching methods by the panel on the one hand and transforming the method which teachers usually practised their teaching, on the other hand.

Despite such challenges, there was no doubt about the value of laboratory work in the study. According to Swain et al (1999), students could relate the application of chemistry to their environments. Similarly, a number of studies have pointed out the main roles of laboratory work. For example, Hodson (1990) states that laboratory work has many functions such as to motivate students by stimulating interest and enjoyment; to teach laboratory skills; to give insight into scientific attitudes like open-mindedness, objectivity and willingness to suspend judgment. Therefore, laboratory work is essential in any science education; particularly in chemistry it is valuable and useful. This is because chemistry is fundamentally an experimental science.

There was a lack of coherence between the theory and laboratory activities that were identified in this study. The intention of the panel was to identify and develop simple, interesting and affordable practical activities in laboratory. For this reason, teachers have been advised to supplement their lessons with practical activities using locally available materials. However, the teachers did not use such materials. As a consequence, the researcher found lack of coherence between laboratory activities and the theories given in the textbooks on one hand, and scarcity of resources (making laboratory activities almost impossible) on the other. A number of other studies have made similar findings. For example, Bekalo and Welford (1999) found the teaching of theory and the carrying out of practical work were generally separated, not integrated in one lesson. Bekalo (1997) cited in Bekalo and Weldford (1999) points out that there was lack of coherence between intention, implementation and evaluation of educational programmes. Integrating stated laboratory activities, the implementation process and the need of students in their daily life was the challenging process.

Another challenging problem found in this study was a shift system. This made teachers feel reluctant to implement laboratory work, as well as unmotivated towards laboratory work. A number of studies indicated such cases. For example, Baire and Mwamwenda (1994) cited in Ghebremariam (2000) point out that teachers sometimes work for long hours, for example, in Zimbabwe from 7: 15am to 5: 20pm. In the afternoons, teachers are often tired, hot and perhaps, less enthusiastic. As a result, they couldn't implement laboratory work. So the finding of this study pointed out that one of the challenges in the implementation was the shift system.

The other challenge is managing large class sizes in laboratory work. The data indicated that the number of the students was about 49 in an average Eritrean Grade 11 class. According to the Ministry of Education in Eritrea, the teacher-student ratio is 1:56 (MoE, 2001). This ratio is very high and it becomes more difficult for teachers to implement laboratory work and to give students individual attention. The problem of large class size has been common in most developing countries for a long time. For instance, Bekalo and Welford (1999) observed in one of the Ethiopian secondary schools classes with more than 60 students. Also, in Taiwan, class sizes are more than 50 to 60 students per class (Tobin and Tippins cited in Ghebremariam, 2002). According to Ajewole cited in Onwu (1998), in Nigeria, a recommended teacher-pupil ratio is 1: 35 for secondary schools, while the reality in some states was between 1: 50 and 1: 85. Ajewole states that in many African schools, not only were classes large but, unlike classes in the industrialized world, they were frequently also overcrowded, and lacked resources. The findings in this study point out that laboratory work is difficult to implement with large classes in the sample secondary schools, so that engaging students is one of the challenging tasks of teaching in large classes in laboratories.

Poor qualifications of laboratory assistants was another problem encountered in the implementation of laboratory work. The results of the data indicated that there were unqualified laboratory assistants that existed in the schools involved in this study. According to Swain, Monk and Johnson (1999), the laboratory assistant in the UK changes the equipment for the science teachers as the classes change. Ware (1992) also pointed out, laboratory assistants need to be able to repair the equipment they have. But the laboratory assistants in the study did not have such skills and this remained as a problem.

The data revealed that there is an inappropriate laboratory timetable. The time for each period in any science discipline was 40 minutes for the schools under study. Laboratory activities require more time than 40-minute period. Since this 40 minutes was not enough, it would have some impact on the implementation process. The panel has left the preparation of timetable to the schools but the schools themselves experienced constraints with time so that it was inconvenient for the schools to set aside sufficient time. As a result, the timetable remained problematic for teachers. According to DeBoer (1991), one practical problem with using the laboratory was that for scheduling purposes, the laboratory periods were fixed at certain days of the week. This means that it was almost impossible to have the kind of free interchange between the laboratory and the classroom that was essential to make the practical approach work. The researcher found that setting out an appropriate laboratory timetable was a challenging process.

The policy of Eritrean education has been to bring forth the students' overall development and then to improve the educational standards of the country, which had suffered during the colonial period. However, the quality of the education system in general, and laboratory work in particular, has continued to deteriorate for the last decade. This seems to indicate that there is something wrong in the education policy. According to Caillods et al (cited in Reddy 1998: 96), policy is a 'blunt instrument' to produce intended educational change. Reasons provided by Caillods for why change has not yet been effected include: (1) a shortage of well-trained and motivated teachers; (2) a failure to implement planned curricula because of a lack of resources; (3) a failure to consider prevailing national conditions; (4) not involving teachers in policy formulation; and a lack of planning and coordination between those institutions concerned with provision of science education. The situation in Eritrea is not far from this reality.

In summary, the study reveals that lack of resources, unqualified laboratory assistants, large class size, teaching overload, double shift system, poor infrastructure of the laboratory rooms, poor preparation of teachers, incoherence of laboratory activities with theory, and time constraints, were the main problems that hindered the implementation of laboratory work. A number of other studies have reached similar conclusions. For instance, Lunetta and Hofstein (1991) identified the constraints of laboratory activities such as 40-minute laboratory periods, safety, budgets and resources. Kerr (1963) also found similar barriers for practical work in British school sciences. These were: insufficient laboratory facilities, overuse of laboratories, shortage of qualified teachers, lack of laboratory assistants, and large classes impair the effectiveness of laboratory work. Thompson (1975) also pointed out obstacles which might restrict the planning of practical work (see chapter two in section 2.7). All these problems hindered the implementation process of laboratory work. The main challenge seems to be how to implement the intended laboratory activities with the existing barriers in the concerned schools.

4.5. CONCLUSION

This chapter has engaged with the analysis of all interviews and the responses to the questionnaires in a more detail. Since similar questions were asked to each group of interviewees, the researcher has arranged the responses according to the question themes rather than to the particular groups of respondents – i.e. teachers, students, laboratory assistants and chemistry panel member.

Most of the discussions reveal research findings similar to the data findings in other developing countries. There was no new data that was obtained or developed out of the research findings. From the findings of the data it is not difficult to understand the weak and strong aspects of the implementation of laboratory work. The data indicated that there are many obstacles to the implementation of laboratory work, including to what extent practice might deviate from theory due to conditions in the schools. The analysis and discussions reveal the challenges which have prevented a meaningful implementation process of laboratory work. The quality of science education has, as a result, declined. Nevertheless, laboratory work should be considered in terms of its appropriateness in providing a wide range of knowledge and experience for students in Eritrean. Similar conclusions and recommendations will be given in the next chapter.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 INTRODUCTION

In Chapter Four, detailed discussions were given about the aims of laboratory work, the kinds of laboratory work, situations of laboratory work, problems and challenges in the implementation of laboratory work in the three selected Eritrean secondary schools.

This final chapter provides an overview of the study, summary of the main findings of the study and their implications to the stakeholders. It also includes some recommendations related to the scope of the laboratory work, class size, double shifts, facilities for laboratory work, laboratory assistants and training of chemistry teachers.

5.2 OVERVIEW OF THE STUDY

The primary intention of the study was to investigate the challenges in the implementation of Grade 11 chemistry laboratory work in the three selected Eritrean secondary schools. The hope was that the findings would be used as essential sources for those who were supposed to carry out large-scale investigations nationwide. As mentioned in Chapter One, some of the aims of the study have attempted specifically to:

- assess whether Kerr's aims of practical work are or promoted or not within the Eritrean context in secondary schools.
- identify the problems that hinder the implementation of laboratory work for Grade 11 chemistry.

- investigate the challenges in the implementation of laboratory work in the sample secondary schools.

The answers to the research questions were described in this study by establishing their importance in laboratory work. According to DeBoer (1991), laboratory work should be used in chemistry teaching, but it should be done in such a way that it enhances the meaning of chemistry to the students, and should not be treated merely as a set of 'empty disciplinary tasks'. This puts an additional burden on the teachers to make connections between laboratory work in chemistry and the life experience of the students. Hodson (1992) points out that any learning method that requires the learner to be active, rather than passive, accords with the belief that students learn best by direct experience, such as 'laboratory work'.

To investigate the challenges, both the interview and questionnaire instruments were used. These instruments included both qualitative and quantitative data, which resulted in triangulation, that is the combination of two or more methods. The data were collected with different stakeholders: teachers, laboratory assistants, students and the chemistry panel member.

To have a holistic perspective, the data was collected from the following sources:

- One-hundred and forty eight student questionnaires were dispatched to three secondary schools in two zones.
- Interviews were conducted with four stakeholders such as teachers, students, laboratory assistants and a member of the chemistry panel.

In this study, inappropriate laboratory work was pointed out by many of the educators interviewed. The overall conditions of laboratory work were not favourable for the implementation of the intended activities in the curriculum, so that the stated objectives of the laboratory work were not achieved. Furthermore, Kerr's aims were not promoted sufficiently. As a result, students did not have the benefits of acquiring the critical knowledge, skills and experiences that would have enhanced their understanding of what they have learnt in classes. The next section will give a summary of the findings.

5.3 SUMMARY OF THE MAJOR FINDINGS OF THE DATA

The study was directed solely at laboratory work. This was because many applications of chemistry (and their importance), are demonstrated through experiments in laboratory work. Also, laboratory work is a good skill-developer for the students, which helps them to solve problems encountered in their daily lives after leaving school. These problems should be closely related to what they have learnt in class.

The study has identified many obstacles and challenges in the implementation of laboratory work. These are not far from the findings obtained by many scholars in many developing countries. These are: inadequate chemicals and equipment, unskilled laboratory assistants, poor preparation of teachers, large class sizes, double shift systems, time constraints, budget constraints, utilizing of a single teaching method. inadequate laboratory buildings, lack of fixed timetables, and teaching workloads (see Kerr, 1963; Thompson, 1975; Ogunniyi, 1977, 1986, 1996).

As the findings indicate, the laboratory facilities were inadequate because the schools were faced with the reality of a limited budget for equipment and apparatus. This budget was probably obtained at the beginning of the year through school registration fee. Students do not have monthly fee. Therefore, the schools must make hard choices about how to get the most out of what they have. There was a lack of congruence between the intended activities of the curriculum and the realities of the typical laboratory conditions. The fact is that theory should be closely followed by relevant practice. The study also indicated that there is a lack of scheduled timetables. However, as DeBoer (1991) indicates, laboratory work takes up space, requires equipment and supplies, and uses up a good portion of time available. According to DeBoer, these were minor when few students attended school, but they became significant concerns as secondary school enrolments increased. Because of large numbers of students and the longer time required for laboratory work, little could be shown for it. As Bekalo and Welford (1999) point out, many teachers in Ethiopian schools perceived the crowded urban school classes of more than 60 students as de-motivating for chemistry laboratory work. They further observed that teachers were not flexible or knowledgeable enough to exploit favourable conditions and to thus provide students with practical experience. All the above-mentioned have also been described in this study, and are among of the challenges in the implementation of laboratory work.

The data also revealed that the teaching and learning process of chemistry teachers in Grade 11 was mainly the lecture method, despite the occurrence of occasional demonstration-type lessons. As Bekalo and Welford (1999) point out, much of the science taught in Ethiopia remains concerned with rote learning of factual knowledge and the passing of examinations predominantly valuing recall of knowledge. Furthermore, Kerr's (1963) study indicates that teachers agreed on the significance of laboratory work for the development of educational values. However, in his study, demonstration was neglected, as stated in section 4.4.2. The introduction and utilization of diverse types of laboratory work were the challenges indicated in this study.

The data of the findings asserted that there was a scarcity of skilled laboratory assistants in the sample secondary schools. A similar study has been done by Ogunniyi (1977, 1996) and shows that the lack of laboratory assistants became an additional burden on science teachers in Nigeria and Botswana, who were already overloaded. This study, however, pointed out that the support of laboratory assistants was crucial in the implementation of laboratory work in the concerned schools. Thus, it was difficult to get skilled assistants at short notice, so that it continued to be a challenge for training as well as for teachers to implement the intended laboratory activities without the support of assistants.

The other indication in this study is that the sample schools had large numbers of students. This was noticed as being problematic and difficult to manage during teachers' demonstrations. Okebukola (1986) also pointed out the problems of large classes in Nigeria. As he indicated, the ratio of qualified teachers to students in secondary schools was 1: 85. To solve such problems, many additional skilled teachers and buildings were needed in order to accommodate the students. Another finding was the problem of the double shift system. This created a greater teaching load and time constraints for chemistry teachers. Providing an appropriate shift system was a challenge for the Ministry of Education as well as for Grade 11 chemistry teachers. This is due to the scarcity of teachers in the country. The data also indicated the problem of the buildings. The buildings were small and lacked infrastructure.

The overall problems and challenges discussed above are the main barriers in the implementation of Grade 11 chemistry laboratory work in the sample secondary schools. The investigation which had been done by Kerr (1963) proposed that three main obstacles prevented full achievement of the possible rewards of learning science through practical/laboratory work. These are: (1) the need to improve the conditions for practical activities with respect to class size, laboratory facilities, and laboratory technicians; (2) the need to concentrate on the development of practical skills rather than meeting examination requirements and (3), the need for greater integration between stated objectives and actual practice.

Most of the problems and challenges identified in this study have some implications for education policy with regard to laboratory work. The policy of Eritrean Education was to bring students into work related activities and through laboratory work, students were to gain some benefit in their daily lives. In addition, to bring changes to the education standards of the country, which had declined during colonial period. However, actual education in general and laboratory work in particular, has continued to deteriorate over the last decade. Recommendations for ongoing considerations will be offered in the next section.

5.3 RECOMMENDATIONS

As the researcher explained earlier in more detail, numerous factors have affected the implementation of laboratory work in the sample secondary schools in Eritrea. Even though they are difficult to avoid completely, there are many ways of reducing their burdens in the implementation of laboratory work. The following recommendations are provided.

a) One recognized research centre should be established at national level to carry out the responsibilities of re-training, recruiting qualified teachers and laboratory assistants and to supply basic materials required for successful implementation of laboratory work. In addition, as Rollnick (1998: 85) points out, "considerations other than financial must motivate them to continue teaching" in the laboratory. Moreover, Swain et al (1999) state that changes to the working environment of teachers through curriculum reform, in-service provision and increased resources will lead to changes in pedagogy which in turn will alter opinions and attitudes.

b) The Ministry of Education should have a strong link with the University of Asmara, to facilitate training and give workshops and seminars for both teachers and assistants on how to use local or 'low cost' materials. Such changes are also necessary to improve the working conditions of teachers in Eritrea.

c) To ameliorate the problems of limited resources, the researcher suggests that this should be improved through the allocation of an increased proportion of the budget from the Ministry of Education and through greater efficiency in the use of existing allocations through 'cost-saving reforms' such as simple beakers.

d) The researcher also recommends that opportunities for methodological dialogue (such as discussions on how to conduct experiments, their advantages and their disadvantages) should be provided among the teachers. In such fora, the teachers will explore and share experiences about the use of various methods. This can then play an important role in the implementation process of laboratory work.

e) The recommended teacher-student ratio in Nigeria was 1:35 for secondary schools whereas the real ratio was greater (i.e. 1:50, and up to 1:85) than this in some states (Ajewole cited in Onwu, 1998). Therefore, this study recommends that the number of students should not exceed 35 per class, so as at least have reasonable management and to pay attention to individual students.

f) Preparing laboratories without scheduled timetables was a challenging process in the implementation of laboratory work. In the view of the researcher, this can be solved if the time for laboratory work is about one hour and a half per week as the chemistry panel proposed in his interviews. This time would help teachers to create a conducive atmosphere and do valuable laboratory work.

g) In terms of the buildings, the researcher recommends that the laboratory should be sufficiently sized and designed to accommodate the students of one class and to support a wide diversity of teaching styles and methods. The laboratory should provide space for students to work safely either in groups or as individuals.

h) Rewards (either money or materials) that parents can become involved in, for teachers, is also important as a form of motivation and encouragement. The panel should develop a plan to ensure the participation of parents and establish an organization that includes teachers, parents and the chemistry panel. Through this, teachers can share and exchange their ideas with one another, with parents and departmental officials. Hopefully, in this way, laboratory teaching will become more attractive to teachers. As a result, the implementation of laboratory teaching will achieve its target and the students will leave secondary schools with more than the minimum requirement of skills that can help them in their daily life or may help them as a base as they move on to higher institutions.

5.4 CONCLUSION

The framework of this study is Kerr's (1963) ten aims of practical work. The researcher has chosen to use Kerr as a reference point because he feels that the ten aims which Kerr has developed for practical/laboratory work accords with the researcher's own views. In addition, various aspects of the teaching and learning situation in Eritrea are similar to those of British. He conducted his study using such aims to be ranked by teachers. Based on these aspects, he analysed the data and his findings determined the relevance of practical work and what it ought to be and identified the problems which contributed towards laboratory work deviating from his theory. He proposed how to achieve successful practical work with the aims intended.

It is important that Kerr's aims are ranked by teachers rather than by students. The intention of using them in this study is to find out how students see them. Though the data obtained in this study are satisfactorily significant, the findings are not the same as Kerr's findings because there are differences in the perceptions of students and teachers based on their level of knowledge. Both findings overlapped each other in some aspects. Interviews with different stakeholders were done to supplement Kerr's aims in order to investigate the challenges in the implementation of laboratory work. In many ways the data of the study are similar to those that had been found by Kerr.

What the data findings have shown is that all the sample secondary schools did not have appropriate situations (i.e. lack of infrastructure and resources). These caused teachers to have less initiative and dedication in implementing laboratory work. As a result, students were denied the opportunity to observe and perform laboratory activities in spite of the fact that they have the inclination and curiosity towards it. As a consequence, students leave secondary schools without initial skills and they remain unproductive. These findings seemed to indicate that there were insufficient laboratory activities aimed at the above aspect in the sample schools. Even the Ministry of Education has been concerned about the outcome of laboratory work and has started to talk about how to transform this from the current situation to a new curriculum (i.e. intend to start 2003/04), which is expected to be more productive. The problems and challenges that have been identified in this study will hopefully play a significant role in the foregoing considerations. The messages emerging from this research study might strike resonance with others embarking on a similar school study elsewhere in the country. However, more detailed investigation is required to include all schools in Eritrea.

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UNIVERSITY OF ASMARA

ERITREAN HUMAN RESOURCES DEVELOPMENT PROJECT (EHRD)

PROJECT COORDINATING UNIT (PCU)

Ref. No.HRD\4/4952/02

DATE: 19 DEC 2002

To:
Harinet Secondary School
Asmara

Dear Sir/Madam,

The bearer of this letter, **Ato Haddish Woldu Fessehatsion,** is one of the students placed by the EHRD Office at the **University of Western Cape** to do his Masters degree in **Education**.

Ato Haddish is presently back in Asmara to collect data/information for his thesis work titled: ***"Investigation of the Current Challenges in the Implementation of Grade-11 Chemistry Laboratory Work in the Three Selected Eritrean Secondary Schools".*** We have come to learn that, to complete his research project successfully, he would definitely need to have access to your organization's data/information base.

I take this opportunity to request you to assist him in his research endeavour.

I thank you for your time and kind consideration.

Awet N'hafash!

Tewelde Zerom, PhD.
Manager, EHRD-PCU
University of Asmara

cc.: Mehari Tewolde
Monotoring & Evaluation Officer, EHRD Project
University of Asmara

Mailing Address:	Tel:	Fax:	E-mail
University of Asmara P. O. Box 1220 Asmara, Eritrea	291-1-119035 291-1-161926	291-1-124300 291-1-162236	hrdpcu@asmara.uoa.edu.er

APPENDIX II

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جامعة اسمرا

UNIVERSITY OF ASMARA
ERITREAN HUMAN RESOURCES DEVELOPMENT PROJECT (EHRD)
PROJECT COORDINATING UNIT (PCU)

Ref. No.HRD\4 /4953/02

DATE: 19 DEC 2002

To:
Tsa'eda Kirstian Secondary School
Tsa'eda Kirstian

Dear Sir/Madam,

The bearer of this letter, **Ato Haddish Woldu Fessehatsion,** is one of the students placed by the EHRD Office at the **University of Western Cape** to do his Masters degree in **Education**.

Ato Haddish is presently back in Asmara to collect data/information for his thesis work titled: ***"Investigation of the Current Challenges in the Implementation of Grade-11 Chemistry Laboratory Work in the Three Selected Eritrean Secondary Schools".*** We have come to learn that, to complete his research project successfully, he would definitely need to have access to your organization's data/information base.

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I thank you for your time and kind consideration.

Awet N'hafash!

Tewelde Zerom, PhD.
Manager, EHRD-PCU
University of Asmara

cc.: Mehari Tewolde
Monotoring & Evaluation Officer, EHRD Project
University of Asmara

Mailing Address:	Tel:	Fax:	E-mail
University of Asmara P. O. Box 1220 Asmara, Eritrea	291-1-119035 291-1-161926	291-1-124300 291-1-162236	hrdpcu@asmara.uoa.edu.er

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جامعة اسمرا

UNIVERSITY OF ASMARA

ERITREAN HUMAN RESOURCES DEVELOPMENT PROJECT (EHRD)

PROJECT COORDINATING UNIT (PCU)

Ref. No.HRD\4/4954/02

DATE: 19 DEC 2002

To:
Adi-Quala Secondary School
Adi-Quala

Dear Sir/Madam,

The bearer of this letter, **Ato Haddish Woldu Fessehatsion,** is one of the students placed by the EHRD Office at the **University of Western Cape** to do his Masters degree in **Education**.

Ato Haddish is presently back in Asmara to collect data/information for his thesis work titled: ***"Investigation of the Current Challenges in the Implementation of Grade-11 Chemistry Laboratory Work in the Three Selected Eritrean Secondary Schools".*** We have come to learn that, to complete his research project successfully, he would definitely need to have access to your organization's data/information base.

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I thank you for your time and kind consideration.

Awet N'hafash!

Tewelde Zerom, PhD.
Manager, EHRD-PCU
University of Asmara

cc.: Mehari Tewolde
Monotoring & Evaluation Officer, EHRD Project
University of Asmara

Mailing Address:	Tel:	Fax:	E-mail
University of Asmara P. O. Box 1220 Asmara, Eritrea	291-1-119035 291-1-161926	291-1-124300 291-1-162236	hrdpcu@asmara.uoa.edu.er

APPENDIX IV

TEACHERS' INTERVIEW

1. What do you think about the importance of laboratory work in the daily life of the students?
2. To what extent does Grade 11 chemistry laboratory work in Eritrean secondary schools promote the achievement of Kerr's aims of practical work in school science, particularly to chemistry?
3. How adequate are the facilities of Grade 11 chemistry laboratory work in your secondary school?
4. How suffice are the facilities provided by the ministry of education for performing laboratory work in chemistry?
5. What criteria(s) do you prefer to do the type(s) of laboratory work whether it is a demonstration, student-centered experiments or group work experiments?
6. What type(s) of laboratory work do you perform most frequently? Why?
7. Is investigation work in chemistry laboratory being carried out? If yes/no—details
8. In your school, do you have enough supply of major equipments such as test tube, bunsen burner, beaker, flask, funnel, etc. in teaching Grade 11 chemistry? If not, why?
9. How does the school replace the broken or non-functioning equipment?
10. What constraints/ problems do chemistry teachers encounter in conducting and teaching laboratory work?
11. How qualified is your laboratory assistant in preparing experiments?
12. How do you see the number of periods per week (or teaching workload) and sections you have in doing laboratory work?
13. What is the average class size in your sections? What do you think about this size in performing laboratory work?
14. What is your view about the double shift in preparing and doing laboratory work?
15. What are the weak and strong sides of Grade 11 chemistry laboratory work in your secondary school?
16. What would you like to say something about implementation of laboratory work?

APPENDIX V

STUDENTS' INTERVIEW

1. What do you think about the importance of learning and role of chemistry laboratory work in Grade 11?
2. from your observation and performing, how do you see the adequate facilities in your practicing day?
3. Which type(s) of experiment(s) is/are more dominant in your laboratory work?
4. Would you like practical approach rather than lecturer method in which teacher use in his/her teaching chemistry? Why?
5. What is your view about the qualification of teachers and laboratory assistants in implementing laboratory work?
6. Do you have any suggestion(s)or comments to say about laboratory work in chemistry?

APPENDIX VI

LABORATORY ASSISTANTS' INTERVIEW

1. What is your qualification? How many years have you been in this work?
2. How adequate are the facilities of Grade 11 chemistry laboratory work in your secondary schools?
3. How do you replace the equipments that are out of functions?
4. To what extent does Grade 11 chemistry teachers perform laboratory work in your school?
5. From your experience, which type(s) of laboratory work do teachers most frequently used?
6. What are the weak and strong sides of Grade 11 chemistry laboratory work in your secondary school?
7. What would you like to say something about the conditions of Grade 11 chemistry laboratory work in general?

APPENDIX VII

MEMBERS OF CHEMISTRY PANEL INTERVIEWS

1. What do you think about the importance of laboratory activities in relating to the daily life of the students?
2. What are the panel's objectives with regard to laboratory work?
3. How does the panel consider the need for students to do laboratory work?
4. How adequate are the facilities of Grade 11 chemistry laboratory work in Eritrean secondary schools?
5. What type(s) of experiments does the panel recommend for Grade 11 chemistry teachers to use as a guide?
6. From your view and experience, what problems and challenges do grade-11chemistry teachers encounter in implementing and teaching laboratory work?
7. Does the panel have a stated timetable for implementing laboratory work?
8. What do you think about the double shift system of teachers in implementing laboratory work?
9. What is your view about the skill of laboratory assistants and teachers in implementing laboratory work?
10. To what extent does Grade 11 chemistry laboratory work in Eritrean secondary schools promote the achievement of Kerr's aims of practical work in school science, particularly to chemistry?
11. What are the weak and strong sides of Grade 11 chemistry laboratory work in Eritrean secondary work?
12. Do you have any recommendations, suggestion(s)or comments to say about the implementation of laboratory work in chemistry?

APPENDIX VIII

STUDENTS' QUESTIONNAIRES

The questionnaires will attempt to find out the conditions of Grade 11 chemistry laboratory work in the sample Eritrean secondary schools. The information to be collected is only for research purpose so your inputs matter this questionnaires. Your honesty is needed to complete every item with regard to your actual learning experience. At the end, your additional suggestion(s) is/are recommended. Your cooperation is welcomed.

A. General information

Please make tick (√) in the appropriate space and fill appropriate data in the space provided.

1. Name of the school_______________________________________
2. Gender: Male= , Female=
3. Age: _______
4. Grade: _____, Section: _______
5. Chemistry period per week:_____
6. Date:______/____/2003

B. Aims of laboratory work

State whether or not you understand about the aims of practical work that refer to your knowledge of practice. Tick the appropriate column that indicates your opinion regarding to the aims of practical work.

No.	Aims of practical work/ laboratory work	Yes	No	Not decided
1	To encourage accurate observation and careful recording			
2	To promote a logical reasoning methods of thought			
3	To develop manipulative skills			
4	To give training in problem-solving			
5	To fit the requirements of practical examination regulations			
6	To elucidate theoretical work so as to aid comprehension			
7	To verify facts and principles already taught			
8	To be an integral part of the process of finding facts by investigation and arriving at principles			
9	To arouse and maintain interest in the subject			
10	To make biological, chemical and physical phenomena more real through actual experience			

C. Kinds of practical/laboratory work

Rate in the appropriate space for the following types of laboratory work.

Types of laboratory work used by teachers	Frequently used	Occasionally used	Never used
Demonstration			
Individual experiment			
Small group experiment			
Investigational work			

D. Conditions/barriers of laboratory work

i. Rate the items in this section in terms of the following keys:

points	**Quantitative**
1	Very little/ very low (none)
2	Little/ low
3	Satisfactory
4	Much/ high
5	Very much/ very high

No.	Factors	1	2	3	4	5
1	The time allotted for laboratory work					
2	Presentation of reports prior to laboratory work					
3	Provision of laboratory facilities or equipment					
4	Contribution of laboratory work in everyday life					
5	Skill of laboratory assistant					
6	Coincidence of laboratory work activities with your text's theories					
7	Skill of your teachers in conducting laboratory work					

ii. Write problems of laboratory work in which you observed in the laboratory work?

____

____

iii. Can you please make any other comments about things that concern you about the laboratory work?

____

____

____

APPENDIX IX

Table 'a' :Number of students responded to the questionnaires

Name of schools	Number of Males	Number of Females	Total participants
Adi-quala	62	10	72
Harnet	24	4	28
Tsaedachristian	26	22	48
Total	112	36	148
Percentage	75,68	24,32	100

Average number of students: $\frac{72+28+48}{3}=49.33$

Table 'b': Students' ages

Age	16-18	19-21	22-25	Missed
Adi-quala	43	25	4	
Harnet	25	3		
Tsaedachristian	32	15		1
Total	100	43	4	1

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