THE DESIGN OF AN INVENTORY OF SKILLS IN SENIOR SECONDARY SCHOOL PRACTICAL BIOLOGY

BY

SANI SALE BICHI

DEPARTMENT OF EDUCATION
AHMADU BELLO UNIVERSITY, ZARIA

JANUARY, 1988

DECLARATION

I hereby certify that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree. All quotations are indicated by quotation marks or indentation and the sources of information are specifically acknowledged by means of references.

Sani Sale Bichi

CERTIFICATION

The undersigned certify that they have read and recommended to the Faculty Board of Education, for acceptance of this thesis titled "The Design of An Inventory of Skills in Senior Secondary School Practical Biology" submitted by S.S. Bichi in partial fulfilment of the requirements for the award of the degree of Master of Education in Science Education.

Dr. M.J. Shuaibu
Chairman, Supervisory Committee — Date: 15.9.88

Dr. O.J. Jegede
Member, Supervisory Committee — Date: 28/9/88

Dr. P. Asun
Member, Supervisory Committee — Date

Dr. A.A. Sambo
Head, Department of Education — Date: 17/9/88

Prof. D.I. Saror
Dean, Postgraduate School — Date: 14/7/97

DEDICATION

This work is dedicated to my beloved children: Nafisatu, Asma'u, Hasiya, Mustapha, Aminu and Abdullahi. I have set the ball rolling. It will soon be in your court.

ACKNOWLEDGEMENTS

I was assisted by numerous individuals and organizations in the course of this study. I wish to thank a few of them that readily come to mind.

I wish to acknowledge my indebtedness and gratitude to Dr. M.J. Shuaibu of the Department of Education, Ahmadu Bello University, Zaria, who provided the supervision, inspiration, encouragement and numerous other assistances that brought this work to fruition.

I am also grateful to Dr. O.J. Jegede of the same address for his immeasurable contributions. I am indebted to Dr. T.C. Mani, Dr. P. Asun, Dr. L. Shirley, Dr. S. Muazu, Dr. J. Dada, Dr. O. Bamidele, Dr. D. Adegboye, Dr. A.A. Oladimeji, Mr. P. Turton, Dr. I.B. Olafimihan and Mallam S. Rafindadi all of Ahmadu Bello University, Zaria, whose constructive criticisms, suggestions and advice helped to improve the quality of this work. Mr. C. Bakoshi and Miss Bridget of the Department of Education, Ahmadu Bello University, Zaria, are thanked for their very capable typing.

I am grateful to the management of the Educational Resource Centre (ERC) Zaria, and the Zonal Education Office, Zaria, for giving me the permission to use the 1986 Mock results in this exercise. I am appreciative of the Department of Education, Ahmadu Bello University, Zaria for its material support. I am indebted to all the authors whom I have quoted or to whom I have referred throughout this study.

Zaria,
December, 1987

S.S. Bichi

ABSTRACT

Practical work in the teaching of biology is an essential requirement for the understanding of the subject and its subsequent application to practical life situations. This research was undertaken to determine empirically:

(i) the objectives of teaching practical biology at the senior secondary school level;

(ii) the desirable skills to be developed through practical biology, and

(iii) how performance in practical biology might be validly and reliably evaluated.

A preliminary investigation showed that students' performance in practical and theory papers in the 1986 mock school certificate examination were correlated (PPM) by as much as 0.68, with a correlated t-value of 2.24, suggesting that the two parts were moderately correlated, although performance in the theory was not necessarily determined by performance in the practical.

From the literature search, a total of 45 objectives for teaching practical biology and eight modes by which these objectives may be assessed were identified. An introductory course in biological techniques to undergraduate students was then analysed and a total of 20 desirable skills were derived. From a population of 665 biology-based professionals in the university, a 20 percent sample assessed these objectives, skills and modes of assessment and rated them according to their importance for senior secondary school graduates. From their assessment and rating, an inventory of 4 objectives, 14 skills and 4 assessment modes in the teaching of practical biology emerged. Recommendations were made on how the findings of the study might be utilized to improve the quality of practical works in biology at the senior secondary school level.

TABLE OF CONTENTS

	Page
Declaration - - - - -	i
Certification - - - - -	ii
Dedication - - - - -	iii
Acknowledgement - - - -	iv
Abstract - - - - - -	vi
Table of Contents - - - -	viii
List of Tables - - -	x
Abbreviations and Definitions of Terms	xi
CHAPTER I: Introduction - - -	1
1.1 Background to the Study -	1
1.2 The Problem - - -	6
1.3 Purposes of the Study -	7
1.4 Significance of the Study -	9
1.5 Basic Assumptions - -	12
1.6 Hypotheses - - -	13
1.7 Delimitation of the Study -	14
CHAPTER II: Review of Related Literature	15
2.0 Introduction - - -	15
2.1 The Contemporary Approaches to Science Instruction - -	16
2.2 The Nature of Psychomotor Objectives in Science Education	24
2.3 The Relationship between Theory and Practicals - - -	36
2.4 The Nature, Relevance and Importance of Practical Works in Biology - - - -	40
2.5 Assessment Procedures of Practical Works in Biology	44
2.6 Methodological Issues in Research into Practical Works in Biology - - -	54
2.7 Summary of the Literature Survey	60
CHAPTER III: Research Design and Procedure - - -	64
3.1 Research Design - -	64
3.2 Research Procedure - -	65
3.3 The Samples - - -	77
3.4 The Instrument - - -	78
3.5 Data Analysis - - -	78

Page

CHAPTER IV: Results, Analysis and Discussions - - - 40

4.0 Introduction - - - 40
4.1 Analysis of the 1986 Meck Results in Biology - - - 61
4.2 Personal Data of the Respondents 84
4.3 The Desirable Psychomotor Objectives of Practical Biology 87
4.4 The Skills Considered Necessary for the Realization of the Objectives of Practical Biology 91
4.5 Desirable Skills that should be Demonstrated by Biology Graduates 94
4.6 Desirable Modes of Assessing the Level of Skills Attained - 96
4.7 Enhancing Validity in the Assessment of Practical Biology 99
4.8 Discussions - - - 101

CHAPTER V: Summary, Limitations, Generalizations and Recommendations - - - - 108

5.1 Summary - - - - 108
5.2 Limitations - - - 117
5.3 Generalizations - - 119
5.4 Recommendations - - 119
5.5 For further Study - - 120

References - - - - - 122

Appendix I - - - - - 131
Appendix II - - - - - 136
Appendix III - - - - - 138
Appendix IV - - - - - 152
Appendix V - - - - - 153

LIST OF TABLES

Table		Page
1	A breakdown of Analysis of Manipulative Skills - - - - - -	52
2	Course B161 Skills Clustered into the Seven Objectives of Practical Biology	72
3	Means and Standard Deviations of Students' Scores in Biology Practical and Theory Papers in the 1986 Mock Examination Results	81
4	Distribution of Biology-based Subjects According to Sex, Highest Qualification and Field of Specialization - -	85
5	Objectives of Practical Biology (in order of importance) According to Biology-based Subjects in Ahmadu Bello University, Zaria. - - - -	88
6	Distribution of Response-types on the Seven Objectives of Practical Biology	90
7	Skills Considered Necessary for the Realization of the Objectives of Practical Biology, According to Biology-based Professionals in Ahmadu Bello University, Zaria. - - -	92
8	Response-types on Desirable Skills -	93
9	Desirable Practical Skills for Senior Secondary School Biology Graduates (in order of importance) According to Biology-based Professionals in Ahmadu Bello University, Zaria. - - -	95
10	Desired Modes of Assessing Practical Biology (in order of importance) According to Biology-based Professionals in Ahmadu Bello University, Zaria -	97
11	Contingency Table Showing Respondents' Choices on Assessment Modes of Practical Biology - - - - - -	98
12	Ways of Enhancing Validity in Assessing Practical Biology (in order of importance) According to Biology-based Subjects in Ahmadu Bello University, Zaria -	100

ABBREVIATIONS AND DEFINITION OF TERMS

A.E.B.: Associated Examining Board, - a U.K.-based examination organization charged with the responsibility of preparation of advanced level syllabuses and the conduct of examinations.

B 161: Is the course number for Biological Techniques, a first year undergraduate course of the Department of Biological Sciences of the Ahmadu Bello University, Zaria. The course embraces the general techniques of investigation in biology.

E. S. S.: Elementary Science Study - a science curriculum innovation that evolved in the 60s in the United States. Its main concern was the improvement of elementary science from Kindergarten through eighth grade.

J. M. B.: Joint Matribulation Board, a U.K.-based examination organization charged with the preparation of syllabuses and the conduct of examinations.

K.E.R.C.: Stands for Kano Educational Resource Centre. A professional arm of the Kano State Ministry of Education whose primary assignment centres around inspection, evaluation and production of resource materials.

N. T. I.: National Teachers' Institute, a body charged with the responsibility of drawing syllabuses and the conduct of Teachers' Grade II Certificate Examinations.

P.S.S.C.: Stands for Physical Science Study Committee a science curriculum reform project that evolved in the year 1958 in the United States. Its main concern centred around improving pedagogy in physical sciences.

S.A.P.A.: Stands for Science, a Process Approach a science curriculum reform project pioneered by the American Association for the Advancement of Science. The curriculum advocates the inculcation of the processes of science.

W.A.E.C.: West African Examinations Council, an examining body that prepares syllabuses and conducts examinations leading to the awards of a number of certificates in the West African sub-region.

Applied Scientists: This term describes professionals working in biology-based faculties and centres other than the faculty of science.

Pure Scientists: This term refers to biology-based professionals working in the faculty of science.

Chapter 1

INTRODUCTION

1.1 Background to the Study

The world is becoming more and more technical and scientific. This is making living more and more sophisticated. Industrialized nations are advancing very rapidly. The key to their progress is the mastery of science and technology.

On the importance of science and technology to human progress, Lefevre (1963) observed that science has invaded all sectors and aspects of human life and is undoubtedly the most powerful instrument of human progress.

Expressing a similar view, Shuaibu (1986) pointed out that education in science was so fundamental to any meaningful development of a country that a nation's effort might come to naught without a strong army of scientists and science-literate citizenry.

Several other people have expressed the same notion in a bid to point out the importance of science education to a nation. Fafunwa (1971)

maintained that;

> We also require scientifically and socially oriented policy makers, as well as scientifically oriented citizens. Science in the twentieth century has, without a doubt become a necessity to good living and good citizenship, to health, agriculture, home-making and leisure.

It would seem, from the foregoing, that science is the universal vehicle for human progress and that nations should endeavour to give priority considerations to science education.

Nigeria's commitment to science education is vividly seen in many instances. The recent creation of the Federal Ministry of Science and Technology is one testimony. The growing popularity of science-based institutions is yet another. Alabi (1980) reported Federal and State Governments' growing interest and commitment to science and technical education by establishing science-based institutions and generous scholarship awards for science and technology courses.

Nigeria's commitment to science education is a bid to attain the national objectives using science as an instrument par excellence. One of

such objectives is:

> The acquisition of appropriate skills, abilities and competence both mental and physical as equipment for the individual to live in and contribute to the development of his society. (National Policy on Education, 1981).

Several factors, however, may combine to militate against the attainment of the desired objectives, using science as an instrument. Such factors include inadequate financial commitment to science education (Shuaibu 1986), teaching science in complete isolation from the needs of the society (Jegede, 1984) and inadequate attention given to practical works in science, leading to haphazard learning of the subject (Green, 1965).

Expressing a concern over the nations inadequate financial commitment to science education, at least relative to the faith attached to it in the National Policy on Education, Shuaibu (1986) lamented that:

> It might seem that our abiding faith in science education has been well recognized in the National Policy on Education. But there is a mismatch between our expressed desire for science-based development, what is stated and our actions in the scientific enterprise.

On the issue of teaching science in complete isolation from the needs of the society, Jegede (1984) observed that "... in no other countries of the world is this neglect more serious than in the developing ones where science is being taught in general as if it has no relationship with the society".

Another problem of science education is the recitational mode of learning which encourages the resort to merely descriptive science rather than practical science (Muazu, 1983). Inadequate attention given to practical works in science teaching has been reported by several researchers, and the consequences have been demonstrated to be detrimental (Green, 1965; Alabi 1980 and Gould, 1983).

However, it is on record that several people view practical works as having little value to science teaching (Hempstead, 1973).

On the other hand, the importance of practical work to science teaching has been emphasized by others (Otuka, 1978; Aminu and Akale, 1981; Jegede, 1982; Abdullahi, 1982 and Mu'azu, 1983).

The concept of practical education has long been supported even by eminent educationists. Rousseau, for instance was quoted by Porter (1967) to have declared that:

> If instead of making a child stick to his books I employ him in a workshop, his hands will work to the advantage of his intellect, he becomes a philosopher while he thinks he is becoming an artisan.

In the biological sciences, practical work plays a very vital role in enhancing the understanding of the subject; in developing manipulative skills; in inculcating the general value of practical work among our students as well as in making the subject relevant to everyday life. In realization of this, Green (1965) observed that:

> Biology should be taught primarily as a practical subject. When treated as a largely theoretical one as it is for too many teachers, pupils suffer in two ways; (i) they lose in understanding, training in skills and (ii) in the relation of the subject to everyday life and there is no opportunity to emphasize the general value of practical work in a sphere where caste or status signify very little or nothing.

It is apparent from the foregoing that learning biology would be impaired without

practical works. And impaired learning of a subject may be reflected in many ways, such as poor performance in examinations and half-baked school products that would perform below expectation when employed.

1.2 The Problem

The role practical work in biology plays especially in the development of psychomotor or manipulative skills as well as in enhancing better understanding of the products and the processes of science justify the need to give a renewed and adequate attention to it in our pedagogy. To that effect, this study attempts to find answers to the following questions:

1. To what extent does performance in practical biology correlate with overall performance in a biology test?
2. What are the desirable psychomotor objectives for the senior secondary school practical biology?
3. What psychomotor skills are appropriate for the attainment of these objectives?
4. What are the modes in which teachers could assess practical biology with some degree of validity and reliability?

1.3 Purposes of the Study

Success in post-secondary school biology is predicated on success at secondary school level. Success at this latter level implies success in the two faces of the same coin (biology practical and theory). The basis for this claim is to be established as support for the whole of this exercise.

However, the basis for determining secondary school practical biology syllabus is hardly ever stated and is least likely to be empirical. What this study seeks to do is to establish empirically:

1. the objectives of doing practical biology;
2. the desirable skills to be developed through experiencing secondary school practical biology; and
3. how performance may be validly and reliably evaluated.

In order to establish the desirable skills to be developed in senior secondary school practical biology, one may take stock of what skills are currently recommended in the West African Examination Council (WAEC) syllabus as

well as the new senior secondary school biology syllabus. But since personal experiences in curriculum review suggest that these syllabuses are almost always based on the designer's whims and experience, it is being suggested that the proper place to evolve such skills is by identifying those future skills graduates of such a programme would be expected to have in order to succeed in biology. The university requirements in biology should provide such a focus.

In the Department of Biological Sciences of the Ahmadu Bello University, Zaria, a course unit embracing techniques of practical biology investigations, called Biological Techniques (B161), is presently being taught as a compulsion for all first year undergraduate students. Such a course is intended to provide basic skills that are pertinent to all undergraduate biology practicals.

Since an ultimate goal of the senior secondary school graduates is to study biology up to the university level, it is logical to base the focus of this study on the university requirements in biology.

1.4 Significance of the Study

There is an increasing public concern with education in Nigeria (The New Nigerian, November 11, 1985). Parents, teachers, education-based organizations and the general public express concern over the multifaceted problems that threaten our system of education. This concern should not be ignored because according to Gage (1963):

> Once a society becomes self-conscious about schooling its young, the seed of educational theory is sown, and if all goes well, educational practice in time ceases to be blindly empirical and guides its footsteps by the insight of the theory.

When public concern with education becomes more insistent, as is the case with Nigeria, the demand for research on teaching mounts.

The National Policy on Education (1981) emphasizes the use of continuous assessment at all levels of our educational system. And continuous assessment demands, among other things, valid assessment of the child's psychomotor domain. Thus, this study may be potentially useful to the nation as it

contributes to the mode of assessing the child's psychomotor abilities in practical biology.

Besides, the 1969 curriculum conference at Ibadan stressed the need for a practical approach to the teaching of science. It identified and recommended a number of mental skills and processes (a modified list of the processes proposed by the American Association for the Advancement of Science in Science - A Process Approach) which were to be at the core of any primary science scheme to be developed for the country.

This emphasis in practical approach to primary science teaching is important for two reasons. Firstly, the primary science is the bedrock or the foundation stone of senior secondary school science. Secondly, primary science teachers emphasize cognitive and affective domains at the expense of the psychomotor (Anderson, 1972). A study of this type geared towards elucidating the psychomotor domain may contribute towards correcting such imbalance.

Schwab (1962) advocated a radical change of the classroom materials from the rhetoric

and dogmatic mode to enquiring mode that facilitates the acquisition of a tangible experience. The enquiring laboratory, he claimed, would play a vital role in this respect as it would erase the artificial distinction between the mind and the hand. This apparently calls for not only a re-emphasis but also a re-orientation of practical work in school science teaching and this is in line with the objective of this study.

Although there is a significant measure of agreement among teachers as to the educational values arising from practical works, there is a lack of consistency between these stated values, the actual form of practical work popular in schools and the assessment procedure (Kerr, 1963). Hence the need for a study in this area.

A major weakness in the present system of practical work assessment is the lack of clear and comprehensive statements of its objectives. The Schools Council (1973) reported that:

> Recent curriculum development has re-emphasized the essential position of practical work in science education. There is, however, lack of clear statements of its objectives in terms of the attributes of the students which should be developed by

> such work. In the absence of such statements, any attempt at assessment of attainment in practical work can be nothing more than a shot in the dark.

This study is an attempt to identify the objectives of practical biology, the skills that are appropriate for the attainment of these objectives as well as the reliable modes of assessing practical work in biology.

The inventory of desirable psychomotor objectives and skills that would evolve at the end of this study would be a useful guide to senior secondary school biology teachers; biology inspectors in the Ministries of Education; researchers in the Institutes and Faculties of Education and examination bodies such as the West African Examination Council (WAEC) and the National Teachers' Institute (NTI). It is also hoped that the work would form a foundation stone for further studies by other researchers.

1.5 Basic Assumptions

The study has the following basic assumptions:

1. Psychomotor, affective and cognitive domains are interrelated and each domain influences and is influenced by others.

2. Psychomotor or manipulative skills can be assessed using:
   (a) the outcome or products of students' practical work,
   (b) observation of practical procedures such as the manipulation of apparatus, the use of instruments, the use of dissection tools and carrying out specific procedures etc. in a biology class.
3. There are psychomotor skills that foster the learning of biology and these can be adequately assessed.

1.6 Hypotheses

The study has the following null hypotheses:

1. Performance in practical biology in Senior Secondary School does not correlate significantly with overall performance in a biology test.
2. There is no significant difference in the level of agreement among the respondents on what should be the desirable objectives in the teaching of senior secondary school practical biology.

3. There is no significant difference in the level of agreement among the respondents on what should be the desirable skills in the learning of senior secondary school practical biology.

4. There is no significant difference in the level of agreement among the respondents onwhat should be the modes of assessing biology practicals.

1.7 Delimitation of the Study

Ideally, this study should cover a wider geographical area, such as the four educational zones of Kaduna State or even the 21 states of the federation. But this is not possible due to the constraints of funds, time, resources, official duties etc. This study is therefore delimited to senior secondary schools of the Zaria Education Zone of Kaduna State. The findings of the study could therefore be generalized only for the research area.

Chapter II

REVIEW OF RELATED LITERATURE

The concept of practical work in school science teaching has for long attracted the attention of many science educators. As far back as 1916, Eliot advised that greater emphasis be placed on hand, ear and eye work and that more time should be allotted to science for observation. He believed that chemistry, physics and biology should provide more opportunity for experimentation necessary for scientific thinking and intellectual depth.

Many studies have been carried out on many facets of practical work in science, resulting in a large amount of literature existing in the field, notably those of Kerr (1963), Abousief and Lee (1965), Buckley (1970), Schools Council (1973), Kempa (1974), Whittaker (1974), Eglen and Kempa (1974), Gunning and Johnstone (1976), Eggleston et. al. (1976), Alabi (1980), Sands (1981), Beatty and Woolnough (1982), Bryce et. al. (1983), Bryce and Robertson (1985), Ango and Sila (1986) and Akusoba (1986). There are,

however, relatively few studies in Nigeria and fewer still in practical biology.

For convenience, the literature review has been organized into the following titles:

1. The contemporary approaches to science instruction.
2. The nature of psychomotor objectives and skills in science education.
3. Relationship between theory and practicals.
4. The nature, relevance and importance of practical works in biology.
5. Assessment procedures of practical work in biology.
6. Methodological issues in research into practical work in biology.
7. Summary of the literature survey.

2.1 The Contemporary Approaches to Science Instruction

Innovation in science instruction was triggered off in October 1957, when the Soviet Union launched the Sputnik, a scientific breakthrough that made many nations, notably the United States and Great Britain reconsider their methods of science instruction in schools.

The aftermath of this development led to the enactment in the United States of the National Education Defence Act of 1958 which provided heavy funding for teaching and research with emphasis on science.

Numerous science curriculum reform projects such as the Science, a Process Approach (SAPA); the Elementary Science Study (ESS); the Physical Science Study Committee (PSSC) and the Biological Science Curriculum Study (BSCS) evolved in the United States. The Nuffield and the Schools Council Science projects evolved in Great Britain.

In all these curriculum reform projects there was a radical change in pedagogy, a shift in emphasis from the traditional, factual or expository method to newer strategies that stress student involvement through learning by doing, resulting in an emphasis on practical work.

The object of practical work is to develop the pupils faculties and manual skills, to teach the hand and the eye to work in unison and to involve the pupils in doing science rather than

reading about science. This is generally the emphasis of the newer approaches to science instruction.

In the Science, a Process Approach to Science (SAPA) for instance, science processes replaced the normal emphasis on contents, and manipulative materials were a central part of the curriculum. The approach was built on two basic premises. Firstly, it was believed that a scientist's behaviour in his pursuits in science constitute a complex set of skills and intellectual activities that can be analyzed into simpler skills and activities. Secondly, such skills and intellectual activities can be learned even at early stages.

In methodology, the enquiry method encourages the students to formulate a problem and systematically attempt to find solution to the problem. Schwab (1962) advocated this approach to science instruction. He identified two syntactical structures for science, namely: (i) the syntax of stable enquiry, likened to Kuhn's normal science and (ii) the syntax of fluid enquiry, which according to Hudson (1985)

resembles the period of extraordinary science immediately preceding and accompanying the Kuhnian scientific revolution.

Stable enquiry refers to the discovery of knowledge, principles, processes etc. just to fill a particular blank space in a growing body of knowledge. Schwab likened it to constructing an edifice without questioning its plan. His concept of fluid enquiry, on the other hand, refers to a mode of investigation which "rests on conceptual innovation proceeding through uncertainty and failure and finally eventuating into knowledge which is contingent, dubitable and hard to come-by".

The discovery approach to science teaching was postulated by several psychologists, notably Bruner (1960) and later Gagne (1965). Discovery learning results when an individual is involved mainly in using his mental processes to mediate some concepts or principles. It is the mental assimilation by which the individual grasps a concept or principle, resulting from physical and mental activity. In elucidating the concept, Bruner maintained that:

> I do not restrict discovery to the act of finding out something that before was unknown to mankind, but rather include all forms of obtaining knowledge for oneself by the use of one's own mind.

He further argued that learning science through discovery would help the child in the following ways:

(i) a shift from extrinsic to intrinsic motivation;

(ii) an increase in intellectual development;

(iii) an increase in memory retention; and

(iv) the learning of the heuristics of discovery, which is valuable to students' investigative processes.

An increased use of the laboratory and laboratory techniques in science teaching is another aspect of instructional methodology that gained momentous recognition after the Sputnik breakthrough. This instructional strategy deals with first-hand experiences regarding materials or facts obtained from investigation or experimentation. It involves experimentation, observation or application by

individuals or small groups dealing with actual materials. Essentially it is the experimental method enlarged and expounded (Lardizabel et. al. 1977).

An important feature of the laboratory technique is that it "erases the artificial distinction between the classroom and the laboratory, between the mind and the hand" (Brandwein and Schwab, 1962).

The laboratory is described by Mani (1983) as a facility for learning what science is and how scientists work. It could be indoor such as the specially designed and equipped rooms found in most schools. It could be outdoor including such places as the riverside, fields, workshops, market places, etc.

Batten (1962) described a laboratory experience as a participation in a series of experimental, observational and demonstrative activities which provide opportunity for students to develop understanding of practical and theoretical concepts through the solution of problems.

Unfortunately many traditional laboratory exercises carried out in schools were frequently verificational i.e. they are used to a great extent to verify materials covered in the lectures (Kerr, 1963 and Alabi, 1980). This practice, however, was of limited value. Investigatory exercise could be much more fruitful (Kerr, 1963).

To change the traditional verificational method of laboratory exercise to a fruitful investigational laboratory experience, Schwab (1962) outlined a three-step procedure. First, the practical work should lead rather than lag the classroom phase of science teaching. Secondly, classroom materials should be converted from "a rhetoric of conclusions" to an exhibition of the course of enquiry, conclusions would no longer be a major component. And, thirdly, a tangible experien e of the problems and difficulty should be encountered in acquiring data. Novak (1964) also suggested that:

> Laboratory experiences must be investigational. They must, for the most part pose real rather than contrived problems. In Biology, the laboratory investigations must deal with events, not just with things.

Schwab later argued that the laboratory must provide the student with the opportunity to experience the difficulty of dealing with problems and the difficulty of acquiring data. He postulated three levels of structuring the laboratory, namely: (i) the guided enquiry level, where the problem is posed but not answered. Ways and means of solving the problem are suggested but the student is free to use his own initiatives; (ii) the modified free enquiry level, where the problem is posed but the student himself decides the procedures to the solution with little or no guidance; (iii) the free enquiry level, where the student formulates the problem without any form of structured guidance.

Thus far, it is apparent that the newer approaches have received much attention in science teaching during the last three decades.

But, there is a tendency of the advocates of these strategies to portray a one-sided picture of each approach, ignoring the other side. For instance, it must be pointed out that both the process approach and the enquiry approach require

large supplies of manipulative materials to operate. Similarly, the laboratory method of teaching is very expensive in terms of space, time and equipment. The discovery approach is not only time-consuming but it entails messing about in trial and error efforts. However, the advantages derived from the approaches are held to outweigh their shortcomings.

2.2 The Nature of Psychomotor Objectives in Science Education

Bloom (1956) classified all educational objectives into three domains, namely: cognitive, affective and psychomotor. The objectives which are generally given most attention by teachers fall within the cognitive domain, which includes the recognition and recall of information and also the development of various intellectual abilities (Anderson, 1972).

The objectives relating to attitudes, values interest and appreciation belong to the affective domain, while physical, manipulative and motor abilities are part of the psychomotor.

Singer and Simpson (1972) made a list of subjects having a significant psychomotor content. Science was, however, not included in that list. Moore and Thomas (1983) argued that this omission was probably because the development of manipulative skills in science was rated traditionally low in importance by non-scientists. They believed that practical works in science should aim at the following psychomotor objectives:

1. To teach manipulative skills and techniques.
2. To consolidate theory and teach concept.
3. To illustrate scientific method.
4. To provide motivation and stimulate interest.

Earlier, Kerr (1963) and Renner (1971) had argued that practical work in science assumes an important role in the development of the psychomotor domain. Kerr even identified ten psychomotor objectives of practical work, namely:

1. To encourage accurate observation and careful recording.

2. To promote simple common-sense and scientific method of thought.
3. To develop manipulative skills.
4. To give training in problem-solving.
5. To fit in the requirements of practical examination regulations.
6. To elucidate the 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 a scientific phenomenon more real through actual experience.

About a decade later, Duffey (1972) categorized all scientific skills into three groups one of which is psychomotoric in nature. He recognized;

1. Skills of communication.
2. Craft or manipulative skills.
3. Mathematical skills,

This review would be incomplete without examining the objectives of some biology curriculum materials in use in some Nigerian secondary schools.

The Nigerian Secondary School Science Projects (NSSSP), Biology series (Books I, II and III) are predominently practical in approach. Numerous activities in the form of exercises and experiments were designed throughout the chapters to facilitate effective learning of the subject. But the curriculum failed to state explicitly or impliedly the objectives to be derived from such activities nor the specific abilities to be assessed.

The Nigerian Integrated Science Project (NISP) goes a step further by outlining precisely the objectives (both practical and non-practical) of each unit at the introductory page of each unit. This gives a sense of direction to both the pupils and the teacher. Its main handicap is the failure to provide hints on assessment techniques in the Teacher's Notes Book which are necessary for uniformity.

Similarly, the Biology scheme of the Kano Educational Resource Centre (KERC) for forms III, IV and V contained selected practical exercises corresponding to each major topic to be taught but failed to state the objectives to be derived from such exercises nor did it state the specific abilities to be assessed. The following are excerpts from the scheme.

YEAR III TERM I

WEEK NO	TOPIC	DEMONSTRATION	PRACTICAL EXERCISE
1.	Characteristics of living things Differences between plants and animals.	Observe an aquarium. Compare the features of living and non-living things.	Instruction on how to draw biological diagrams.
6.	Structure and method of reproduction, nutrition and respiration of spirogyra.	Slides, charts and drawings.	Observe spirogyra with a handlens and draw.
	YEAR IV TERM I		
1.	Measurement of temp. relative humidity, rainfall, light intensity, depth of water, water flow, turgidity etc. and their effects on kinds and numbers of organisms.	All measurements of the habitat factors should be demonstrated	Apparatus such as rain gauge, hygrometer, thermometer etc. should be acquired and students be made to acquint themselves with them.

WEEK NO	TOPIC	DEMONSTRATION	PRACTICAL EXERCISE
12.	Dispersal of fruits and seeds. Differences between fruits and seeds. Internal and external structure of seeds. (Maize and beans seeds to be used as examples).	Adaptations of wind-dispersed and animal dispersed seeds to be demonstrated.	Study and draw the internal and external structures of bean, maize and castor oil seeds.

A critical look at the scheme above would reveal the following weaknesses:

(i) The practical exercises are predominantly drawing and observation. It is doubtful if biological drawings in the laboratory stimulate much analytical observation or retention of facts.

(ii) The scheme did not provide the objectives of the practical exercises nor the specific abilities to be assessed.

These shortcoming are serious for the schools council (1973) cautioned that the lack of objectives in practical works would lead to an exercise in futility.

carry out instructions for experiments, make accurate observations and draw reasonable conclusions. The practical examination has the following expectations of a candidate:

1. Show familiarity with the use of the light microscope and with simple apparatus used for field studies;
2. make microscopical or similar temporary preparations of plants and animals and to make labelled drawing of permanent preparations provided;
3. assign specimens to phyla (or divisions) and where possible to classes and orders, giving reasons for the assignments;
4. make simple observations on the behaviour of living animals or plants or to make comparative observations upon the structure of related forms and to be able to interprete such observations;
5. recognize in broad terms the habitats of plants and animals;

6. make simple measurements of plants and animals and to construct and interprete graphs from the results;
7. perform simple physiological and biochemical experiments;
8. analyse the significance of material representing results of genetical crosses;
9. dissect the mammal to show especially the digestive, vascular, respiratory and urinogenetal systems; and
10. dissect flowers to show floral morphology.

The adaptability of the WAEC syllabi to the environment is a major concern. Several topics are often taught at the wrong seasons of the year. Esezober (1986) cautioned that "there is no point in teaching the life history of a toad in the dry season".

The WAEC syllabi are also criticised for being "difficult to handle or overloaded with topics and often confused with teaching syllabi" (Esezobor, 1986).

The ordinary level biology syllabus of the General Certificate of Education (GCE) London, has eight objectives of which the following two are psychomotoric:

1. to be able to make accurate observations of living material and preparation; and
2. to be able to assess and interpret simple biological experiments and data.

At the Advanced level, the GCE London assesses the following practical abilities:

1. observational skills;
2. manipulative skills;
3. ability to interpret observations and data; and
4. ability to plan experiments and investigational routes.

At the ordinary level, one weakness is obvious. The final examination does not provide for assessment of students practical abilities. The candidates, according to the syllabus, sit for two final papers none of which is practical.

One other shortcoming is the failure of the syllabus to expose the student to practical

experiences other than that of observation. For example, a section of the syllabus on mammals states that "students should have the opportunity of seeing a dissected mammal but they need not do any dissection themselves".

One may therefore ask the question, "at what level would the GCE London expose the students to practical techniques such as dissection, mounting, handling of apparatus, cutting sections, staining preparations etc.?" It is argued that at least a rudimentary experience at the ordinary level is essential to future success in science. If an educational system permits it, the teaching of science ought to start from the elementary school. The delay in science education often leads to a situation whereby students come to higher stages with defective background in science.

The English Joint Matriculation Board (JMB) listed four practical abilities to be assessed in their Biology Advanced level programme, viz:

A. Possession of appropriate manipulative skills, which comprises:

(i) the use of dissection instruments;

(ii) cutting sections, mounting and staining of temporary preparations;

(iii) the use of lens and a microscope (both low and high magnifications);

(iv) the handling of apparatus.

B. Carrying out observational investigations which includes ability to exercise powers of observation, to identify, to interpret and record important features microscopically and where appropriate, to make comparison.

C. Carrying out experimental investigations such as the ability to carry out investigation in accordance with specified procedures, the ability to handle, present and interpret results.

D. Planning investigations in which assessment is based on student's ability to plan an investigation with proper regard for the limitation of the methods proposed, the need for controls, the choice of a format of presentation of the results and the weight to be attached to such results.

Although the JMBs list is clearly spelt out and comprehensive, there are overlappings especially between the skills listed in categories A and B and between A and C. Sands (1981) cautioned that:

> the skills listed under category A will be involved in the investigations in category B and care must be taken to avoid confusing assessment of two categories.

It is apparent from the foregoing that numerous individuals and organizations have attempted to outline the psychomotor objectives and skills in the teaching of practical biology. There is, however, an obvious weakness of lack of uniformity among them.

2.3 The Relationship Between Theory and Practicals

Many teachers place great value in practicals in science. The practical nature of the subject is commonly regarded as an important source of pupil motivation (Bryce and Robertson, 1985).

Others however, view it as having little value to learning (Hempstead, 1973). It is on record that practical work in science is

often described by critics as being too expensive in terms of space and equipment, not subject to reliable assessment of pupils and too dangerous for pupils in junior secondary schools. Experiments in practical work often are not open-ended (i.e. outcomes are usually already known even before the experiment) resulting in little interest and learning. It has been argued that certain specific skills and techniques learned during the practical work are of little value in later life for the majority of students.

Several other science educationists, however, recognize the value of practical work in science teaching (Schwab, 1962; Kerr, 1963; Green, 1965; Eglen and Kempa, 1974; Brian, 1975; Otuka, 1978; Alabi, 1980; Aminu and Akale, 1981 and Jegede 1982). Similarly, Ango and Sila (1986) believed that:

> Practical experience in any science subject is crucial for the real understanding of principles and application of the knowledge ingrained in that subject for cognitive growth and technological orientation and advancement.

Frequently teachers are faced with the question "what proportion of the available time shall be

given to practical and theoretical work?" Green (1965) suggested that practical works be given approximately twice as much time as the theory in the teaching of biology. At the Department of Biological Sciences of the Ahmadu Bello University, Zaria, every one hour of theory lesson is followed by a 3-hour practical session in all the undergraduate courses.

Alabi (1980) however, reported that more time was allocated to theory than practical work in Advanced level Chemistry in one post-secondary institution in Zaria.

Beaty and Woolnough (1982) reported that most elementary science teachers in England spent between 40 to 80 percent of their time on practical works. This was seen as an activity which developed practical skills, in particular, accurate observation and description and deductive logic. Furthermore, the development of problem solving and manipulative skills and the arousal of interest were identified as important aims of practical activities (Bryce and Robertson, 1985).

It is clear from the foregoing that many teachers recognize and value practical works in

science. But there seems to be a mismatch between their expressed opinion and their efforts in the assessment of practical works. Bryce and Robertson (1985) reported that:

> Many teachers place great value in science as a practical subject. The practical nature of the subject is commonly regarded as an important source of pupil motivation. Science is taught in laboratories and teachers spend a considerable amount of time in supervising practical work. Yet the bulk of science assessment is predominantly non-practical.

Eggleston et. al. (1976) found that the most popular style with biology teachers had:

1. non-practical bias;
2. a relatively high incidence of statement of facts;
3. relatively few teachers' questions except ones demanding factual recall.

A situation where teachers preach for practical work only in words while their assessment mode and teaching style remain predominantly non-practical is nothing short of paying a lip-service to practical science and this, in the present

researcher's opinion, is detrimental to effective learning and understanding of science.

2.4 The Nature, Relevance and Importance of Practical Works in Biology

Science can best be learned by doing. Practical experience is essential for the proper understanding of the principles and application of knowledge and technological orientation, and hence the need for practical works in biology.

The teaching of biology should reflect its processes and knowledge contents for the students to have a complete picture of the subject. The process contents include the development of manipulative, investigative, communicative, organisational and creative skills while the knowledge contents include concept formation, acquisition of facts, principles, generalizations, theories and laws.

To get the complete picture of the subject therefore, biology should be taught primarily as a practical subject. Morever some aspects of the subject notably physiology, ecology and comparative anatomy can best be understood with considerable amount of practical work.

Several researchers have identified numerous exercises relevant to biology practicals both at ordinary and advanced levels.

Green (1965) made a list of topics he believed practical biology should cater for. The titles include the following:

1. Animal dissection.
2. Animal physiology.
3. Photosynthesis.
4. Respiration.
5. Plant nutrition.
6. Water relations.
7. Growth.
8. Germination.
9. Response to stimuli.
10. Ecology
11. Farm work
12. Genetics
13. Embryology.

Green's list does not seem to be exhaustive for it does not include such essential topics as classification; plant form and function; animal behaviour; cytology and entomology.

Sands (1981) proposed 14 titles of practical exercises essential in assessing abilities in advanced level practical biology. The titles are enumerated below:

1. Anatomy, histology and morphology.
2. Animal physiology.
3. Behaviour.
4. Bio-chemistry.
5. Cell division.
6. Classification
7. Dissection.
8. Ecology.
9. Enzymes.
10. Genetics.
11. Insects.
12. Microbiology
13. Plant morphology.
14. Water relations.

Under each of the 14 titles above, a set of relevant exercises were listed. For example, under the title "Insects", the following exercises were listed:

(a) Life cycle of green house whitefly.
(b) Growth of locust.
(c) Comparison of three arthropods.

(d) Observation of honey bee castes.

(e) Preparation, observation and drawing of insects mouthparts e.g. locust and cockroach.

(f) Removal and examination of spiracles and appendages of calliphora and pieris larvae.

(g) Apis and vespula, remove, mount and draw hair, mandibles and hind legs.

Sands, however, failed to include biological techniques in his titles, a title that cannot be ignored for two reasons. First, it specifically deals with manipulative skills with particular reference to biological processes, and second, it is relevant to all the titles he has proposed.

Lastly, it must be borne in mind that practical exercises are not hitch-free. For example, it is on record that beliefs and traditions in some communities are against the killing or dissection of some animals. The present researcher came across instances in some parts of Anambra State where snakes and frogs should never be killed. Green (1965) also reported that:

> Among some peoples, there is a reluctance to take animal life in any form. There are also various attitudes towards dissecting animals, ranging from physical repugnance to an idealistic unwillingness to destroy the harmony of a once living form.

Other problems include time-consumption, high demand for resource materials such as chemicals, specimens, apparatus etc. This will certainly affect the study adversely.

The effects may, however be minimised through careful portraying of the amorality of science as well as through the popular preaching that man learns about the lower organisms so as to know them and possibly improve their existence. Other problems may be solved through careful planning, effective use of resource materials and improvisation.

2.5 Assessment Procedures of Practical Works in Biology

In the literature, few reports have been made in respect of assessments of practical works. Bryce and Robertson (1985) opined that the scarcity of documented reports in practical biology is probably due to its difficult and unreliable nature of assessment.

Klopfer (1981) had earlier reported that research in psychomotor domain assessment was woefully lacking and that the little that existed was opinion-based rather than research-based.

There is certainly evidence that practical work is sufficiently distinct from more cognitive aspects of science to merit direct assessment. Several researchers agreed that it should be assessed (Abousief and Lee, 1965; Kelly and Lister, 1969; Tamir, 1972; Stanford, 1982; Lynch, 1984 and Ango and Sila, 1986).

Controversy exists on the methods used to assess practical works in biology. Traditionally, a one-shot external practical examination is set to assess students performance by an external examining body. WAEC ordinary and advanced levels biology practicals are still assessed in this way. The JMB advanced level biology and the sixth form science of the Schools Council in Britain used to be assessed in the same way.

This procedure ensures uniformity in assessment techniques and minimises biases or favouratism which Sands (1981) ascribed to "hallo effect", where the marker is subconsciously

influenced by a general impression of the student or by his previous work. Another advantage is that teachers tend to work very hard to cover the syllabus at all costs in order to prepare the students for any questions from any part of the syllabus. The Schools Council (1973) outlined the advantages to be:

(i) Uniformity of practice and standard;

(ii) rapid dissemination on large scale of what is best and generally accepted in curriculum development;

(iii) some teachers and students feel the need for external examination as a spur to work and for guidance on their achievements;

(iv) for purposes of selection, some employers and educators prefer to use the results of external assessment rather than those of internal assessment.

The shortcomings of external assessment procedure are numerous. They include:

(i) high cost of management when large number of candidates are involved in providing apparatus, chemicals and specimens;

(ii) it depends largely on performance during a very short period of time at the end of the course;

(iii) it restricts the freedom of students and teachers to follow their special interests and objectives and that techniques are also restricted to those which can be administered on a large scale; and

(iv) it mainly tests the outcomes of practical work, the finished dissection and drawing or the written-up experiment, rather than the processes and skills employed.

Although, traditionally, proficiency in manipulative skills has generally been inferred from the quality of experimental results normally communicated by the student to the assessor in the form of laboratory reports and practical scripts (Stark and Chalmers, 1968), critics have warned against making wrong assumptions about skill acquisition from larboratory reports or results (Kelly, 1971; Eglen and Kempa, 1974; Whittaker, 1974 and Beasley, 1980). Sands (1981) also maintained that to test practical

ability, the procedures used and practical manipulation as the student does them should also be included in the assessment.

Internal assessment of students' practical work is another major procedure advocated by several researchers, notably Bryce et. al. (1983) and Sands (1981).

The main distinguishing feature between externally devised and internally controlled practical assessment is the role the teacher plays. In the former, the teacher has little involvement during the examination, though he may be required to assess the end-product of an investigation (e.g. a dissection) with a marking scheme supplied by the examining body that conducted the examination.

In the latter, the teacher will be involved in the design of the examination as well as participate actively during the actual examination (e.g. observing and assessing practical skills as they are performed by students).

This procedure was found to be satisfactory and more appropriate than the external practical examination (Sands, 1981). The Schools Council

(1973) outlined the merits of this procedure as follows:

(i) increased freedom on the part of students and teachers to choose their own objectives, subject matter and activities;

(ii) intermittent internal assessment reduces the dangers of chance failure or success by increasing the number of occasions on which assessment is made;

(iii) direct observation by teachers extends the range of student attributes which can be assessed beyond those which are assessed on written evidence alone;

(iv) it encourages continuous work by students throughout the course instead of only at the end; and

(v) it encourages teachers to clarify their objectives and provides an opportunity for them to assess the achievement of those objectives with a view to adjusting their own teaching.

The procedure is, however, not without its shortcomings. Critics denounce it for the following

reasons;

(i) it is more subjective than external assessment and may alter the relationship between students and teachers - often for the worse;

(ii) it is self-evident that such an assessment can be no better than the instrument of assessment allows. It would be unwise, therefore, to assume that even a minority of teachers are capable of constructing instruments of assessment which are more reliable than those externally constructed;

(iii) standardisation of performance between sets and between schools is a matter of great difficulty;

(iv) internal assessment may not necessarily make less demands on resources of time, manpower and finance; and

(v) difficulties may arise from changes of staff and students and from private candidates.

This researcher is advocating the use of internal assessment for two main reasons. Firstly, it has numerous advantages and appears to be more reliable. Secondly, it is in line with

Nigeria's emphasis on continous assessment, an innovation in assessment that is predominantly teacher-based, systematic, comprehensive, cumulative and guidance-oriented. Teachers must become aware of what and how to assess practical works in biology under the new system. This study attempts to identify the requisite skills in secondary school biology and how such skills may be assessed.

Another major issue in the assessment of practical works is the question "what constitutes manipulative skills and how should they be assessed?".

The assessment of any ability requires an apriori agreement about: (a) the components of that ability, and (b) the achievement criteria to be used as reference standard in the assessment operation. Eglen and Kemfa (1974) produced a breakdown of the manipulative skills area into four sub-categories and specified for each sub-category generalized performance criteria as indicated in the table below.

Table 1

A breakdown of Analysis of Manipulative Skills

Component	Generalized Criteria/Performance features
Methodical working	Correct sequencing of tasks forming part of an overall operation. Effective and purposeful utilization of equipment. Efficient use of working time. Ability to develop an acceptable working procedure on the basis of limited instruction.
Experimental technique	Correct handling of apparatus, chemicals, specimens, etc. Safe execution of an experimental procedure. Taking of adequate precautions to ensure reliable observations and results.
Manual dexterity	Swift and confident manner of execution of practical tasks successful completion of an operation or its constituent part tasks.
Orderliness	Tidiness of the working area. Good utilization of available bench space. Organization in the placing of equipment used.

The performance criteria suggested in the table above are generalized ones. However, they can be amplified in relation to the practical tasks to be carried out.

Three modes of assessing manipulative skills have been suggested by Eglen and Kempa (1974).

The most immediate mode by direct observation is to form a general impression of a student's performance in the laboratory, noting good and weak performance points and then to translate the impression gained into a point on the 1-to-5 rating scale. This assessment mode is certainly subjective.

Objective assessments of manipulative skills are fairly difficult to accomplish in that they require specific performance criteria to be available against which a particular practical task can be judged. For instance, when assessing a student's competence in the use of a microscope, specific points that may be assessed might include (a) whether or not the microscope was properly handled; (b) whether or not the appropriate magnification was used; (c) whether or not there was a sharp focus free from air bubles interfering with observations. Such points are compiled in the form of a checklist of performance criteria, to be used in assessing a students overall practical performance.

The third assessment mode suggested is intermediate, relative to the two outlined above.

In this, the subjective impression-based form of assessing skills is retained but it is applied to the main components of the manipulative domain (as identified in the table above), instead of the practical task as a whole.

2.6 Methodological Issues in Research into Practical Work in Biology

Several issues confront research work in practical science assessment. Two of such issues include the distinction between norm and criterion-referenced techniques of assessment and the other involves techniques of establishing validity and moderation of assessment instruments (Bryce and Robertson, 1985).

Norm-referenced and criterion-referenced tests are frequently used in the assessment of practical biology. The former involves the use of grading scales while the latter involves the use of checklists. This is the main distinction between the two.

Grading scales of five points 1-5; A-E etc. are commonly used by many assessors. For instance, the Schools Council (1973) used the following five-point scale to assess General Certificate of Education Advanced level Biology.

5 - Outstanding

4 - Good

3 - Average

2 - Weak

1 - Poor

(NB. Average refers to average A level candidate).

The abilities assessed using the scale above were listed thus:

(a) Manipulative.

(b) Observation.

(c) Interpretation.

(d) Planning.

(e) Attitudes to practical work.

Other researchers that used grading scales in their studies were Kelley and Lister (1969); Eglen and Kempa (1974) and Gunning (1978).

An apparent weakness with the grading scale is the lack of grade descriptors that would guide the teacher in the assessment. Another weakness is that in practice, teachers tend to avoid extremes of any rating scales.

The Associated Examining Board (AEB) (1979) and the Joint Matriculation Board (JMB) (1979) used criterion-referenced tests to assess Advanced

level practical biology. A checklist of behaviourally defined performances was devised to assess the following practical abilities, namely:

1. ability to apply experimental techniques viz setting up equipment and following instructions, application of suitable techniques with relevant manipulative skills;
2. ability to identify and present the components of investigation, plan and carry out investigation viz recognition of the problem, defining the problem, identifying the variables, etc.

The AEB used the checklist below to assess the abilities above.

5 marks - Has reached independence in effectively demonstrating competence.

4 marks - Can carry out most of the listed procedures effectively and with minimal assistance from the teacher.

3 marks - Can successfully carry out a number of procedures but only with considerable assistance from the teacher.

2 marks - Finds difficulty in achieving any significant success even though an attempt is made with considerable assistance from the teacher.

1 mark - Makes little attempt to undertake practical work or to follow through a series of activities.

0 marks - No acceptable work produced.

In contrast to the checklist is the open-ended procedure (based largely on impression grading) that may lead to great variations in grades awarded by teachers for the same practical performance. Several researchers notably Abousief and Lee (1965), Kelly and Lister (1969), Eggleston and Newbould (1969), Schools Council (1969), Eglen and Kempa (1974), Wood and Ferguson (1975) and Gunning (1978) used impression grading of practical work using rating scales.

The WAEC grading system for ordinary level practical biology is more or less open-ended except that there is a marking scheme that guides the assessor. The weakness with the open-ended system of assessment is that it tends to be subjective.

The next issue at stake is that of moderation. A teacher may make reliable assessments of his students in relation to each other, but different teachers have different experiences of students which may be compounded by the use of different sets of assessment tests. These differences along with other factors produce standards which may very from one teacher to another. Hence the need for moderation.

There are several ways of moderation. Sands (1981) identified statistical methods, re-marking and the use of visiting moderators. Statistical metheds are the most suitable and involve the use of a common reference test designed to be a moderating instrument, against which the teachers' assessments are compared and all relevant statistics calculated.

Earlier, the Schools Council (1973) outlined the procedure for re-marking method in the Nuffield Advanced level assessment of biology project works.

1. Each moderator is responsible for about one hundred students from six to eight schools. He samples about three project

reports from each school and from the eighteen or so reports he selects the three best and three worst reports.

2. There is then a moderators' meeting to which each moderator takes his three best and worst reports and a sample of three of his average reports.

3. The average reports are then divided into three grades. The teachers' grades are then moderated for standard and discrimination on the following assumptions:

   (i) Only a moderator is in a position to compare the standards between schools.

   (ii) Only a moderator is in a position to determine the proportion of different grades that is appropriate for one school compared with others.

   (iii) The teachers are in as good a position (or better) than the moderator to rank pupils within their own class.

"If there is a difference of one grade between a moderator's grade and a teacher's grade, the

teacher's grade is accepted. If there is a difference of more than one grade, the moderator re-examines the student's report".

The evaluation unit of the Kano Educational Resource Centre (KERC) moderates Mock examinations in a way not very much different from the Schools Councils! Moderators meet and examine three best scripts, three worst scripts and three average scripts from each school in relation to marking scheme. A few scripts are then selected at random and treated the same way. Where a marking procedure is too liberal in a particular school, it is scaled down by an appropriate unit. Similarly, terse assessment is up-graded by an appropriate unit.

This study advocates the use of criterion referenced mode of assessment as it tends to be fairly objective. The moderation technique of the KERC which appears practical and reliable is also advocated.

2.7 Summary of the Literature Survey

It is apparent from the foregoing review that practical work play a very vital role in school science instruction. The Soviet invention

of Sputnik in October 1957, triggered off radical changes in science pedagogy resulting in the evolution of newer strategies to science teaching and all of which emphasize doing science rather than reading about science. Hence, practical work in the teaching of biology has been increasingly emphasized in recent years. Several concepts, such as Osmosis, photosynthesis germination in plants, population studies, respiration and the determination of food chains and food webs in ecology can hardly be learnt effectively without a considerable amount of practical work.

In the literature surveyed, several issues on the conduct of practical works in school science instruction remained unexplained and many weaknesses were identified. For example, there were no statements of practical or psychomotor objectives in some of the programmes or curriculum materials reviewed. Neither was there a uniform inventory of manipulative skills assessed in practical work.

This study is designed to evolve a comprehensive inventory of manipulative skills essential in Senior Secondary practical biology.

Investigations on the relationships between theory and practicals reveal many inconsistencies. Most science teachers advocate practical work in science but their instructional and assessment modes remain predominantly non-practical. Also time allocation ratio between theory and practicals has not been uniform even within the same locality.

Assessment procedures in practical biology constitute another focus of interest. Several examination bodies, especially in the United Kingdom, are moving towards internally devised assessment modes as against the one-shot external examination. WAEC however, remains conservatively sticked to the latter.

A critical look at the WAEC's ordinary level practical biology examination questions reveals an emphasis on drawing and observation of specimens at the expense of such vital process skills as dissection, preparing and mounting slides, operating the microscope, preserving specimens etc. An emphasis on drawing and observation of specimen can stifle analytical observation and the retention of facts. This observation may be the price to be paid for the one-shot external practical examination system.

In this study, a comprehensive list of practical skills preparatory for success in biology at tertiary level of education is to be derived. Techniques of establishing validity and reliability of assessment of practical works in biology are to be investigated.

Chapter III

RESEARCH DESIGN AND PROCEDURE

This study was an attempt to develop an inventory of essential psychomotor objectives and skills in the learning of senior secondary school practical biology.

In this chapter, the research design, the procedure, the instrument, the samples, data collection and analysis are discussed.

3.1 Research Design

The study was a survey exercise designed to investigate and determine:

1. the relationship between students' attainments in both practical and overall biology examinations;
2. the desirable objectives in the teaching of practical biology;
3. the desirable skills in the learning of practical biology; and
4. the extent of agreement on the suitability of various modes of assessing practical biology.

3.2 Research Procedure

The research strategy adopted was a six-step procedure designed to (i) determine the correlation coefficient between the variables stated in item 1 and (ii) to develop an inventory of the variables in items 2, 3 and 4 of the research design above.

Step I

As part of the preliminary investigation, this step was undertaken to establish the support for the whole of this study. Students' performance in practical biology was correlated with their overall performance to determine whether or not success in biology implied success in the two faces of the same coin (i.e. biology practical and theory).

The 1986 General Certificate Mock Examination results for Zaria Education Zone were used. About 30 percent of the biology candidates in each school in the zone, giving a total of 122 candidates, were used. The per centage was selected because it gave a sample size greater than the minimum sample size considered to be large enough at the 5 percent level of significance (Roscoe, 1975).

At each school the candidates were determined using a simple random sampling technique. Each candidate was assigned an identification number. Identical numbers were then written on pieces of paper folded and placed in a bag. About 20 percent of all the numbers were then drawn by lot and those candidates whose identification numbers were drawn were selected for the study. A correlation statistic was then applied to the practical and overall scores of the selected candidates and the correlation coefficient between the two variables was then determined.

Step II

A search was conducted on the available literature to identify the desirable psychomotor objectives for teaching practical biology.

A total of 45 desirable objectives of teaching practical biology was derived from the literature search. Several of these objectives however were identical in nature and were therefore condensed into seven broad objectives, as stated below:

1. To develop or enhance manipulative abilities;

2. To consolidate concepts principles, explanations, models and theories.
3. To motivate and stimulate students' interest.
4. To develop the ability to design and carry out investigations.
5. To illustrate the scientific method.
6. To apply scientific knowledge to every-day life in matters of personal and community health and agriculture.
7. To satisfy special requirements of the examining bodies

The broad objectives above were further expatiated thus:

1. To develop manipulative abilities refers to the swift and confident manner in which practical tasks are carried out; the safe handling of apparatus, chemicals, specimens and the execution of an experimental procedure with some degree of manual dexterity.
2. To consolidate concepts, principles, explanations, models and theories refers to relating practical experiences to theoretical knowledge so that the former

enhances the latter. For instance, the ability to relate form to function or the functional knowledge of concepts that are peculiar to biology practicals such as longitudinal/transverse sections, low power plan, abaxial surface, lateral/ventral/dorsal view, bilateral/radial symmetry etc. In a nutshell, this objective refers to the student's hands working to the advantage of his intellect.

3. To motivate and stimulate students' interest refers to the satisfaction the students get when engaged in practical activity and the subsequent desire to keep long on the learning activity, resulting into intrinsic motivation. Youngsters enjoy performing experiments especially if routineness is minimized.

4. To develop the ability to design and carry out investigations refers to the ability to formulate a problem and systematically attempt to find a solution to it. This is facilitated by an appropriate sequencing of tasks, effective and purposeful utilization of equipment, efficient use of working

time and acceptable working procedure on the basis of limited instruction.

5. To illustrate the scientific method refers to subjecting the students to the requirements of the scientific method. Exposure to the stages of the scientific method namely:

   (i) observing;

   (ii) question-asking;

   (iii) hypothesising;

   (iv) experimenting; and

   (v) generalizing has the following effects:

      (a) the students will develop reflective thinking; and

      (b) the method of science will be illustrated.

6. To apply scientific knowledge to everyday life in matters of personal and community health, agriculture etc. refers to positive application of science to practical life situations. For instance, after learning how to prevent rusting in the chemistry class, the student should apply same to prevent father's farm implement from rusting; after learning

purification of water in the biology class, the student should not drink impure water at his house; after learning the life cycle of the mosquito, the student should apply same to control the menances of the insect at home.

7. To satisfy the requirements of the examining bodies refers to achieving some specific emphasis of the examining bodies. For example several such bodies emphasize that scientific names be underlined. Others insist that generic names be written in full. The West African Examination Council (WAEC), for instance, stresses the use of very thin, unbroken lines in biological drawings, while shadings, tracing etc. are penalized. Other peculiar requirements may include writing the magnifications used in microscopic works and the use of specific patterns of writing laboratory reports.

Step III

The contents of course B161, Biological Techniques, a first year undergraduate course on biology practicals of the Ahmadu Bello University Zaria, were examined and analysed. Course B161 is

designed to teach skills that are pertinent to all undergraduate biology practical works. It must be pointed out that each course in the Department of Biological Sciences at the Ahmadu Bello University has its own practicals but course B161 is supposed to embrace all the techniques and skills that are essential in all biology practicals.

The analysis of course B161 gave 20 skills that include the following:

1. Manual dexterity.
2. Observational skills.
3. Mathematical skills such as measuring, calibrating, etc.
4. Handling of scientific equipment.
5. Familiarity with instruments, studying parts and their functions.
6. Skills of operating the microscope.
7. Controlling variables in an experiment.
8. Preparing temporary slides.
9. Mechanical presentation of results.
10. Biological drawing skills.
11. Cutting thin sections of specimens using a razor blade.
12. Following a procedure in logical sequence.
13. Staining techniques.

14. Mounting techniques.
15. Dissection skills.
16. Communication skills,
17. Skills of preserving specimens.
18. Record keeping skills.
19. Cleanliness in the conduct of practical works.
20. Blood smear techniques.

Step IV

The twenty skills obtained from the analysis of course B161 were then clustered into the seven broad objectives obtained from the literature search. The twenty skills fit into the seven objectives as detailed below:

Table 2

Course B161 Skills clustered into the Seven Objectives of Practical Biology

Objective of Practical Biology	Skills Identified to be Relevant
1. To develop or enhance manipulative ability	Manual dexterity; skills of operating the microscope; Biological drawing skills; handling common laboratory equipment; dissection skills; skills of preserving specimens; skills in sectioning, blood smear techniques and mounting techniques.

Objective of Practical Biology	Skills Identified to be Relevant
2. To consolidate concepts, principles explanations, models and theories.	Observational skills.
3. To motivate and stimulate students interest.	Observational skills; handling common laboratory equipment; operating the microscope.
4. To develop the ability to design and carry out in investigations.	Controlling variables; following a procedure; mathematical skills; communication skills; presentation of result; record keeping and cleanliness in the conduct of practical work.
5. To illustrate the scientific method.	Observation, controlling variables; following a procedure; presentation of results; mathematical skills; record keeping and communication.
6. To apply scientific knowledge to every-day life in matters of personal and community health and agriculture.	Observational skills; relating form to function; evaluative skills; record keeping.
7. To satisfy special requirements of the examining body.	Skills unique to the examining body and may include the following: cleanliness in the conduct of practical work; record keeping; biological drawing skills, observational skills; classification skills; controlling variables; manual dexterity and relating form to function.

The model above was presented to five specialist biologists at the Ahmadu Bello University, Zaria for its validation (See Appendix I). The five biologists examined the model and confirmed its validity.

Step V

This step was undertaken as a stage towards the determination of the appropriate mode of assessment of students skills in practical biology.

A comprehensive list of how teachers might assess students' achievement in practical works was drawn. The list comprises the following modes of assessment:

1. One-to-one mode of assessment in which one trainee is assessed by one teacher as is found in an apprentice system. In such a case each examinee takes on his practical tasks alone.

2. Group or joint projects in which several trainees are taught and assessed by one teacher. In this case the practical tasks are undertaken collectively by two or more trainees but each trainee is assessed according to his inputs into the project.

3. Pencil and paper substitutes as in practical biology in which practical tasks are done by the examinees, who communicate their responses in the form of written answers, drawings etc.

4. Short-term system of assessing practical tasks in which a stage is set for a practical test which is undertaken and completed in a one-shot examination usually lasting a few hours.

5. Along term system of assessing practical tasks in which the tasks or projects undertaken for the examination takes place over a long period of time.

6. A continuous system of assessing practical tasks in which case practical exercises are built into every lesson, or into every unit of instruction. The examinee's work is then assessed on a continuous basis.

7. A self-assessment mode in which the student designs a practical work for himself to answer a question or solve a problem which has arisen from a lesson presentation to the class or from any other learning situation. This may be individual or group

work depending on the complexity and demands of equipment with which the practical work would be done.

The list above was presented to five science educators at the Ahmadu Bello University, Zaria, for validation (See Appendix II). Responses from the science educators confirmed the comprehensiveness of the list.

Step VI

A 50-item questionnaire was designed on a 5-point Likert scale to gather data for the study (See Appendix III). It was validated by a team of ten professionals comprising three science educators; three senior secondary school biology teachers; two research scientists; one professional biologist at the tertiary level and one English language specialist.

The validated instrument was then administered to selected professionals or specialists in biology-based professions and careers, whose responses on the 5-point Likert scale provided the data from which an inventory of the stated variables was developed and the appropriate modes of assessment were determined.

3.3 The Samples

The population of the study consisted of all the senior staff in the biology-based departments of the faculties of Science, Agriculture, Medicine, Pharmaceutical Sciences and Veterinary Medicine as well as related centres, including Agricultural Extension and Research Liason Service (AERLS), National Animal Production Research Institute (NAPRI), the College of Agriculture, Samaru and the University Clinic, Sick Bay.

The samples for the study were determined from the population in the following way:

A search was conducted to determine the staff strengths of the faculties/centres above. Using the 1984-86 University Calender, the staff strength of all the faculties/centres was determined to be 665 staff (See Appendix IV).

About 20 percent of the staff in each faculty/centre giving a total of 133 staff members were randomly selected for the study. The percentage was selected because it gave a sample size greater than the minimum sample size considered to be large enough at the 5 percent level of significance (Roscoe, 1975).

At each faculty/centre, the subjects were selected using a simple random sampling technique. Using the staff lists in the University Calender, each staff was assigned an identification number. Identical numbers were then written on pieces of paper, folded and placed in a bag. About 20 percent of all the members of each faculty/centre were then drawn by lot, and those staff whose identification numbers were drawn were requested to participate in the study.

3.4 The Instrument

A questionnaire designed by the researcher was the main instrument used to gather data for the study. It was validated by a team of ten experts comprising three science educators, three senior secondary school biology teachers, two research scientists, one professional biologist and one English language specialist (See Appendix III).

3.5 Data Analysis

The data for the study came from two sources, namely (i) the 1986 General Certificate Mock Examination results in biology; and (ii) the data collected using the questionnaire.

The General Certificate Mock Examination results were subjected to correlated t-test to assess the extent of the difference between the mean scores of the same students in practical biology and the overall performance in biology.

The data collected using the questionnaire were analysed to design an inventory of psychomotor skills in the senior secondary school practical biology. Since the 5-point Likert scale was used throughout the questionnaire, responses gathered were either positive, negative or neutral.

The mean scores, standard deviations and levels of agreement among the respondents were calculated for each item in the questionnaire. Those items with highest mean scores and levels of agreement were included in the inventory. A chi-square statistic was then used to check if choice of objectives, skills, assessment modes etc. was independent of field of specialization among the respondents.

Chapter IV

RESULTS, ANALYSES AND DISCUSSIONS

4.0 Introduction

This chapter contains the results, analyses and a discussion of the findings that emerged from the analyses.

Two sets of data, namely: (i) the 1986 General Certificate Mock Examination results in Biology and (ii) the data collected using a questionnaire were used. The two sets of data were subjected to various statistical tests.

The main concerns of this study were two-fold. The first was to establish a support for the claim that success in biology implied success in the two faces of the same coin; biology practical and theory. The second was to investigate and determine an inventory of desirable psychomotor objectives and skills in the teaching and learning of practical biology.

4.1 Analysis of the 1986 Mock Results in Biology

The 1986 mock examination results in biology were used to investigate the relationship between students' attainment in biology practical and theory. About 122 paired (biology practical and theory) results were randomly selected as the variables for this purpose. Pearson's product-moment correlation (r) statistic was then used to determine the extent of correlation between these variables. An r of 0.68 was found, suggesting a moderately high positive correlation between the variables.

A correlated t-test was then applied to check if the difference between the means of the two variables was statistically significant. The mean scores and the standard deviations for the two variables were computed. Table 3 below presents the summary of data for these variables.

Table 3

Means and Standard Deviations of Students' Scores in Biology Practical and Theory Papers in the 1986 Mock Examination Results.

($n_A = n_B = 122$)

Paper/variable	Mean Score	Standard Deviation
Practical paper	42.43	15.50
Theory paper	44.90	14.90

The details of the data for this part of the analysis are presented in Appendix V.

The correlated t-test was applied because according to Ferguson (1974), a correlated t-test should be used in a situation where the variables being correlated are not independent and originate from a single sample. The variables being correlated in this exercise fall into this category. Besides, a correlated t-test is a more sensitive test of significance of the difference between two means, as it reduces the experimental errors and thus increases the probability of rejecting the null hypothesis when it is false. Furthermore, this statistic was chosen because it is the most appropriate for determining the significance of the difference between means when the number of participants in each of the two groups is about equal (Carol et. al., 1978).

The correlated t is given by $t = \frac{\bar{X}_A - \bar{X}_B}{\frac{S_A^2}{n_A} + \frac{S_B^2}{n_B} - 2r\left(\frac{S_A}{\sqrt{n_A}}\right)\left(\frac{S_B}{\sqrt{n_B}}\right)}$

where:

$\bar{X}_A$ = mean of the practical examination scores.

$\bar{X}_B$ = mean of the theory examination scores.

n_A = number of subjects in the practical examination.

n_B = number of subjects in the theory examination.

S_A = standard deviation of the practical examination scores.

S_B = standard deviation of the theory examination scores.

S_A^2 = variance of the practical examination scores.

S_B^2 = variance of the theory examination scores.

r = extent of correlation between the practical and theory scores.

This way, the correlated t was calculated to be 2.24. The critical t-value at 0.05 level of significance and df=242 was 1.96. Since the computed t-value is larger than the critical t-value, the difference between the two means is statistically significant.

The establishment of an r of 0.68 and the presence of a statistically significant difference between the two means suggested that the two sets of scores were moderately correlated. Since correlation does not imply causation, both scores do not necessarily belong to the same parent scores. Thus, students that did well in practical biology generally performed well in the

theory although their practical biology performance did not necessarily determine their performance in the theory.

This finding had two important implications for this study. First, it implied that the first null hypothesis in this study which suggested that "performance in practical biology does not correlate significantly with performance in theory" had to be rejected. Secondly, it provided the basis for the next stage in this study, namely, the empirical determination of aspects of practical biology which were considered pertinent to success in a biology examination, involving both practical and theory. The object of this whole exercise was to design an inventory of psychomotor objectives and skills in senior secondary school practical biology which will enhance future successes in biology and biology-related disciplines at higher levels of education. The subsequent steps in this chapter were undertaken to achieve this later objective.

4.2 Personal Data of Respondents

A structured instrument, consisting of six sections A,B,C,D,E and F, was used to gather the data used in the subsequent stages of this study.

A copy of the instrument is in Appendix III.

Section A of the instrument dealt with the general information or personal particulars of the subjects, all of whom were professionals in biology-based fields.

Table 4 presents the frequency distribution of the subjects according to sex, highest qualification and field of specialization.

Table 4

Distribution of Biology-based Respondents According to Sex, Highest Qualification and Field of Specialization.

(N = 103)

Item No.	Variable	Category	Frequency	Percentage
1.	Sex	Male	89	86.4
		Female	14	13.6
2.	Highest Qualification	Ph.D.	39	37.8
		M.Ed./M.Sc.	35	33.9
		B.Ed./B.Sc.	9	8.8
		N.C.E./Diploma	6	5.8
		Others e.g. City and Guilds, Nursing Certificate, A-Level, AIST, FTC, etc.	14	13.6
3.	Field of Specialization	*Applied Scientists	93	90.3
		Pure Scientists	10	9.7

*The term "Applied Scientists" describes professionals working in biology-based faculties/centres other than the faculty of Science. "Pure Scientists" refer to professionals working in the Faculty of Science.

The frequency distribution in Table 4 suggests that:

(i) There were about six males to one female (6:1) staffers in professions requiring biology in Ahmadu Bello University, Zaria. Thus, even biology-related professions that were normally assumed to be female-dominated were in fact male-dominated (in a ratio 6:1) in Ahmadu Bello University, Zaria.

(ii) The majority (about 71 percent) of the biology-based professionals in Ahmadu Bello University, Zaria, held at least a second degree, about 8 percent had a first degree and about 20 percent held non-degree qualifications ranging from Diploma to various certificates such as City and Guilds, Nursing Certificate and Full Technological Certificate (FTC).

(iii) The majority (about 90 percent) of the respondents were applied scientists, while about 10 percent were pure scientists.

4.3 The Desirable Psychomotor Objectives of Practical Biology

This section was designed to assess the relative standing of the objectives of practical biology as derived from the literature, according to respondents. Table 5 presents the first seven items ranked highest.

Table 5

Objectives of Practical Biology (in order of importance) according to Biology-based Subjects in Ahmadu Bello University, Zaria.

(N = 103)

Rank	Item No	Objective of Practical Biology	Response					Mean	Standard deviation
			SA	A	U	D	SD		
1	10	To stimulate students' interest.	65	34	1	3	0	1.56	0.67
2	12	To inculcate the scientific method of investigation.	56	41	2	2	2	1.42	0.80
3	11	To develop the ability to design and carry out investigations.	46	49	1	6	1	1.29	0.83
4	8	To develop the ability to manipulate biological equipment.	40	50	6	5	2	1.17	0.89
5	13	To satisfy special requirements of examining bodies.	21	59	15	5	3	0.87	0.90
6	9	To apply scientific knowledge to practical life situations.	32	43	7	14	7	0.76	1.22
7	14	To consolidate concepts.	31	41	10	14	7	0.72	1.22

In order to determine those objectives that should be a part of the inventory, a cut-off point

on the means was imposed. To determine the cut-off point, all the mean values were summed up and divided by the number of items in the section. The cut-off point was therefore the mean of all the means. In this case (in Table 5) the cut-off point was about 1.00. The cut-off point helped to identify those objectives adjudged by respondents as most significant for the purpose of the inventory.

An analysis of Table 5 showed that the objectives 1,2,3 and 4 each with a mean value greater than the cut-off point would meet this criterion.

In order to test the second null hypothesis in this study which suggested that "there was no significant difference in the level of agreement among the respondents in their choice of desirable psychomotor objectives", the chi-square statistic was applied.

The respondents were classified into two groups, pure scientists and applied scientists. The 2x2 contingency table is shown in Table 6.

Table 6

Distribution of Response-types on the Seven Objectives of Practical Biology

Scientists	Positive Responses	Negative Responses	
Pure Scientists	65	1	66
	*(59.19)	(6.80)	
Applied Scientists	544	69	613
	(549.80)	(63.19)	
	609	70	679

*The figures in bracket show the expected frequencies of the respondents.

Obtained chi-square (X^2) = 6.10

Critical chi-square (X^2) at 0.05 and I df = 3.84

An analysis of Table 6 showed that the obtained chi-square (X^2) was larger than the critical chi-square value. This suggested a strong association of the field of specialization with the choice of objectives and the null hypothesis was rejected.

4.4 The Skills Considered Necessary for the Realization of the Objectives of Practical Bilogy

It was necessary to assess the respondents' perception of not only the desired objectives but also the means (the how, in terms of desired skills) necessary to achieve these objectives. For this reason, seven other items were designed to elicit this information. The results are presented in order of relative weighting for these items in Table 7.

1	19d	Following a procedure in experimental investigation	36	57	3	7	0	1.18	0.78
2	19e	Orderliness in the conduct of practical work	42	50	3	7	1	1.21	0.86
3	19f	Record Keeping skills	40	48	3	10	2	1.10	0.98
4	19a	Controlling variables	28	53	10	8	4	0.91	1.00
5	19c	Mathematical skills	21	56	6	14	6	0.69	1.12
6	19b	Commucation skills	21	56	6	14	6	0.69	1.12

			RESPONSES						
Rank	Item No	OBJECTIVE 7: To Consolidate Concepts	SA	A	U	D	SD	MEAN	SD
1	16b	Skills of relating form to function	25	58	15	5	0	1.0	0.76
2	16a	Classification skills	16	58	14	12	3	0.69	0.92

Using the same method as for Table 5, the cut-off points in this table were determined to be:

1.45 for objective 1
1.30 for objective 2
1.10 for objective 3
1.10 for objective 4
1.00 for objective 5
0.90 for objective 6, and
0.80 for objective 7.

Table 7 above contains responses gathered on skills necessary for the realization of the seven objectives of practical biology. But only objectives 1, 2, 5 and 6 qualified for the inventory.

1	21a	Orderliness in the conduct of practical work	52	47	1	2	1	1.42	0.72
2	21d	Observational skills	50	48	3	2	0	1.41	0.66
3	21c	Biological drawing skills	37	60	4	2	0	1.28	0.63
4	21b	Record keeping skills	38	56	4	4	1	1.22	0.78
5	21i	Relating form to function	31	61	7	3	1	1.14	0.75
6	21e	Classification skills	38	52	9	4	3	1.20	0.75
7	21f	Dissection skills	39	51	9	4	0	1.21	0.76
8	21g	Controlling variables	24	49	21	8	1	0.86	0.88
9	21h	Manual dexterity	19	51	20	6	7	0.66	1.05
		OBJECTIVE 4: To enhance application of knowledge to practical life situations							
1	20a	Observational skills	52	44	1	4	2	1.35	0.82
2	20b	Relating form to function	36	53	10	2	2	1.15	0.87
3	20d	Record keeping skills	33	52	6	3	4	0.99	1.01
4	20c	Evaluation skills	35	49	12	5	2	1.06	0.91

RESPONSES

Rank	Item No	OBJECTIVE 5: To inculcate the ability to design and carry out investigations	SA	A	U	D	SD	MEAN	SD
1	18f	Orderliness in the conduct of practical work	48	45	5	4	1	1.31	0.81
2	18e	Record keeping skills	48	44	6	3	2	1.29	0.85
3	18d	Familiarity with common laboratory equipment	42	48	5	7	1	1.19	0.88
4	18i	Evaluation skills	37	49	10	5	2	1.10	0.90
5	18h	Following a procedure with minimum instructions	36	50	9	6	2	1.10	0.91
6	18b	Controlling variables	35	45	7	15	1	0.95	1.03
7	18c	Manual dexterity	29	48	20	5	1	0.96	0.86
8	18a	Communication skills	35	42	10	14	2	0.90	1.04
9	18g	Mathematical skills	12	52	22	13	4	0.53	0.98
		OBJECTIVE 6: To inculcate the Scientific Method							

Table 7

Skills Considered Necessary for the Realization of the Objectives of Practical Biology, According to Biology-based Professionals in Ahmadu Bello University, Zaria.
(N = 103)

Rank	Item No	OBJECTIVE 1: To Stimulate Students' Interest	RESPONSES SA	A	U	D	SD	MEAN	SD
1	17a	Observational skills	59	41	3	0	0	1.54	0.55
2	17b	Working with or manipulating instruments	49	45	8	0	1	1.36	0.73
		OBJECTIVE 2: To enhance manipulating ability							
1	15e	Biological drawing skills	45	55	3	0	0	1.38	0.90
2	15d	Safe handling of common laboratory equipment	54	45	2	1	0	1.47	0.61
3	15b	Operating the ordinary light microscope	44	54	1	3	1	1.33	0.73
4	15c	Dissection specimens	52	45	5	1	0	1.43	0.64
5	15a	Manual dexterity in conducting practical tasks	32	58	10	3	0	1.15	0.71
6	15f	Blood smear techniques	35	49	11	6	2	1.05	0.93

Rank	Item No	OBJECTIVE 3: Skills that may be emphasised in practical biology by examining bodies	RESPONSES SA	A	U	D	SD	MEAN	SD

In order to test the third null hypothesis which suggested that "there was no significant difference in the level of agreement among the respondents in their choice of desirable skills, the chi-square statistic was again used.

The respondents were classified into two groups, pure scientists and applied scientists. The responses gathered from these groups were used to draw the contigency table below from which the chi-square statistic was calculated.

Table 8

Response-types on Desirable Skills

Scientists	Positive Responses	Negative Responses	
Pure Scientists	358 *(333.32)	3 (27.67)	361
Applied Scientists	2954 (2978.67)	272 (247.32)	3226
	3312	275	3587

*The figures in bracket show the expected frequencies of the responses.

Obtained chi-square (X^2) = 26.47

Critical chi-square at 0.05 and 1df = 3.84

The computed chi-square (X^2) was larger than the critical chi-square, indicating a statistically significant difference in the type of responses. This suggested a strong association of the field of specialization with the choice of desirable skills. The null hypothesis was rejected.

4.5 Desirable Skills that Should be Demonstrated by Biology Graduates.

The ultimate objective of instruction in practical biology, beyond what students actually do in the classroom during their secondary education, is the acquisition of transferable skills. In order to assess what constitute these ultimate and transferable skills, the respondents were asked to suggest those skills they considered most appropriate and useful to the graduates. The ten items which were designed to elicit such information were rated as shown in Table 9.

Table 9

Desirable Practical Skills for Senior Secondary School Biology, Graduates (in order of importance) According to Biology-based Professionals in Ahmadu Bello University, Zaria
(N = 103)

Rank	Item No	Desirable Skills	Responses SA	A	U	D	SD	Mean	Standard Deviation
1	28	Orderliness in the conduct of practical work	50	52	1	0	0	1.47	0.52
2	25	Operating the ordinary light microscope satisfactorily	52	50	0	1	0	1.47	0.59
3	23	Safe handling of common laboratory equipment	50	50	2	1	0	1.44	0.60
4.	27	Presenting biological diagrams satisfactorily	56	43	1	3	0	1.47	0.67
5.	22	Keen observations that arouse curiousity	56	43	1	3	0	1.47	0.67
6	30	Communicating experimental results to the audience satisfactorily	32	64	4	3	0	1.21	0.65
7	31	Mannual dexterity when engaged on practical tasks	19	75	6	3	0	1.06	0.60
8	24	Dissecting a lizard to trace the alimentary canal satisfactorily	42	48	9	4	0	1.24	0.77
9	26	Record keeping skills	38	42	11	11	1	1.01	0.92
10	29	Mathematical skills in measuring, calibrating and elementary statistics	10	51	11	22	9	0.30	1.16

Using the same method as for Table 5, the cut-off point in this table was determined to be about 1.0. All items in Table 9 except item 10, would satisfy this criterion and therefore would be a part of the inventory.

4.6 Desirable Modes of Assessing the Level of Skills Attained

It was not sufficient to identify the desired psychomotor objectives and skills. The respondents were also requested to suggest the desirable modes of assessing the level of attainment of these skills for completeness. The literature review has pointed to the lack of agreement on how these skills should be assessed, and therefore has left the teacher in greater confusion. Nine items were therefore designed to elicit information to that effect. The responses to these items are tabulated in Table 10 below.

Table 10

Desired Modes of Assessing Practical Biology (in order of importance) According to Biology-Based Professionals in Ahmadu Bello University, Zaria.
(N=103)

Rank	Item No	Assessment Mode	Responses					Mean	Standard Deviation
			SA	A	U	D	SD		
1	37	Continuous assessment	51	45	4	2	1	1.38	0.75
2	38	One-shot final examination	46	36	5	10	6	1.02	1.19
3	35	Short-term task-oriented assessment mode	15	52	10	22	4	0.50	1.09
4	34	Paper and pencil assessment mode	16	43	10	25	9	0.31	1.24
5	33	Group assessments	21	35	15	28	4	0.39	1.19
6	36	Long-term project type of assessments	6	39	13	27	9	0.23	1.23
7	39	Internal rather than external examinations	19	27	16	30	11	0.12	1.30
8	32	Individualised modes of assessment	19	25	9	42	8	0.04	1.29
9	40	Self-assessment mode	13	27	22	28	13	0.01	1.24

Using the same method as for Table 5, the cut-off point in this table was determined to be about 0.4.

The results in Table 10 suggest that assessment modes 1, 2, 3, and 5 each with a mean value greater than the cut-off point be included in the inventory.

In order to test the fourth null hypothesis which suggested that there was no significant difference in the level of agreement among the respondents in their choice of assessment modes, the chi-square statistic was again applied.

The respondents were classified into two groups, pure scientists and applied scientists. The responses gathered from these groups were used to draw the contigency table below, from which the chi-square statistic was computed.

Table 11

Contingency Table Showing Respondents' Choices On Assessment Modes of Practical Biology

Scientists	Positive Responses	Negative Responses	
Pure Scientists	45 *(46.49)	38 (36.50)	83
Applied Scientists	416 (414.50)	324 (325.49)	740
	461	362	823

*Figures in bracket show the expected frequencies

Obtained chi-square (X^2) = 0.11

Critical chi-square (X^2) at 0.05 and 1df=3.84

Analysis of Table 11 above showed that the computed chi-square was smaller than the critical chi-square. Thus, chi-square was not statistically significant. The null hypothesis could not be rejected. This suggests that the choice of assessment mode was independent of field of specialization among the respondents.

4.7 Enhancing Validity in the Assessment of Practical Biology.

According to the literature review, a major problem of assessment of practical works was the lack of validity or the fear of absence of validity in the assessment of practical works. In order to enhance validity, respondents were requested to suggest ways of improving the validity and reliability of teacher assessments. Ten items were designed to elicit such information.

The responses gathered are presented in Table 12 below.

Table 12

Ways of Enhancing Validity in Assessing Practical Biology (in order of importance) According to Biology-based Subjects in Ahmadu Bello University, Zaria.
(N = 103)

Rank	Item No	Ways of Enhancing Validity	RESPONSE SA	A	U	D	SD	MEAN	SD
1	41	The use of a rating scale to assess performance in practical biology.	38	51	8	5	1	1.16	0.84
2	46	Physical presence of the examiner to administer the examination.	19	60	10	9	5	0.76	1.01
3	47	Uniform assessment procedure throughout the federation.	45	34	7	6	9	0.91	1.39
4	43	The use of subjective, open-ended way of assessing practical biology.	22	56	8	14	3	0.77	1.02
5	49	The use of statistical method to moderate practical biology examination.	18	54	21	10	0	0.77	0.85
6	42	The use of checklist to assess performance in practical biology.	28	44	11	17	3	0.74	1.11
7	44	The use of a panel of examiners to assess performance in practical biology.	16	47	13	27	0	0.50	1.03
8	45	The use of just one examiner to assess performance.	13	49	12	23	3	0.44	1.06
9	48	The use of different assessment procedure to suit local needs.	19	39	10	23	12	0.29	1.31
10	50	The use of re-marking method to moderate examination performance.	6	48	20	23	6	0.24	1.04

Using the same method as for Table 5, the cut-off point in this table was determined to be about 0.6.

The results in Table 12 suggest that items 1, 2, 3, 4, 5 and 6, each with a mean value greater than the cut-off point, should be included in the inventory.

4.8 Discussions

All the biology-based professionals that participated in this study perceived practical biology to be helpful in their post-primary school days and advised that it should be continued. This finding gave credence to the worthwhileness of this exercise.

The results in Table 5 suggest that the most important objective of teaching practical biology according to respondents was to stimulate students' interest. It is noteworthy that the most highly rated objective of practical biology relates to the affective domain, rather than the psychomotor domain.

This finding implies that the biology-based professionals at the tertiary level, which ultimately absorb the senior secondary school biology graduates, demand that practical biology be structured to arouse and stimulate students' interest. The question of whether

or not this objective receives the attention it deserves remains to be checked empirically. The dismal performance in practical biology has been attributed to routine, boring and non-challanging laboratory sessions (Muazu, 1983).

The inculcation of scientific method of investigation was, according to the respondents, the second most important objective. This objective was rated high probably because of the relative importance of the scientific method in the pursuit of science.

The third most important objective was the development of the ability to design and carry out investigations. This rating reflected the respondents' desire for creativity in the students - a much needed talent for national development.

The fourth and the least rated objective was the development of the ability to manipulate biological equipment. This low rating might suggest a limited emphasis on the objective probably because biological equipment could best be manipulated and cared for by trained laboratory technologists and assistants who receive special training in these skills.

A chi-square analysis indicated a strong association of the field of specialization with the rating of these objectives. While the pure scientists rated them very high (with a mean value of 1.96 on a 2-point scale) the applied scientists rated them relatively low (with a mean value of 1.52).

The analysis of data in Table 7 indicated that the most important skill necessary for the realization of the objective "to stimulate students' interest", was the skill of observation. The emphasis on observation might be due to the importance the respondents attached to it as a trigger which arouses interest and as an important component of the scientific method. Robinson (1965) has suggested that observation is the foundation stone in the construction of scientific knowledge.

In order to enhance manipulative ability, the respondents suggested that emphasis should be placed on biological drawing skills, safe handling of common laboratory equipment, operating the ordinary light microscope and dissection skills.

It should be noted, however, that a careful study of the new senior secondary school biology syllabus reveals an increased emphasis on these skills, compared to the earlier KERC and W.AEC syllabuses. This researcher analysed all these syllabuses.and noted the highest frequency of these skills in the new senior secondary school syllabus.

Orderliness in the conduct of practical works, record keeping and familiarity with the common laboratory equipment were rated very high, as skills necessary to inculcate the ability to design and carry out investigations. Yoloye (1981) identified lack of orderliness as one of the major problems facing the Nigerian society. The War Against Indiscipline programme introduced in 1984 is a testimony of this national malaise, which appears to transcend students' behaviour even in the science laboratory.

Communication and mathematical skills received the least rating from the respondents, indicating their limited value in practical biology. This finding agrees with the traditionally held view that language and

mathematics are not indispensable in the pursuit of biological sciences.

To inculcate the scientific method of investigation, four skills that comprise orderliness, record keeping, following a procedure in experimental investigations and controlling variables were considered pertinent by the respondents. Communication and mathematical skills were again rated very low.

A chi-square analysis indicated a statistically significant difference between the pure scientists and the applied scientists on the rating of all the desirable skills considered necessary for the realization of the objectives stated against them. While the pure scientists rated the skills 1.06 on a 2-point scale, the applied scientists rated them 0.82 on the same scale. This suggested a strong association of the field of specialization with the rating of desirable skills.

The results in Table 9 indicate that the most desirable skill senior secondary school biology graduates should demonstrate after leaving school is again orderliness. For

the third time, however, mathematical skills were rated very low by the respondents.

A thorough analysis of past WASC biology question papers, syllabus and recommended textbooks indicated an abysmally poor incidence of mathematical concepts or their usage (Jegede, 1986).

The biology-based professionals in Ahmadu Bello University, Zaria, advocate the use of continuous assessment as the first among the means of enhancing valid assessment of practical biology. This high rating (a mean value of 1.38 on a 2-point scale, Table 10) in favour of continuous assessment is in line with the nation's emphasis on Continuous Assessment Scheme. One-shot final examinations was rated second, indicating that this tradition was still considered a useful means of assessment. Self-assessment mode was least-rated probably because the respondents doubted the validity in students assessing themselves.

A chi-square analysis indicated that the choice of assessment mode was independent of field of specialization among the pure and the applied scientists.

The use of a rating scale in assessing students' performance in practical work was highly rated by the respondents. This, according to them would enhance validity. Other accepted means of enhancing validity include the use of a single, uniform assessment procedure throughout the federation and the use of statistical method to moderate examinations.

The use of re-marking method to moderate examinations was least-rated by the respondents indicating that this moderation tradition may have outlived its usefulness.

The above findings have several implications on the external examination system practised at the tertiary level of education. Few of such implications include the following: First, it implies that a rating scale should be used to assess students' performance. Secondly, the use of re-marking method to moderate examinations should be discontinued in favour of statistical method. Thirdly, the use of continuous assessment should be stressed.

Chapter V

SUMMARY, LIMITATIONS, GENERALIZATIONS AND RECOMMENDATIONS

5.1 Summary

This study was undertaken to design an inventory of psychomotor objectives and skills essential in the learning of senior secondary school practical biology.

A search of the available literature revealed an increasing emphasis on practical work in school science teaching, as a result of the new universally-accepted view of "doing science" rather than "reading about science" in schools.

But several issues on the conduct and assessment of practical work in biology remained unexplained. For example, the researcher noted that no research was reported which attempted to determine, empirically:

(i) the objectives of doing practical biology;

(ii) the desirable skills to be developed through practical biology; and

(iii) how performance might be validly and reliably assessed.

In the absence of an adequate treatment on the above issues, any attempt at practical work in biology may be nothing more than a shot in the dark. This study was therefore conducted to investigate the above issues, with particular reference to senior secondary school practical biology.

The first task was to establish the basis for the claim that success in biology implied success in both practical and theory. The 1986 mock examination results in biology were therefore used to investigate the relationship between the candidates' practical scores and theory scores. The Pearson's product-moment correlation statistic was performed on 122 randomly selected paired scores of biology practical and theory. The r was computed to be 0.68, indicating a reasonably high positive correlation.

A correlated t-test was subsequently used to check if the difference between the means of practical scores and that of the theory scores was large enough to be considered statistically significant or whether the difference was of a

size that could easily have occurred by chance. The result indicated that the difference between the mean of practical scores ($\bar{X}_A$ = 42.43) and that of the theory scores ($\bar{X}_B$ = 44.90) was statistically significant since the calculated correlated t-value (2.24) was larger than the critical t-value (1.96) at 0.05 level of significance and at df = 242.

The presence of an r of 0.68 suggested that students that did well in practical biology performed well in the theory while the presence of the significant difference between the two means indicated that performance in the theory was not necessarily determined by performance in practical.

A structured questionnaire consisting of six sections A, B, C, D, E and F was then designed as an instrument to gather data for the subsequent stages of the study.

Section A of the instrument sought the personal particulars of the respondents, who were biology-based professionals in Ahmadu Bello University, Zaria. Section B was designed to investigate and determine the objectives of practical biology. Of the seven objectives presented to the respondents,

four were rated high enough to qualify for an inventory which was to be designed. A chi-square analysis indicated a strong association of the field of specialisation with the choice of objectives.

Section C of the questionnaire was designed to identify the skills considered necessary for the realization of the objectives of practical biology at the senior secondary school level. An analysis of the responses indicated that 14 skills were considered essential for the realization of the four objectives that qualified for the inventory. A chi-square analysis showed that the choice of desirable skills was not independent of the field of specialization.

Section D of the questionnaire sought the desirable and transferable skills that should be demonstrated by the senior secondary school biology graduates after leaving school. Three of such skills, orderliness, record keeping and observation were especially emphasized by the respondents.

Section E was designed to elicit information on how best practical work in biology could be

validly and reliably assessed. Of the nine alternative modes presented to the respondents, four were rated high enough to qualify for the inventory. A chi-square analysis suggested that the choice of assessment mode among the pure and the applied scientists was independent of the field of specialization.

Section F was designed to identify the means of enhancing validity in the assessment of practical biology, so that the teacher may be assisted in his test administration. There were ten items in this section. An analysis of the responses indicated that six of the ten alternative modes were rated high enough to qualify for the inventory.

At the end of the exercise, the study established empirically, the answers to the four basic questions it set out to investigate.

1. There was a high positive correlation (of r=0.68) between students' performances in biology practical and theory papers. Students that performed well in biology practical would be expected to perform well in the theory paper.

2. A total of four desirable psychomotor objectives for the teaching of senior secondary school practical biology were rated most highly by respondents. These were:

   (a) To stimulate students' interest,

   (b) To inculcate the scientific method of investigation,

   (c) To develop the ability to design and carry out investigations, and

   (d) To develop the ability to manipulate biological equipments.

3. There were eleven psychomotor skills that were assessed pertinent to the attainment of the four objectives above. They include:

   (1) Observations;

   (2) Orderliness;

   (3) Following a procedure;

   (4) Record keeping;

   (5) Controlling variables;

   (6) Familiarity with the common lab. equipment;

   (7) Evaluation skills;

   (8) Biological drawing skills;

   (9) Safe handling of laboratory equipments;

(10) Operating skills of the ordinary Light microscope, and

(11) Dissection skills.

4. Teachers could assess practical biology with some degree of validity and reliability using the following modes in order of merit.

(a) Continuous assessment;

(b) One-shot final examinations;

(c) Short-term task-oriented assessment mode;

(d) Group assessment.

On the basis of these results, the following inventory emerged.

A. <u>An Inventory (by rank) of Desirable Psychomotor Objectives and Skills in Senior Secondary School Pratical Biology.</u>

1. To stimulate students' interest;
2. To inculcate the scientific method of investigation;
3. To develop the ability to design and carry out investigations;
4. To develop the ability to manipulate biological equipment.

3. Skills Essential for the Attainment of the Objectives of Practical Biology

Objectives	Essential Skills
1. To stimulate students' interest	Observational skills.
2. To inculcate the scientific method of investigation	(i) Orderliness, (ii) Following a procedure, (iii) Record keeping, (iv) Controlling variables,
3. To develop the ability to design and carry out investigations	(i) Orderliness, (ii) Record keeping, (iii) Familiarity with laboratory equipment, (iv) Evaluation skills, (v) Following a procedure.
4. To enhance the ability to manipulate biological equipment.	(i) Biological drawing skills, (ii) Safe handling of laboratory equipment, (iii) Operating skills of the ordinary light microscope, (iv) Dissection skills.

C. Desirable Demonstrable Skills that should be Acquired by Senior Secondary School Biology Graduates

1. Orderliness in the conduct of practical work;
2. Skills of operating the ordinary light microscope successfully;
3. Safe Handling of common laboratory equipment;
4. Presenting biological diagrams satisfactorily;
5. Keen observations that arouse interest;
6. Communicating experimental results to the audience satisfactorily;
7. Manual dexterity when engaged in practical tasks;
8. Dissecting a lizard to trace the alimentary canal satisfactorily;
9. Record keeping skills.

D. Desired Modes of Assessing Senior Secondary School Practical Biology

1. Through the use of continuous assessment;
2. Through the use of one-shot final examinations;
3. Through the use of short-term task-oriented assessment;
4. Through the use of group assessment.

3. Ways of Enhance Validity in the Assessment of Practical Biology

1. The use of a rating scale to assess students' performance;
2. Physical presence of an examiner to administer the examination;
3. The use of a single, uniform assessment procedure throughout the federation;
4. The use of an open-ended method to assess practical biology;
5. The use of statistical methods to moderate examination performance;
6. The use of a checklist to assess students' performance.

5.2 Limitations

The study has the following limitations:

(i) The restriction of this research to Zaria Education Zone of Kaduna State made the scope of the generalizations that can be made from the study very narrow.

(ii) Only 122 paired scores from the 1985 mock results were used to establish a correlation between practical biology and theory. With much larger samples, the same results may not be obtained.

(iii) All the respondents came from a university community with an advantaged educational background (71 per cent held at least a second degree). Responses from this advantaged group in the society might differ from samples outside the university community.

(iv) All the subjects came from biology-based faculties/centres and this might colour their perceptions of what is desirable.

(v) There were obvious limitations imposed by the research design, procedure and the statistical analyses employed. Some alternative design and statistical analyses such as a factor-analytical approach will have been better.

5.3 Generalizations

Within the limits of this study, the following generalizations may be drawn:

(i) Students that perform well in practical biology tend to perform well in the theory.

(ii) Among the pure and the applied biologists, there is a strong association of the field of specialization with the choice of objectives and skills essential in the learning of practical biology.

(iii) Orderliness, observation and record keeping are essential skills in the pursuit of practical biology.

(iv) Communication and mathematical skills in the learning of practical biology are least desired by biologist and other biology-based professionals.

5.4 Recommendations

It is suggested that proper attention be given to practical biology in our senior secondary schools since it has been shown to be

positively and statis tically related to the overall performance of students in the biological sciences. This can be done by establishing and equipping laboratories and making the practical sessions stimulating to the students.

Besides, an inventory of the objectives, skills and assessment modes in practical biology has been evolved as a result of this study. Such an inventory may be of particular interest to classroom teachers, Ministries and Institutes of Education and examining bodies such as the West African Examinations Council (WAEC) and the National Teachers' Institute (NTI). They can utilize the inventory by directing the teaching of practical biology towards the identified objectives, skills, assessment modes. etc. so as to enhance effective instruction in practical biology in our senior secondary schools.

5.5 For Further Study

This study may be extended in any of the following dimensions:

(i) It may be extended to cover the whole of Kaduna State or even the country as a whole.

(ii) Similar studies may be conducted to cover the other sciences, notably Chemistry, Physics, Earth Sciences etc.

(iii) A similar exercise may be carried out using a factor-analytical approach to determine the variables instead of the design and statistical analyses employed in this study.

(iv) Experimental studies designed to assess the statistical effect of each of the variables in this study may also be a worthwhile exercise.

REFERENCES

1. Abdullahi, A. (1982). Science Teaching in Nigeria. Atoto Press Ltd., Ilorin pg. 69 - 86.

2. Abousief, A.A. and Lee, D.M. (1965). The Evaluation of Certain Science Practical Tests at Secondary School Level. British Journal of Educational Psychology No. 35. pg. 41-49.

3. Alabi, T.O. (1980). An Evaluation of the Nature and Objectives of Chemistry Practical Lessons at the Katsina College of Arts, Science and Technology, Zaria. Unpublished M.Ed. Thesis, Ahmadu Bello University, Zaria.

4. Akusoba, E.U. (1985). The Secondary School Chemistry Teachers' Perception of the Goals of Laboratory Activities and the skills students should derive from them. Journal of the Science Teachers Association of Nigeria Vol. 23, Nos. 1 & 2 December, pg. 116-121.

5. Aminu, D.M. and Akale, M.A. (1981). Laboratory Design. Journal of Science Teachers Association of Nigeria, Vol. 19, No.3 August pg. 15-23.

6. Anderson, R.D. (1972). Formulating Objectives for Elementary Science. Readings in Science Education, edited by Ronald G. Good. WMC Brown Co. Dubuque, Iowa pg. 370-377.

7. Ango, M.L. and Sila, M.D. (1986). Teaching and Learning of Biology Practicals: The Experience of Some Nigerian Secondary Schools. Journal of Science Teachers' Association of Nigeria, Vol. 24, Nos. 1 and 2 April, pg. 35-46.

8. Associated Examining Board, (1979). AEB Biology Atext 607 5d XV Aldershot, England.

9. Battern, J.W. (1962). An Investigation and Analysis of Laboratory Experiences in Earth Science. Unpublished Thesis, University of North Carolina, U.S.A.

10. Beasley, W.F. (1980). Analysing Laboratory Performance: What Do They Really Measure? The Australian Science Teachers' Journal Vol. 26, No.1 pg. 69-72.

11. Beaty, J.W. and Woolnough, B.E. (1982). Practical Work in 11-13 Science: The Context, Type and Aims of c Current Practice. British Educational Research Journal Vol.8 No.1, pg. 23-30.

12. Bloom, B.S. (1956). Taxonomy of Educational Objectives. The Classification of Educational Goals: Handbook 1, Cognitive Domain. David Mckay Company Inc. New York.

13. Brandwein, P.F. and Schwab, J.J. (1962). The Teaching of Science Harvard University Press, Cambridge, Massachusetts, pg.3-103.

14. Brian, E.W. (1975). The Place of Technology in Schools. The School Science Review Vol. 56, No. 196, March, pg. 443-448.

15. Brown, D.P. (1982). Newer Approaches to Science Teaching. Mimeographed Handbook on Science Teaching. Ahmadu Bello University, Zaria pg. 15-24.

16. Bruner, J.S. (1960). The Process of Education. Harvard University Press, Cambridge Massachusetts, pg. 18-39.

17. Bruner, J.S. (1961). The Art of Discovery Harvard Educational Review Vol. 31, No.1, pg. 21-32.

18. Bryce, T.K.G. et. al. (1983). The Diagnostic Assessment of Practical Skills in Foundation Science. Scottish Educational Review Vol. 15, No.1, pg. 41-51.

19. Bryce, T.K.G. and Robertson, J.J. (1985). What can They Do? A Review of Practical Assessment in Science. Studies in Science Education. Vol.12, pg. 1-2.

20. Buckley, J.G. (1970). An Investigation into the Assessment of Practical Abilities in Sixthform Chemistry Courses. Unpublished M.Sc. Thesis University of East Anglia.

21. Buckley, J.G. and Kempa, R.F. (1972). Student Performances for Different Methods of Assessing Practical Works in Chemistry. The School Science Review Vol. 521, No. 186, pg. 157-160.

22. Carol, T. et.al. (1978). How to Calculate Statistics. Sage Publications, Inc. Beverly, Hills London.

23. Duffey, J. (1972). The Assessment of Progress in Science. The School Science Review Vol. 54, No. 186, September, pg. 13-25.

24. Eggleston, J.F. and Newbould, C.A. (1969). Assessing Attainment in Science at CSE Level, in Eggleston and Kerr (1969). Studies in Assessment, English University Press, London.

25. Eggleston, J.F., Galton, M. and Jones, M.E. (1976). Processes and Products of Science Teaching. Macmillan, London.

26. Eglen, J.R. and Kempa, R.F. (1974). Assessing Manipulative Skills in Practical Chemistry. The School Science Review Vol. 56, No.195, December, pg. 261-273.

27. Eliot, C.W. (1916).in Nay, M.A. (1975). The Fruitful Laboratory Mimeographed Seminar Paper EDCL630, University of Alberta, Edmonton.

28. Esezobor, S.A. (1986). The Challenge of Students' Underachievement in Science. Keynote Address delivered at STANS 27th Annual Conference, Owerri, Imo State, August 25-30.

29. Fafunwa, A.B. (1971). Premature Specialization in Science Education; A Disservice to Developing Nations. Address to the UNESCO/UNICEF Workshop on Integrated Science Teaching. September 20th-4th October.

30. Federal Ministry of Education, Science and Technology, Lagos, (1985). A Handbook on Continuous Assessment. Heinemann Educational Books, Lagos, pg. 1-14.

31. Federal Ministry of Education, Lagos, (1982). Core-Curriculum for Primary Science. Federal Government Press, Lagos.

32. Federal Republic of Nigeria, (1981). National Policy on Education, Federal Government Press, Lagos.

33. Ferguson, G.A. (1974). Statistical Analysis in Psychology and Education. McGrow Hill, New York.

34. Gage, M.L. (1963). Handbook of Research on Teaching: A Project of the American Educational Research Association, Rand McMally and Company, Chicago, pg. 1-2.

35. Gagne, R.M. (1965). The Conditions of Learning. Holt, Rinehort and Winston. New York.

36. Gould, C. (1983). Biology Teaching: Is There Another Way? The School Science Review Vol. 65, No.231, December, pg. 273-376.

37. Gunning, D.J. and Johnstone, A.H. (1976). Practical Work in the Scottish O-Grade. Education in Chemistry Vol. 13, No.12.

38. Gunning, D.J. (1978). Report on the Assessment of Practical Work in Science Subjects on the Ordinary Grade. Scottish Examination Board, Dalkeith.

39. Green, T.L. (1965). The Teaching of Biology in Tropical Secondary Schools, Vol. X: UNESCO Handbook on the Teaching of Science in Tropical Countries. Oxford University Press, pg. 35-123.

40. Hemstead, C.A. (1973). Experiments in Science Teaching. The School Science Review Vol. 54, No. 189, June pg. 661-669.

41. Hudson, D. (1985). Philosophy of Science, Science and Science Education. Studies in Science Education Vol.12, pg. 25-57.

42. Jegede, O.J. (1979). Proposals for A New Post-Primary School Biology Curriculum and that will Engender Adequate Relevance to National Development. Journal of Science Teachers Association of Nigeria Vol.17, No.3.

43. Jegede, O.J. (1982). The Science Laboratory As an Indispensable Factor in Effective School Science Teaching. Mimeograph.

44. Jegede, O.J. (1984). Integrated Science at Senior Secondary School: What Prospectus? A paper presented at WAEC's monthly seminar, January, pg. 1-8.

45. Jegede, O.J. (1986). Mathematical Requirements of the West African School Certificate Biology: 1976-1985. Paper presented at the WAEC's monthly seminar.

46. Jeffrey, J.C. (1967). Evaluation of Science Laboratory Instruction. Science Education Vol. 51, pg. 186-194.

47. Joint Matriculation Board, (1979). Teacher Assessment of Practical Work in JMB A-level Biology JMB Manchester, MIS6EU

48. Kelly, P.J. and Lister, R.E. (1969). Assessing Practical Ability in Nuffield A-level Biology in Eggleston and Kerr. Studies in Assessment, English University Press, London pg. 121-151.

49. Kelly, P.J. (1971). Evaluation Studies of the Nuffield A-level Biology Trials. Journal of Biological Education No.5, 315-327.

50. Kempa, R.F. (1974). Science Education Research: Some Thoughts and Observations. Studies in Science Education Vol.3, pg. 53-97.

51. K.E.R.C. (1983). Kano Educational Resource Centre Biology Syllabus for Secondary Schools.

52. Kerr, J.F. (1963). Practical Work in School Science Leicester University Press.

53. Klopfer, L. (1981). Evaluation of Learning in Science in Bloom, B.S. et.al. A Handbook of Formative and Summative Evaluation of Students Learning. McGrow Hill New York.

54. Lardizabal A. et. al. (1977).in Brown D.P. (1982). Newer Approaches to Science Teaching. Mimeographed Handbook on Science Teaching, Ahmadu Bello University Zaria, pg. 33-40.

55. Lefevre, T. (1963). Ministers Talk About Science. Organization for Economic and Co-operative Development. Paris pg. 15.

56. Lynch, P.P. (1984). The Status of Practical Skills in Tasmanian Science Teaching. The Australian Science Teachers' Journal Vol.30, No.1, pg. 29-37.

57. Mani, T.C. (1983). Essays on Laboratory Practices. Mimeographed M.Ed. Course Material, Ahmadu Bello University, Zaria, pg. 1-28.

58. Ma'azu, S. (1983). Science in Culture Myth. Paper presented at the International Symposium on the Cultural Implications of Science Education, Ahmadu Bello University, Zaria, November.

59. Mager, R. (1962). Preparing Instructional Objectives. Fearon, New York, pg. 8.

60. Moore, J.L. and Thomas, F.H. (1983). Computer Simulation of Experiments. A Valuable Alternative to Traditional Laboratory Work for Secondary School Science Teaching. The School Science Review Vol.64, No.229, June.

61. Novak, A. (1964). Scientific Inquiry in the Lab. American Biology Teacher Vol.25, pg. 342-346.

62. New Nigerian Newspapers (1985). Changing Policies Harm Education. Front page story, November 11.

63 Novak, A. in Nay, M.A. (1975). The Fruitful Laboratory Mimeographed Seminar paper, EDCL680, University of Alborta, Edmonton.

64. Oladimeji, A.A. (1976). The Use of Models in Biology Teaching at Secondary Schools. Journal of Science Teachers' Association of Nigeria Vol.14, No.2 April.

65. Otuka, J.O. (1978). Laboratory Safety Practices for Nigerian Secondary Schools. Unpublished M.Ed. Project, Ahmadu Bello University Zaria.

66. Porter, D.J.R. (1967). A School Approach to Technology. Schools Council Curriculum Bulletin No.2, Her Majestey's Stationery Office, London pg. 3.

67. Renner, J.W. (1973). The Laboratory Science Teaching. Harper and Raw, New York.

68. Robinson, J.T. (1965). Science Teaching and the Nature of Science. The Journal of Research in Science Teaching Vol. 3, No.1, pg. 37-50.

69. Roscoe, G.T. (1975). Fundamental Research Statistics for Behavioural Sciences. Second Edition Holt, Rinehort and Winston, New York pg. 183-184.

70. Sands, M.K. (1981). Teacher Assessment of Practical Work in JMB A-level Biology. JMB Richard Bates Ltd. Manchester, pg. 6-36.

71. Schwab, J.J. (1962). The Teaching of Science as Enquiry In the Teaching of Science. Harvard University Press, Cambridge, Massachusetts pg. 24.

72. Schools Council Publications, (1973). Assessment of Attainment in Sixth Form Science. Evans Educational, London pg. 11-45.

73. Shuaibu, M.J. (1986). The Problems of Science Education in Nigeria. First Inaugural Lecture of the College of Advanced Studies, Zaria, January pg. 1-6.

74. Singer, R.N. and Simpson, E.J. (1972). The Psychomotor Domain: A Resource Book for Medical Specialists. Gryphon, Washington D.C.

75. Stannard, P. (1982). Evaluating Laboratory Performance. The Queensland Science Teacher, November, pg.41-63.

76. Stark, J. and Chalmers, R.K. (1968). Continuous Assessment of Practical Abilities in Scottish HNC Course in Chemistry. Education in Chemistry Vol.5, No. 154.

77. Tamir, P. (1972). The Practical Mode - A Distinct Mode of Performance in Biology. Journal of Biological Education, Vol. 6, No.3, pg. 173-182.

78. Thompson, J.J. (1976). Practical Work in Sixth Form Science. Oxford University Press.

79. Whittaker, R.J. (1974). The Assessment of Practical Work in Maclintosh, H.G. Techniques and Problems of Assessment. Arnold, New York.

80. Wood, R. and Ferguson, C.M. (1975). Teacher Assessment of Practical Skills in A-level chemistry. The School Science Review Vol. 56, pg. 605-608.

81. Yoloye, E.A. (1981) in Brown, D.P. (1982). Newer Approaches to Science Teaching. Mimeographed Material on Science Teaching, Ahmadu Bello University, Zaria.

APPENDIX I

Department of Education
Ahmadu Bello University
Zaria.

May 20, 1987

_____

_____

_____

_____

Dear Sir,

CONFIRMING STEPS II AND III OF MY RESEARCH WORK

I am trying to design an inventory of practical skills in biology, as part of the requirements for my M.Ed. Thesis.

The research strategy adopted is a six-step procedure. The first three steps are outlined below:

Step I: A search was conducted on the available literature to identify the desirable psychomotor objectives for teaching practical biology. Seven broad objectives were derived from the search.

Step II: The contents of course B161, Biological Techniques of a first year undergraduate course on Biology practicals of the Ahmadu Bello University, Zaria, were analysed to identify the skills essential for success in the course. 26 skills were derived.

Step III: The skills obtained in step II above were then clustered round the seven broad objectives identified in Step I and the attached model was derived.

I would be most grateful if you would please go thro through the model and confirm that the skills clustered round each objective are relevant.

Your comments, criticisms and suggestions are very much welcomed.

Thank you.

Yours faithfully,

S.S. Bichi

Step II

Practical works in biology should help students to achieve the following skills derived from the analysis of course B161, Biological Techniques.

1. Manual dexterity
2. Observational skills
3. Mathematical skills such as measuring, calibrating etc.
4. Handling of scientific equipment
5. Familiarity with instruments, studying parts and their functions.
6. Skills of operating the microscope
7. Controlling variables in an experiment.
8. Preparing temporary slides.
9. Presentation of results.
10. Biological drawing skills.
11. Cutting thin sections of specimens using a razor blade.
12. Following a procedure in logical sequence.
13. Staining techniques.
14. Mounting techniques.
15. Identification skills.
16. Dissection skills.
17. Classification skills.
18. Skills of preserving plant and animal specimens.
19. Record keeping skills.
20. Knowledge of concepts peculiar to biology practicals e.g. longitudinal/transverse sections, air buble etc.
21. Cleanliness in the conduct of practical works.
22. Evaluative skills.
23. Blood smear techniques.
24. Inference.

25. Generalization.

26. Presentation of results offer practical works.

Step III

The skills above may be clustered in categories as follows:

	Objective of Practical Biology	Skills Identified to be Relevant
1.	To develop or enhance manipulative ability	Manual dexterity, skills of operating the microscope; Biological drawing skills, handling common laboratory equipment; dissection skills of preserving specimens, skills in sectioning, blood smear techniques and mounting techniques.
2.	To consolidate concepts principles, explanations, models and theories.	Observational skills; classification skills; functional knowledge of concepts peculiar to biology practicals.
3.	To motivate and stimulate students' interest.	Observational skills, handling common laboratory equipment, operating the microscope, following a procedure, dissection skills.
4.	To develop the ability to design and carry out investigations.	Controlling variables; following a procedure, mathematical skills; communication skills, presentation of result, inference, generalization, record keeping, and cleanliness in the conduct of practical work.
5.	To illustrate the scientific method	Observation, controlling variables, following a procedure presentation of results, mathematical skills, inference, generalizations, record keeping and communication.

	Objective of Practical Biology	Skills Identified to be Relevant
6.	To apply scientific knowledge to everyday life in matters of personal and community health and agriculture	Generalizations, relating form to function, evaluative skills, record keeping.
7.	To satisfy special requirements of the examining body.	Skills unique to the examining body and may include the following; cleanliness in the conduct of practical work; record keeping; biological drawing skills; observational skills; classification skills; dissection skills; controlling variables and manual dexterity.

A list of how teachers might assess students' achievement in practical work was drawn. The list comprises the following modes of assessment.

	Rank order them here
1. One-to-one mode of assessment in which one trainee is assessed by one teacher as is found in an apprentice system. In such a case each examinee takes on his practical tasks alone.	
2. Group or joint projects in which several trainees are taught and assessed by one teacher. In this case the practical tasks are undertaken collectively by two or more trainees but each trainee is assessed according to his inputs into the project.	
3. Pencil and paper substitutes as in practical biology in which practical tasks are done by the examinees, who communicate their responses in the form of written answers, drawings, etc.	
4. Short-term system of assessing practical tasks in which a stage is set for a practical test which is undertaken and completed in a one-short examination usually lasting a few hours.	
5. Long term system of assessing practical tasks in which the tasks or projects undertaken for the examination takes place over along period of time.	
6. Continuous system of assessing practical tasks in which case practical exercises (group or individual projects) are build into every lessong, or into every unit of instruction. The examinees' work is then assessed on a continuous basis.	

Please list, in the space provided below, other modes that you know or have used that may not have been included in 1-6 above.

_____

_____

APPENDIX II

Department of Education
Ahmadu Bello University
Zaria.

June 5, 1987

_____

_____

_____

_____

Dear Sir,

MODES OF ASSESSING PRACTICAL WORKS IN BIOLOGY

Attached is a list of ways in which teachers might assess students' achievements in practical works. The list may not be exhaustive.

I write, therefore, to request you to please:

1. rank order them according to your preference in the column provided.
2. List, in the space provided, other modes that you know or have used that may not have been included.

Your comments, criticisms and suggestions are very much welcomed.

Thank you.

Yours faithfully,

Sani Sale Bichi

APPENDIX III

Department of Education
Ahmadu Bello University
Zaria.

August 1, 1987.

_____

_____

_____

Dear Sir/Madam,

I am trying to design an inventory of practical skills in biology, as part of the requirements for my M.Ed. Thesis. It is hoped that such an inventory will assist senior secondary school teachers in their assessment of students' abilities in practical biology to meet the demands of the new 6-3-3-4 system.

As a specialist in a related area where practical skills in biology are important for success in your field, I am requesting you to please complete this questionnaire to assist me gather the relevant data for the study.

The information in this questionnaire cannot and will not be used against respondents. Your honest opinion is therefore solicited.

Thank you for your co-operation.

Sani Sale Bichi

SECTION A

GENERAL INFORMATION ABOUT THE RESPONDENT

Instruction

In items 1-7, please tick the response that applies to you

Name (optional) _____ Place of Work _____

1. Sex: Male ☐ Female ☐

2. Highest qualification:

Ph.D. ☐

M.Ed./M.Sc. ☐

B.Ed./B-Sc. ☐

N.C.E./Diploma ☐

Others (please specify) _____

3. I am a Botanist ☐

" " " Zoologist ☐

Microbiologist ☐

Agricultural Scientist ☐

Pharmacist ☐

Medical Doctor ☐

Veterinary Doctor ☐

Laboratory technologist ☐

Food and nutrition specialist ☐

Examiner in biology-based field ☐

I am a Physical and Health Education specialist ☐

Forestry specialist ☐

Biochemist ☐

Science inspector in the M.O.E. ☐

Biology teacher ☐

Others (please specify) _____

4. I offered Biology as a subject up to

Ph.D. Level ☐

M.Ed./M.Sc. level ☐

B.Ed./B.Sc. level ☐

N.C.E./Diploma level ☐

Others (please specify) _____

5. During my post-primary school days, I found practical biology to be

Very helpful ☐

Helpful ☐

Irrelevant ☐

Useless ☐

Most useless ☐

6. Would you advise that practical biology be continued in the senior secondary schools?

Yes ☐ No ☐

7. If your response to question 6 above is "No", do you have any advice?

_____

_____

SECTION B

Objectives of Practical Biology

In items 8-13, statements are made on the objectives of pratical biology in the senior secondary schools. Against each statement is a five-point scale designed to measure the extent of your agreement or disagreement to the statement. The letters SA, A, U, D and SD on the scale mean strongly agree, agree, undecided, disagree and strongly disagree respectively. Please express your opinion by ticking the appropriate column of the scale.

		SA	A	U	D	SD
8.	In my opinion, practicals in biology should teach the ability to manipulate biological equipment.	-	-	-	-	-
9.	Practical biology offers limited assistance in consolidating concepts.	-	-	-	-	-
10.	Practical biology does not stimulate students' interest.	-	-	-	-	-
11.	Biology practicals should aim at developing the ability to design and carry out investigations.	-	-	-	-	-
12.	Exposure to practical biology experiences does not help the students to develop the scientific method of investigation.	-	-	-	-	-

	SA	A	U	D	SD
13. Some examining bodies have special emphasis or expectations in biology practicals. Practicals in biology should satisfy such expectations.	-	-	-	-	-
14. Practical biology offers limited assistance in making the students apply scientific knowledge to everyday life.	-	-	-	-	-

SECTION C

Skills that may be relevant to the attainment of Objectives of practical biology.

Instruction

In items 15-21, statements are made on skills that may be pertinent to the realization of the objectives of practical biology. After each statement a set of skills are listed a, b, c. Against these skills, a five-point scale designed to measure the extent of your agreement or otherwise is provided. Express your opinion by ticking the appropriate column of the scale for each listed skill.

		SA	A	U	D	SD
15.	The underlisted skills are pertinent in enhancing manipulative ability in senior secondary school practical biology.					
	(a) Manual dexterity in conducting practical tasks.	-	-	-	-	-
	(b) Operating the ordinary light microscope.	-	-	-	-	-
	(c) Dissecting specimens.	-	-	-	-	-
	(d) Safe handling of common laboratory equipment.	-	-	-	-	-
	(e) Biological drawing skills.	-	-	-	-	-
	(f) Blood smear and mounting techniques.	-	-	-	-	-
16.	These skills do not help in consolidating concepts, principles, explanations and theories in practical biology.					
	(a) Classification skills.	-	-	-	-	-
	(b) Skills of relating form to function.	-	-	-	-	-
17.	The skills below motivate and stimulate students' interest in practical biology.					
	(a) Observational skills.	-	-	-	-	-
	(b) Working with or manipulating instruments.	-	-	-	-	-

		SA	A	U	D	SD
18.	The underlisted skills are not relevant in inculcating the ability to design and carry out investigations in senior secondary school practical biology.					
	(a) Communication skills.	-	-	-	-	-
	(b) Controlling variables.	-	-	-	-	-
	(c) Manual dexterity.	-	-	-	-	-
	(d) Familiarity with the common laboratory equipment.	-	-	-	-	-
	(e) Record keeping.	-	-	-	-	-
	(f) Orderliness in the conduct of practical work.	-	-	-	-	-
	(g) Mathematical skills.	-	-	-	-	-
	(h) Following a procedure with minimum instruction.	-	-	-	-	-
	(i) Evaluation skills.	-	-	-	-	-
19.	The following skills do not illustrate the scientific method.					
	(a) Controlling variables.	-	-	-	-	-
	(b) Communication skills.	-	-	-	-	-
	(c) Mathematical skills.	-	-	-	-	-
	(d) Following a procedure in experimental investigation.	-	-	-	-	-
	(e) Orderliness in the conduct of practical work.	-	-	-	-	-
	(f) Record keeping skills.	-	-	-	-	-

		SA	A	U	D	SD
20.	These skills do not enhance the application of scientific knowledge to practical life situations.	-	-	-	-	-
	(a) Observational skills.	-	-	-	-	-
	(b) Relating form to function.	-	-	-	-	-
	(c) Evaluation skills.	-	-	-	-	-
	(d) Record keeping skills.	-	-	-	-	-
21.	The following skills may be emphasized by an examining body such as WAEC in practical biology examination.					
	(a) Orderliness in the conduct of practical work.	-	-	-	-	-
	(b) Record keeping skills.	-	-	-	-	-
	(c) Biological drawing skills.	-	-	-	-	-
	(d) Observational skills.	-	-	-	-	-
	(e) Classification skills.	-	-	-	-	-
	(f) Dissection skills.	-	-	-	-	-
	(g) Controlling variables.	-	-	-	-	-
	(h) Manual dexterity.	-	-	-	-	-
	(i) Relating form to function.	-	-	-	-	-

SECTION D

Desirable skills in the learning of practical biology.

Instruction

In items 22-31, statements are made on what skills should be demonstrated after successfully completing senior secondary school practical biology courses. A five-point scale designed to measure the extent of your agreement or otherwise is provided. Express your opinion by ticking the appropriate column of the scale.

		SA	A	U	D	SD
22.	Senior secondary school biology graduates should be keen at observations that arouse curiousity.	-	-	-	-	-
23.	They should be able to handle common laboratory equipment.	-	-	-	-	-
24.	Senior secondary school biology graduates should be able to dissect a lizard and trace its alimentary canal satisfactorily.	-	-	-	-	-
25.	The graduates should be able to operate the ordinary light microscope satisfactorily.	-	-	-	-	-
26.	They don't have to acquire and demonstrate record keeping skills as they are not necessary in scientific studies.	-	-	-	-	-
27.	They should be able to present biological diagrams satisfactorily.	-	-	-	-	-

		SA	A	U	D	SD
28.	Orderliness in the conduct of practical work should be demonstrated by the students.	-	-	-	-	-
29.	Mathematical skills in measuring, calibrating and elementary statistics are not essential in the learning of senior secondary school practical biology.	-	-	-	-	-
30.	Senior secondary school biology graduates should be able to communicate experimental results satisfactorily to their audience.	-	-	-	-	-
31.	They should demonstrate some degree of manual dexterity when engaged in practical tasks.	-	-	-	-	-

SECTION E

Modes of assessing practical work in biology

Instruction

Questions 32-40 deal with assessment procedures in practical biology. Statements are made on the suitability of each procedure. Against each statement, a five-point scale designed to measure the extent of your agreement or otherwise is provided. Please express your opinion by ticking the appropriate column of the scale.

		SA	A	U	D	SD
32.	Practical biology can best be assessed using one-to-one procedure in which one teacher just as is found in apprentice system where each examinee takes on his practical tasks alone.	-	-	-	-	-
33.	The best way to assess practical biology is to use the group or joint procedure in which several trainees collectively undertake a joint project or tasks but each person is assessed in accordance to his inputs into the project.	-	-	-	-	-
34.	The paper and pencil procedure of conducting practical biology examinations in which the examinees conduct practical exercises and communicate their responses in form of written answers, drawings etc. is the least suitable procedure in the conduct and assessment of practical biology.	-	-	-	-	-
35.	The use of short-term system of assessing practical biology in which practical tasks last for less than 3 hours should be preferred for secondary schools.	-	-	-	-	-
36.	Long term system of assessing practical biology in which practical tasks or projects undertaken for the examination last over at least 3 hours duration should not be advocated for secondary schools.	-	-	-	-	-
37.	Continuous system of assessing practical biology in which practical exercises (group or individual project) are built into every lesson, or into every unit of instruction would be most welcomed.	-	-	-	-	-

		SA	A	U	D	SD
38.	One-shot final examination system of assessing practical biology in which students' assessment is wholly based on the final examination should be advocated for schools.	-	-	-	-	-
39.	Internal mode of assessing practical biology in which the students are predominantly assessed by their respective subject teachers should be preferred to the external mode of assessment in which the students are predominantly assessed through external examinations.	-	-	-	-	-
40.	Self -assessment mode in which the students self-design a practical work for himself to answer a question or solve a problem which has arisen from a lesson and which may be individual or group in nature depending on the complexity and demands of equipment would be of limited value.	-	-	-	-	-

SECTION F

Modes of enhancing objectivity in assessing biology Practical.

Instruction

Items 41-50 deal with improving the objectivity and reliability in the assessment of practical biology. Statements are made on how best such could be improved. Against each Statement a five-point scale designed to measure the extent of your agreement or otherwise is provided. Please express your opinion by ticking the appropriate column of the scale.

		SA	A	U	D	SD
41.	Practical tasks in biology should be assessed using a rating scale in which grades or scores are assigned relative to the level of performance	-	-	-	-	-
42.	Practical biology should be assessed using a checklist in which the skills are detailed and outlined such that profiency is assessed by how much of items has been accomplished.	-	-	-	-	-
43.	Practical tasks in biology should be assessed using the open-ended procedure in which the students' performances are assessed subjectively without reference to detailed achievement criteria other than marking scheme.	-	-	-	-	-
44.	In my opinion, practical bilogy should be assessed by a panel of examiners.	-	-	-	-	-
45.	Practical biology should be assessed by just one examiner.	-	-	-	-	-
46.	The assessor in practical biology should be physically present to administer the instrument.	-	-	-	-	-
47.	Practical biology should be assessed using a uniform assessment procedure throughout the federation.	-	-	-	-	-
48.	Practical biology should be assessed using different assessment procedures to suit prevailing circumstances of each locality.	-	-	-	-	-

		SA	A	U	D	SD
49.	Statistical method of moderation which involves the use of a common reference test designed to be a moderating instrument against which the teachers' assessments are compared and all relevant statistics calculated should be advocated for practical biology assessment.	-	-	-	-	-
50.	Re-marking method of moderation in which moderators meet and examine the 3 best scripts, the 3 worst scripts and the 3 average scripts from each school in relation to the marking scheme should not be advocated for practical biology assessment.	-	-	-	-	-

APPENDIX IV

Ahmadu Bello University, Zaria.
Staff Strengths of Biology-based Faculties/ Centres.

	Faculty/Centre	Staff Strength	20%
1.	Faculty of Science	55	11
2.	Faculty of Medicine	88	18
3.	Faculty of Agriculture	231	46
4.	Faculty of Pharmaceutical Sciences	57	11
5.	Faculty of Veterinary Medicine	80	16
6.	AERLS	21	4
7.	College of Agriculture, Samaru	40	8
8.	NAPRI	52	10
9.	University Clinic, Sick Bay	41	8
	Total	N=665	n=133

*Source: The University Calendar (1984-86)
Ahmadu Bello University, Zaria
Pages 41-160.

APPENDIX V

SELECTED RESULTS IN BIOLOGY PRACTICAL AND THEORY IN THE 1986 MOCK EXAMINATION

S/NO	Practical Score/75	Practical Score %	Theory Score/125	Theory Score %
1	28	37.3	56	44.8
2	22	29.3	48	38.4
3	34	45.3	47	37.6
4	30	40.0	43	34.4
5	20	26.6	46	36.8
6	16	21.3	46	36.8
7	32	42.6	46	36.8
8	14	18.6	41	32.8
9	30	40.0	54	43.2
10	49	65.3	63	50.4
11	27	36.0	53	42.4
12	39	52.0	61	48.8
13	32	42.6	58	46.4
14	30	40.0	53	42.4
15	26	34.6	48	38.4
16	41	54.6	68	54.4
17	44	58.6	69	55.2
18	17	22.6	63	50.4
19	33	44.0	46	36.8
20	37	49.3	82	65.6
21	52	69.3	93	74.4
22	56	74.6	87	69.6
23	06	8.0	58	46.4
24	22	29.3	51	40.8
25	17	22.6	26	20.8
26	18	24.0	37	29.6

APPENDIX V (Cont'd)

S/NO	Practical Score/75	Practical Score %	Theory Score/125	Theory Score %
27	35	46.6	62	49.6
28	56	74.6	70	56.0
29	58	77.3	85	68.0
30	30	40.0	55	44.0
31	42	56.0	69	55.2
32	26	34.6	56	44.8
33	38	50.6	53	42.4
34	16	21.3	42	33.6
35	37	49.3	71	56.8
36	30	40.0	79	63.2
37	38	50.6	68	54.4
38	49	65.3	89	71.2
39	34	45.3	77	61.6
40	22	29.3	41	32.8
41	33	44.0	45	36.0
42	29	38.6	54	43.2
43	55	73.3	69	55.2
44	21	28.0	65	52.0
45	20	26.6	38	30.4
46	48	64.0	91	72.8
47	30	40.0	56	44.8
48	54	72.0	77	61.6
49	32	42.6	54	43.2
50	39	52.0	36	28.8
51	23.5	31.3	37	29.6
52	27	36.0	83	66.4
53	38	50.6	71	57.2
54	28	37.3	50	40.0
55	16.5	22.0	38	30.4
56	40	53.3	81	64.8

APPENDIX V (Cont'd)

S/No	Practical Score/75	Practical Score %	Theory Score/125	Theory Score %
57	34.5	46.0	71	56.8
58	19.5	26.0	78	62.4
59	27.5	36.6	35	28.0
60	27.5	36.6	45	36.0
61	45.5	60.6	76	60.8
62	21	28.0	77	61.6
63	18	24.0	39	31.2
64	15	20.0	29	23.2
65	24.5	32.6	57	44.6
66	13.5	18.0	55	44.0
67	21	28.0	43	34.4
68	24.5	32.6	61	48.8
69	23.5	31.3	56	44.8
70	45.5	60.6	94	75.0
71	28.5	38.0	15	12.0
72	57	76.0	86	68.8
73	37	49.0	47	37.6
74	46	61.3	83	66.4
75	43	57.3	63	50.4
76	45	60.0	67	53.6
77	45	60.0	87	69.6
78	45	60.0	65	52.0
79	47	62.6	77	61.6
80	25	33.3	43	34.4
81	28	37.3	41	32.8
82	36	48.0	65	52.0
83	27	36.0	27	21.6
84	29	38.6	46	36.8
85	19	25.3	44	35.2

APPENDIX V (Cont'd)

S/No	Practical Score/75	Practical Score %	Theory Score/125	Theory Score %
86	34	45.3	83	66.4
87	45	60.0	69	55.2
88	33	44.0	60	48.0
89	56	74.6	110	88.0
90	28	37.3	54	43.0
91	14	18.6	25	20.0
92	20	26.0	24	19.2
93	45	60.0	82	65.6
94	52	69.3	83	66.4
95	20	26.6	72	57.6
96	32.5	43.3	58	46.4
97	23.5	31.3	34	27.2
98	41	54.6	57	45.6
99	36.5	48.6	32	25.6
100	46	61.3	54.5	43.6
101	35.5	47.0	53	42.4
102	30.5	40.6	37	29.6
103	25.5	34.0	31	24.8
104	18	24.0	20	16.0
105	32	42.6	36	28.8
106	17	22.6	47	37.6
107	27	36.0	46	36.8
108	27	36.0	40	32.0
109	34	45.3	67	53.6
110	37	49.3	51.5	41.2
111	34.5	46.0	49	39.2
112	40.5	54.0	49	39.2
113	30.5	40.6	45	36.0
114	04	5.3	14	11.2

APPENDIX V (Cont'd)

S/No	Practical Score/75	Practical Score %	Theory Score/125	Theory Score %
115	29	38.6	73	58.4
116	29	38.6	43.5	38.8
117	39.5	52.6	67.5	54.0
118	48.5	64.6	66	52.8
119	25	33.3	37.5	30.0
120	23	30.6	21	16.8
121	16	21.3	36	28.8
122	22	29.3	40.5	32.4