Students' Practical Experience in Biology First Year Laboratory Manual of Addis Ababa University

Akalewold Eshete*

Abstract: *Though Laboratory work is taken an integral part of the Ethiopian school biology curriculum starting from grade 7, its nature is mainly restricted to demonstration of theoretical concepts. Similarly, the freshman biology laboratory manual discloses at the very onset that the purpose of practical biology is to illustrate the lecture part of the course. Both laboratory instructors and freshmen students respond consistently that practical biology should focus on helping students to learn basic practical skills and bridge the gap between theory and practice. In the ten laboratory lessons, about 56 practical works were identified and their content was analyzed through widely used schemes. Consistent with the purpose of the manual, analysis of the content revealed that illustrative practicals dominated the manual (58.93%) followed by experience practicals (21.43%) and exercise (17.86%) with only 1.78% investigative type. The majority of the practicals (98.21%) emphasize the lowest Level of Inquiry Index, 0 and 1, with only 1.79% of the practicals having Level 2 Inquiry Index. Both boys and girls responded above average to the list of statements and showed significant differences in some of the things they did in the laboratory.*

Introduction

Teaching in the laboratories served as an indispensable part of science in higher education. Hence, one cannot find a science course without a laboratory session. Lots of arguments have been raised in the past to give the justification or rationale for its use. Even though laboratory sessions were generally taken as necessary and important, very little justification was given for their inclusion (Boud *et. al.* 1989; Matiru *et. al.* 1995; Lazarowitz and Tamir 1994; Tamir 1991; Akalewold 2001).

* Lecturer, Department of Curriculum and Instruction, Addis Ababa University.

Some of the debates surfaced against the use of practical work in higher education, according to Matiru *et. al.* (1995:186), include:

- High cost of laboratory work, making it difficult to continue providing facilities and resources to the standard felt necessary;
- Severe time constraints and overloading of timetables leading to serious problems in meeting syllabus requirements in quality and quantity; and
- Dissatisfaction with the effectiveness of conventional laboratory work which does not foster the understanding of scientific concepts and the application of scientific principles to solve problems.

These reactions against the role of practical work, in general, have dual purposes. First, one should justify the need to have a clear rationale and administration for the purpose for which the practical work addresses best (Lazarowitz and Tamir 1994). Secondly, the inclusion of laboratory task should be defended for the sake of the objective it addresses in the educational programme and not for the sake of filling a content gap (Boud *et. al.* 1989).

Even though the instructional potential of the laboratory is enormous (Lazarowitz and Tamir 1994), most practicals in higher education are by nature illustrative or demonstrative (Matiru *et. al.* 1995). Too often they emphasizes the acquisition of observational and manipulative skills and training in the use of equipment (ibid); and allow pupils to 'see' the concepts dealt in action and relate theory more closely to reality (Gott and Duggan 1995; Tamir 1991; Woolnough and Allosp 1985).

This paper is the first attempt to question the nature of biology laboratory works in higher institutions of Ethiopia. Hence, its significance is three fold: (1) to introduce recent changes in the past few decades that have been made to the biology teaching; (2) to attempt to challenge the existing ubiquitous 'cookery book' type practicals (Akalewold 2001); and (3) it is also timely to the recent concern that the country has given to higher education.

Even if in light of the coming revision, which phases out the current first year program from higher institutions, the relevance of this study seems theoretical, the recommendation of this study will directly apply to the preparatory level (grade 11 and 12) where the content of this program will be in use.

The purpose of this paper is thus to analyze the status of biology first year laboratory work in terms of the new developments in the field. In line with this purpose, the following research questions were posed:

- What objectives of practical biology are served by the activities included in the manual?
- How do first year students and laboratory instructors react to what should be the objective of the laboratory tasks?
- What types of practical work dominate the first year biology laboratory manual?
- What levels of inquiry were assigned to the laboratory tasks?
- What are students actually doing in biology laboratory sessions?
- How do students react to their experience in the laboratory?

Definition of terms

According to Lazarowitz and Tamir (1994), the term *laboratory work* is used in the U.S. literature, and it corresponds to the term *practical work* in the United Kingdom and its previously affiliated countries.

Laboratory work: is a form of practical work taking place in purposefully assigned environment (called *laboratory*) where students engage in planned learning experiences (*manual*), and interact with the materials to observe and understand phenomena. Some other forms of practical work such as field trips are thus excluded (Hegarty 1990: 4). (emphasis added).

Related Literature

History of Laboratory in Science Education

A number of authors discussed the issue in detail (Boud *et. al.* 1989; Lazarowitz and Tamir 1994; Gott and Duggan 1995; Matiru *et. al.* 1995; Hudson 1996). The emergence of laboratory teaching can be traced back to the mid-nineteenth century by Liebig at Giessen and Eton at the Rensselaer Polytechnic Institute (Boud *et. al.* 1989). In Britain, biology laboratory teaching can be traced to the influence of T. H. Huxley at the Northern School of Science in South Kensington and his first summer course for science teaching in 1871 (ibid).

Laboratory teaching became established in response to two sets of pressures (Boud *et. al.* 1989; Gott and Duggan 1995). According to Boud *et. al.*, these pressures are (1) the students' demand for practical work; (2) a need for training in research and the demand for the industry section; and (3) technological development which influenced the emergency of laboratory teaching.

The recognition of practical work in science education was also attributed to two schools of thought (Gott and Duggan 1995). These include (1) the recognition that the social and economical importance of science; and (2) the philosophical argument that had arisen from the work of Huxley and Spencer.

According to Anderson (1976), laboratory teaching particularly served the following four purposes:

- The laboratory is a place where a person or group of persons engage in a human enterprise of examining and explaining natural phenomena;
- The laboratory provides the student with the opportunities to learn generalized systematic ways of thinking that should transfer to other problem situations;
- The laboratory experience should allow each student to appreciate and in part emulate the role of the scientist in inquiry; and
- The result of laboratory instruction should be a more comprehensive view of science including not only the orderliness of its interpretations of nature, but also the tentative nature of its theories and models (Boud *et. al.* 1989).

With the explosion of scientific knowledge, a variety of practical works was introduced and students were required to work spending considerable time and writing reports. According to Matiru *et. al.* (1995), such practices were common more than a quarter of a century ago and still serve as a dominant type in many universities.

Intended learning outcomes of laboratory

According to Boud *et. al.* (1989), any discussion of aims and objectives should be conducted within the umbrella of the overall purpose of the program. In biology instructions, one should be clear of making sharp distinctions between outcomes expected from the biology laboratory and out comes from non-laboratory classroom work. A number of authorities suggested taxonomy of aims and objectives for practical work (Anderson 1976; Hofstein and Lunetta 1982; Boud *et. al.* 1989; Hegarty 1990; Tamir 1991; Lazarowitz and Tamir 1994; Gott and Duggan 1995; Matiru *et. al.* 1995).

The new emphasis on practical work calls for change in the conventional methods and with more experimental and discovery-based strategies leading to higher cognitive learning and to less repetitive and time-consuming activities. A number of authors summarized the current goals of practical work in science education (Hofstein and Lunetta, 1982; Boud *et. al.* 1989; Hegarty-Hazel, 1990; Tamir 1991; Gott and Duggan 1995).

Hofstein and Lunetta (1982) emphasized the need to define goals where laboratory work could make a special and significant contribution. Hegarty-hazel (1990), for example, identified four basic outcomes of laboratory activities as (a) learning technical skills; (b) learning scientific enquiry; (c) learning scientific knowledge; and (d) developing student's attitudes. Matiru *et. al.* add another element - developing systematic problem-solving skills to the list.

According to Tamir (1991), this list can be structured under five main headings: (a) understanding concepts (declarative knowledge); (b) acquiring habits and capacities; (c) gaining skills (procedural knowledge), including planning and design, performance, organization, analysis and interpretation of data, and application to new situations; (d) appreciating the nature of science; and (e) developing attitudes. To him, such taxonomy offers a broad list of potential outcome and can only be achieved if opportunities are given to students to involve in the necessary experience.

To relate objectives with the laboratory task, authorities suggest the use of aim-content matrix. Such a matrix can be used to determine exactly what the laboratory tasks seek to attain by relating the objective of practical science placed at one side and the laboratory lessons on the other. This, hence, balances the two concerns in planning laboratory courses (Boud, *et. al.* 1989).

Types of practical work

In designing a course for laboratory, once decisions are made about the aims and objectives, then the major part of the design is to make a right balance of concept development, skill development and motivational aspect.

Science teaching in schools is often criticized, especially by older students, for being prescribed, impersonal, lacking in opportunity for personal judgments and creativity. Science has become reduced to a series of small, apparently trivial activities and pieces of knowledge, unrelated to the world in which students are growing up, and inhibiting to their developing personalities and aspirations.

Woolnough and Allosp (1985) identify three distinct types of practical work: *experiences*, which are intended to give pupils a 'feel' for phenomena; *exercises*, which are designed to develop practical skills and techniques; and *investigations*, which give pupils the opportunity to tackle more open-ended tasks like a 'problem-solving scientist (in Millar 1991:44).

Woolnough (1991) also classified the practical work into four major types: *exercises, experiences, demonstrations and investigations*. Each of these types of practicals has its own place in science teaching. Field works are likely to include aspects of all these functions. Table 1 gives the definition of each practical work and this list also serves as the classifying scheme.

Depending on their purposes and the degree of detailed control exercised by the staff over students' activities, Boud *et. al.* (1989:36) classified laboratory courses into three main ways: *controlled exercises, experimental investigations and research projects.* According to these authors, these are some of the strategies which may provide opportunities for the pursuit of various educational aims in the laboratory teaching (ibid).

The level of inquiry of the laboratory work

A number of researchers (Herron 1971; Tamir and Lunette 1978; Tamir 1991) analyzed different types of laboratory investigations based on the level of openness and the demand for inquiry skills. Through a revised form, Tamir (1991), in table 2 and 3, compared a typical laboratory lesson with that of a typical investigation carried out by a scientist in terms of who does what and he concludes that what students are actually doing in a typical laboratory is like technicians and not like scientists.

Tamir, as shown in Table 3, has suggested that this openness can occur at different stages of an investigation: in the problem to be solved; in the planning and operation of the investigation; and in the possible solutions to the problems. Based on this, he produces a four-way classification of investigations, depending on whether each stage is open - that is left to the student to decide - or closed (in Woolnough 1994).

Table 1: Types Of Practical Work

Exercise	To develop practical skills
Experiences	To gain experience of a phenomenon
Demonstrations	To develop a scientific argument or cause an impression.
Investigations	Hypothesis-testing: to reinforce theoretical understanding. Problem solving: to learn the ways of working as a problem solving scientist.

Source: Woolnough (1991:107) **Effective Science Teaching - Developing Science and Technology Education Series.**

At level zero, all the problems, procedures and conclusions are given and hence, there is no experience of scientific inquiry. At this level, one may find exercises involving practices in some techniques and/or confirmation where the answer is already provided to the students. They may provide opportunities for students to learn accuracy in the process of trying to replicate a known answer.

In level one, both problems and procedures are given and they have to collect data and draw the conclusions.

Table 2: Who does what in the science laboratory?

Activity	School Lab	Scientist's Lab
Identifying problem for Investigation	Textbook or Teacher	Scientist
Formulating Hypothesis	Textbook or Teacher	Scientist
Designing procedures and experiment	Textbook or Teacher	Scientist
Collecting data	Student	Technician
Drawing conclusions	Student or teacher	Scientist

(**Source**: Tamir (1991) *Practical work in school science: an analysis of current practice.* In Woolnough (Ed) PRACTICAL SCIENCE.

In level two, only the problem given and the student has to design the procedure, collect the data and draw conclusions. These are called investigative practicals (see Box 1 for examples of level 2 practicals).

In level three, the student has to do every thing beginning with problem formulation up to drawing of conclusions (Tamir 1991, Boud *et. al.* 1989; Hegarty 1990).

Table 3: Level of Inquiry in the Science Laboratory

Level of Inquiry	Problem	Procedures	Conclusions
Level 0	Given	Given	Given
Level 1	Given	Given	Open
Level 2	Given	Open	Open
Level 3	Open	Open	Open

Source: Tamir (1991) *Practical work in school science: an analysis of current practice.* In Woolnough (Ed) **Practical Science**.

Box 1: Some Examples of Scientific Investigation (Indian experience)

- Study the pH of local fruit and vegetables and its effect on enzyme action.
- Study the effect of common chemicals on the heartbeat of a frog.
- Estimate the rate of oxygen consumption by local fish
- Study the effect of different colors of light on the germination of bajra seeds
- Study the effect of common detergents on the growth of plants
- Identify the blood group of students in a class

Source: UNESCO (1986) UNESCO sourcebook for out-of-school science and technology education. UNESCO: Presses Centrales Lausanne S. A.

Using a somewhat similar scheme, Hegarty (1979) analyzed about 500 exercises published in nine commercially available manuals for college and university microbiology and found no single exercise that provided students with experience of scientific inquiry beyond collecting and analyzing data.

Abraham's and Raghubir in Boud *et. al.* (1989:141) criticized university chemistry and biology course respectively. For instance, Abraham (1982) argued that:

> The verification of laboratory can be characterized as the traditional laboratory materials available from commercial publishers. Basically, the format follows a stereotyped sequence of events. First, there is either a written or an oral discussion of the theoretical and mathematical ideas and concept associated with investigations but also gives the mathematical and skill background necessary to carryout the investigation and subsequent data analyses. This is usually followed by step-by-step instructions for carrying out the investigations in order to collect the data necessary. After the data have been collected, they are put in tables or graphs and analyzed; and then used to show that the concept originally introduced in the first part of the experiment is verified by the information collected.

Similar to Abraham, Raghubir (1979) also criticized the school and university biology courses by saying that:

> Teachers tell students too much; they deprive them of the opportunity to learn themselves. In the laboratory, for example, they are likely to tell them just about everything-how to assemble an apparatus, how to design and experiment, and what outcome to expect. Of course, they think they do this for a good reason - to save time and to 'save the experiment' (ibid)

The Freshman Biology Course

Today practical work occupies an important place in the education of science teachers and scientists in AAU. In the biology B.Sc program, for instance, each course is coupled with a laboratory session. In the first year biology course students spend a maximum of 33 hours in the laboratory and what they perform in this part of the course accounts for one-fourth of the total grade (Kifle 1998).

As a result of recent revision, the first year program was revised to include all basic courses given by the different departments of the faculty. Hence, those courses that were offered in both semesters were reduced to a single course in one of the semester of the first year. Table 4 and 5 provide the major themes of first year biology course and the laboratory respectively.

Objectives of the Manual

The most important objective of the freshman biology laboratory is identified as *strengthening the theoretical part of the course* (Kifle 1998:1). In addition to this, the manual also identifies other subordinate objectives- to familiarize students with the basic laboratory practices, use basic tools in biology, apply scientific methods and develop scientific attitudes' (ibid).

Table 4: First Year Biology Course Outline

No.	Content	Contact Hour
1	Introduction to the course	1
2	The Common Properties of Living Things	5
3	The Biology of the Cell	7
4	Chemical Reactions: The Role of Enzymes as Biocatalyst	3
5	Cellular Respiration and Photosynthesis	4
6	Genetics and Its Role in Human Affairs	4
7	Origin of Life	10
8	Environmental Biology	

Source: Biology Department, Addis Ababa University.

Hence, according to Kifle, to address these objectives the laboratory class should closely follow what students learn in the lecture sessions of the course (ibid). In cases where the theme of the laboratory does not follow what is outlined in the lecture, students will be supplied with sufficient background information before they start doing the lab work.

Table 5: Major themes of first year biology laboratory of AAU

1	The basic tools of the biologist
2	Preliminary use of the microscope
3	The cell
4	Testing for biologically important molecules
5	Diffusion, osmosis and dialysis
6	Biocatalysis – enzymes
7	Cellular respiration
8	Factors involved in photosynthesis
9	Liverworts, mosses and ferns*
10	Bacteria, algae and fungi*
11	A visit to the natural history museum**
12	Film show

Source: Kifle Dagne (1998) Introductory Biology Laboratory Manual I

* Available in Handout.

** Is not laboratory work according to our definition, hence, is not included in the analysis.

Methodology

Design of the study

This paper attempts to study the nature of laboratory work presented in the first year biology manual of Addis Ababa University together with students' and teachers' perceptions of what the objectives of biology laboratory should be and what they do in the laboratory. Hence, a descriptive research design was employed.

Sources of Information

A number of sources of information were taken in line with the research questions. Hence, first year biology laboratory manual together with students and laboratory instructors served as source of information.

Sampling Procedures

All the activities suggested in the manual (N=56) were taken in the study. The subjects of this study were all first year students (N=1113; M=906 and F=207) and all laboratory instructors (N=13) of the 2001/2 academic year. There were 22 sections of laboratory classes. For the two sets of questionnaire, a separate sampling was made to take four students from each section with a return rate of 95 and 75 percent respectively. All laboratory instructors (N=13) were used in the study with a return rate of 76.9 percent.

Instruments of data Collection

Based on the research objectives, a widely employed content analysis scheme developed by woolnough (1991) and Tamir (1991) was used to analyze the type of practical work and the degree of inquiry level. Content analysis of the manual was made with the assistance of two biology graduate students with the reliability coefficients of 0.70 and 0.74 for the two sets of instruments.

Two sets of questionnaire were also prepared from the literature focusing on the aim of biology laboratory and students' perceptions of their practical work. Questionnaire one (with the list of aims for laboratory) was given to first year students [(N=76), that is, (Girls n=35), (Boys n=41)] and laboratory instructors (N=10) to rank the list of aims from the most important to the least important.

Questionnaire two was again given to students [(N= 60; that is, 30 Girls and Boys)] to react to the statements about what they did in the biology laboratory. The students were asked to rate the statements on a five point Likert scale from 'strongly agree' (5) to 'strongly disagree' (1), where the higher the score the more the students agreed with the statement. The average scores of boys and girls were taken separately and through independent t-test, the significant difference (<5%) between them was computed.

Data and Discussion of Findings

Analysis of the Objectives of the Laboratory Manual

Much discussion today surfaced concerning the need to specify goals, aims and objectives for courses in higher education, especially to laboratory teaching (Boud *et. al.* 1989). The statement of aims and objectives, in any course has importance for they provide significant implication as to how the course should be planned and structured.

Most authors agree that when planning a course, care should be taken to ensure the consistency of course aims with that of the more specific objectives and the kind of experiences provided to serve the objectives (ibid).

Aim- content Matrix of the Biology Laboratory Tasks

A close observation of the course objective with that of the major objectives of the manual discloses consistency. Those objectives of the course that lean to practical biology were stated in the form of demonstration of biological concepts and, therefore, were consistent with the objectives of serving to strengthen the theoretical part of the course, which was the most important objective of the manual.

Through the analysis of the lesson tasks, it was also discovered that the most emphasized objective of the laboratory work was as already stated by the manual. Most lessons were demonstration by nature. About seven out of ten lessons were primarily illustrative and no lesson was identified primarily targeted to the development of objective **d** (help students apply scientific method) and **e** (develop scientific attitude) of the manual (see Box 2).

According to literature on laboratory (Hegarty 1990; Dunn *et. al.* 1989; Woolnough 1991), to realize outcomes that focus on scientific method requires the provision of experience in real investigations. Students should have experiences in seeing problems and seeking ways to solve them (when students themselves design experimental procedures), interpret data, make generalizations and build explanatory models to make sense of the findings etc., which are non-existent in the manual.

Besides fostering cognitive development and psychomotor skills, laboratory work also contributes to the development of scientific attitude. Gardner and Gauld (in Hegarty 1990), in this line, identified two broad categories of attitude: *attitude towards science and scientific attitudes*. Attitude towards science refers to students' favorable and unfavorable reactions to some specified attitude objects (e.g., 'doing biology laboratory work). It includes terms like interest, enjoyment and satisfaction.

Scientific attitudes, on the other hand, are used to describe the personality traits (e.g., 'open mindedness', 'objectivity') which are related to habitual styles of thinking. A realization of this outcome is unthinkable through the experience emphasized by the manual.

Box 2: The Major Emphasized Aims In The Laboratory Lesson of The Freshman Biology Manual

		Laboratory Lesson									
		1	2	3	4	5	6	7	8	9	10
Educational	a			X	X	X	X	X	X	X	X
Aims	b		X								
	c	X									
	d										
	e										

Note: Numbers represent laboratory lessons; letters represent aims for practical biology.

1-The basic tools of the biologist
2-Preliminary use of the microscope
3-The cell
4-Testing for biologically important molecules
5-Diffusion, osmosis and dialysis
6-Biocatalysis-enzymes
7-Cellular respiration
8-Factors involved in photosynthesis
9-Liverworts, mosses and ferns*
10-Bacteria, algae and fungi*

a. To strengthen the theoretical part of the course
b. Familiarize students with basic laboratory practices
c. Use basic tools in biology
d. Help students apply scientific methods
e. Develop scientific attitudes

The heart of most laboratory lessons, as shown in box 2, has been identified as the acquisition of biological concepts. This was manifested through a close relationship between the content of the course and the students' task in the laboratory. Such traditional view of science in school has exposed many of the students to failure and frustration (Gott and Mashiter 1991).

Among other things, they were identified as reasons for pupils' failure since they emphasized *the relying on of practical work as a means of enhancing conceptual learning rather than acting as a source for the learning of essential skills* (ibid). The most exalted aim of the manual, to devote laboratory lessons follows closely the theoretical part, clearly illustrate its assigned task: to make practice subservient to theory.

Woolnough and Allosp (1985) argued the danger of carelessly mixing the two aspects (theory and practice) and suggested the need to separate these two aspects of science initially in our thinking, identify their separate justifications for developing both, and then reconsider their mutually supportive interaction. They argue that a tightly coupling of practice and theory can have a detrimental effect both on the quality of practical work done and on the theoretical understandings gained by the students.

Instructors' and Students' Ranking of Objectives

Both teachers' and students' reactions to the major objectives of laboratory were found in contrary to what was identified by the manual and the objective-content analysis. As shown in tables 6 and 7, both laboratory instructors and first year students were consistent in ranking the first two most important objectives the biology laboratory should aim at: to learn basic practical skills, and to help bridge the gap between theory and practice.

The major objective of the manual, that is, *to illustrate the material taught in lecture*, was rated fourth by instructors and sixth by students.

Another important result was that the development of critical awareness (scientific attitudes through, for example, the extraction of information from data) was taken as one of the least objectives by the two groups. Moreover, the role of practical work in developing interest in biology field was rated least by students.

Table 6: Four Aims Ranked Highest by Laboratory Instructors and First Year Students

Laboratory instructors	First year students
1. To learn basic practical skills	1. To learn basic practical skills
2. To help bridge the gap between theory and practice	2. To help bridge the gap between theory and practice
3. To familiarize with important standard apparatus and measuring techniques	3. To learn some theoretical not taught in lecture
4. To illustrate material taught in lecture	4. To familiarize with important standard apparatus and measuring instruments

Types of practical work in the manual

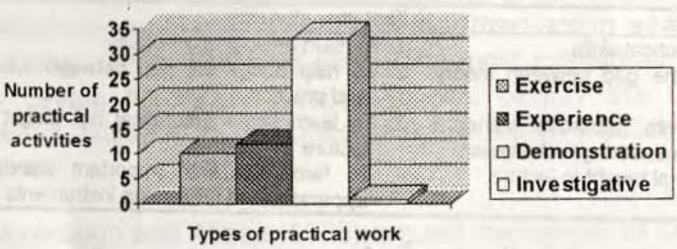
Based on the discussion of the literature part, the content of each practical work was analyzed in order to determine their type. About 56 discrete laboratory exercises were identified in the manual.

Table 7: Four Aims Ranked Lowest by Laboratory Instructors and First Year Students

Laboratory instructors	First year students
1. To instill confidence in biology	1. To use experimental data to solve specific problems
2. To use experimental data to solve specific problems	2. To stimulate and maintain interest in biology
3. To foster a critical awareness (e.g., extraction of information from data)	3. To foster a critical awareness (e.g., extraction of information from data)
4. To learn some theoretical material not taught in lecture	4. To instill confidence in biology

As shown in Figure 1, students spend much of their laboratory time performing demonstration activities (58.93%, 33), followed by experience (21.43%, 12) and exercises (17.86%, 10) practicals. According to Gott and Duggan (1995:28), the principal learning outcome of demonstration activities is to help the student grasp the conceptual understandings of the course.

Fig 1: Summary of the Types of Practical Work



Demonstration activities are primarily targeted to illustrate a particular concept, law or principle which has already been introduced by the teacher and allow pupils to 'see' the concept in action. Hence, they always aim at relating theory more closely to reality (ibid 21). They can be taken as activities done by the teacher or activities done by students, given a detailed procedure or 'recipe' to follow.

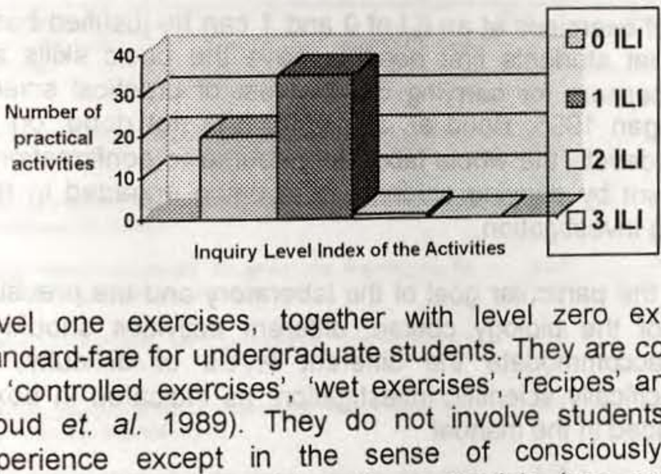
Only 1.78% (1) of the laboratory activity is investigative. Investigative practical work gives freedom to students to choose their own approaches to the problem (Gott and Duggan 1995; Woolnough 1991) (see example, Test for the unknown in Appendix 1). This result is generally consistent with the objective of the manual, that is, to strengthen the theoretical part of the course (Kifle 1998:1).

To sum up, almost all suggested activities are controlled exercises (98.21%) for they are characterized by detailed experimental procedures and a known destination. According to Boud *et. al.* (1989), these activities are the major emphasis of the early stages of undergraduate programs. Such activities have the potential to familiarize students with the materials of biological science, for example, microscope, and are used effectively to train students in basic skills and techniques.

Level of Inquiry of the Biology Laboratory Works in the Manual

Understanding of the process of scientific inquiry could perhaps be developed using a variety of teaching approaches. Laboratory work can play an important role in developing students' understanding of the process of scientific inquiry, their intellectual and practical skills (Klopfer 1990). Based on the procedure identified in the literature part, all exercises were analyzed to determine their level of inquiry.

Fig 2: Summary of the ILI of the Practicals



Level one exercises, together with level zero exercises, are a standard-fare for undergraduate students. They are commonly known as 'controlled exercises', 'wet exercises', 'recipes' and 'cook books' (Boud *et. al.* 1989). They do not involve students in an inquiry experience except in the sense of consciously 'copying' an investigation conducted by other scientists (see appendixes 1 for some examples from the manual.).

As shown in Figure 2, 98.21% (55) of the laboratory work is devoted to the two lower levels, namely 0 and 1. There is only one activity, in the whole manual, having the Inquiry Level Index (ILI) of two and there is no practical with the ILI of three. For example, the second activity in Appendix 1 was classified as level 1 ILI because it does not involve the student in designing the material and method to be used, but only to draw a conclusion. A level 2 ILI index is assigned to an exercise when a problem is given (by the manual) and students are required to design a method and to draw conclusions.

According to Tamir (1991:16), the main criticism of practical work in schools science has been its unique emphasis on the lower levels. Students' failure to see the connections between what they actually do and the theory, and the place of laboratory in the larger context of the scientific enterprise are included in the criticism (ibid). Content analysis of laboratory manual reveals that even those curricula that claim to be inquiry-oriented have a significant portion of the laboratory exercises devoted to the low-level inquiry (Herron 1971; Tamir and Lunetta, 1981).

The inclusion of exercises at an ILI of 0 and 1 can be justified based on the view that students first need to have the basic skills and techniques necessary for carrying out the rest of practical science (Gott and Duggan 1995; Boud *et. al.* 1989). It is not good, on the other hand, to devote the whole laboratory course to confirmation of biological content by denying students from being engaged in real-problem solving investigation.

Depending on the particular goal of the laboratory and the prevailing local context of the biology course, different activities should be designed to accommodate the different levels of difficulty and guidance. Specifically scientific investigation, as indicated in box 1, should be included in the manual.

Students' Opinions to Biology Practical Work

Table 8 summarizes the students' response to the list of statements about biology practicals. They were asked to what extent they agreed or disagreed to a statement, on a five-point scale, about the task they did in the biology laboratory.

The average scores, of boys and girls were taken separately. The two groups generally responded above average for all the items. A statistical difference in responses of females and males was observed in items 1, 3 and 4. The opportunity given to plan their work in the laboratory lessons was found more satisfying to females than males, where in reality they were doing nothing but fill their observation in prescribed worksheets.

It was also identified that a standard activity (with detailed notes and procedures for carrying out the experiments) was found more satisfying and gave confidence to pursue in the field of biology more to females than males. Unlike females, males thought the biology laboratory as a place where they could investigate about things.

Table 8: Mean student response to laboratory work in biology

Responses	Girls	Boys	*(<5%)
I found the opportunity to plan my own experiment very satisfying	4.29	3.71	*
I felt happiest when clear instructions were given to follow when doing practical experiment	4.47	4.27	-
Standard experiments, written up correctly, give confidence to continue with biology	4.41	3.67	*
Biology laboratory should be about the learning to do science through scientific investigations	4.00	4.51	*
Standard experiments, full of procedures, give confidence to continue with biology	4.18	4.44	-
Extended practical projects showed me what biology was like and got me interested in it	4.12	3.78	-
I feel most confident when the biology lessons were well structured and teacher-directed	4.18	3.97	-
I valued the opportunity when the teacher let us plan our own activities in lessons	4.24	3.80	-

Summary of Results

From the discussion made in the preceding pages, a number of important findings can be summarized as follows:

- Unlike what was identified in the manual and content analysis of the tasks, students and laboratory instructors believe that the most important objectives of the laboratory work should be helping students to learn basic practical skills and to help them bridge the gap between theory and practice. The most exalted objective of the manual, consolidation of theoretical concepts dealt in the lecture, according to many authors, served the traditional science teaching.

- Consistent with the conceptions of the manual, still the dominant practical work identified was the demonstration practical. It comprised 58.93% of the practical work included in the manual with 21.43% experience practicals, 17.86% exercise practicals and only 1.78% of investigative.

- Again, the majority of the activities have the Inquiry Level Index of one. They comprise 62.8%, followed by Level 0 Inquiry Index (35.71%) and with only 1.78% level two Inquiry Index practical.

- Both groups responded to a number of statements on biology practical work above average. Females seem to prefer the standard experiments as more satisfying than do males.

Recommendations

Undergraduate laboratory activities generally have two major purposes (Boud *et. al.* 1989): They should give the student an opportunity to practice various inquiry skills, such as planning and devising an experimental program to solve problem, and an investigational work, which involves individualized problem solving, which is highly motivational especially if the student develops a sense of ownership for the problem.

Laboratory teaching methods, besides providing exercises to be followed through detailed procedures, should allow the student to display some personal initiatives in the performance of the task and aims to develop students' abilities in scientific inquiry (ibid). To this effect, the following recommendations can be made:

- The objectives of the manual should be revised to accommodate the current understandings and contributions of practical work in science teaching and learning. Hence, beside its role of strengthening the theoretical parts, other aims like acquiring habits and capacities, gaining skills including the skills of planning and designing, performance, organization, analysis and interpretations of data and application to new situations; together with appreciating the nature of science and developing attitudes should be sought.

- Attempt should be made to construct the aim-content matrix during course planning in order to include as much as possible the different types of practical work that would serve the particular objective and content identified by the matrix.

- Empirical enquiry, which is the hallmark of the natural science, should be considered in designing the laboratory work. Laboratory teaching should convey a firm sense of the nature and functions of empirical enquiry to students. Instead of devoting the whole experiment to a low Inquiry Level Index, as much as possible, revision should be made to include the higher Inquiry Level Indexes as well. The revision is also justified since the biology practical curriculum needs to be balanced through the inclusion of appropriate experimental investigations that will provide graduates with the requisite skills needed to meet the range of professional demands.

Reference

Akalewold, E. (2001). The Nature and Purpose of Practical Work in the Science Curriculum Material of the Addis Ababa Administrative Town-The Case of Grade 8. Addis Ababa University School of Graduate Studies. (Unpublished Master Thesis)

Boud D, Dunn J and Hegarty-Hazel E. (1989). **Teaching in the Laboratories**. Philadelphia, Open University Press.

Dagne, K. (1998). **Introductory Biology Laboratory Manual I**. Addis Ababa University Press.

Gardner, P and Gauld, C. (1990). *Labwork and Students' Attitude* in Hegarty-Hazel E (ed.), **The Student Laboratory and the Science Curriculum**. London, Croom Helm.

Gott, R. and Duggan, S. (1995). **Investigative Work in The Science Curriculum**. Buckingham, Open University Press.

_____, and Mashiter, J. (1991). *Practical work in Science - A Task- Based approach* in woolnough, B, E. (ed.), **Practical Science**, Milton Keyness, Open University Press.

Hegarty-Hazel, E (ed.), (1990). **The Student Laboratory and the Science Curriculum**. London, Croom Helm.

_____(1990). *Learning Technical Skills in the Students Laboratory* in Hegarty-Hazel, E. (ed.), **The Student Laboratory and the Science Curriculum**. London, Croom Helm.

Herron, M.D. (1971). *The Nature of Scientific Inquiry*. **School Review**, 79, 171-212.

Hudson, D. (1996). *Laboratory Work as Scientific Method: Three Decades of Confusion and Distortion*. **Curriculum Studies**, 28, 115-135.

Klopfer L, E. (1990). *Learning Scientific Enquiry in the Students Laboratory*. In Hegarty-Hazel E (ed.), **The Student Laboratory and the Science Curriculum**. London, Croom Helm.

Lazarowitz, R., and Tamir, P. (1994). *Research on Using laboratory Instructions in Science* in Gabel D.L (Ed) ***Handbook of Research in Science Teaching and Learning***, National Science Association.

Matiru B; Mwangi A and Schlette R. (Eds) (1995). **Teach Your Best: A Handbook for University Lecturer**. Germany, University of Kassel.

Millar, R. (1991). *A means to an end: the role of process in science education*. In Woolnough, B, E. (ed.), **Practical Science**. Buckingham, Open University Press.

Tamir P. and Lunetta, V.I (1978). *An Analysis of Laboratory Activities in the BSCS Version*. **The American Biology Teachers**, 40, 353-357.

_____, (1991). *Practical Work in School Science: an Analysis of current Practice*. In Woolnough, B, E. (ed.), **Practical Science**. Milton Keyness, Open University Press.

_____, and Lunetta, V.N. (1981). *Inquiry Related Tasks*. In **High School Science Laboratory Handbooks**. Science Education, 65, 477-484.

_____, and Pillar Garcia, M. (1992) *Characteristics of Laboratory Exercises Included in Science Text Books in Catalonia (Spain)*. **International Journal of Science Education**, 14, 381-392.

Woolnough, B., and Allosp, T. (1985). **Practical Work in Science**, Cambridge, Cambridge University Press.

Woolnough, B, E (ed.), (1991). **Practical Science**. Milton keyness, Open University Press.

Woolnough, B, E (1994). **Effective Science Teaching**. Buckingham: Open University Press.

APPENDIX 1
A TYPICAL LEVEL 0, 1 AND 2 INQUIRY EXERCISES IN THE MANUAL.

TESTS FOR CARBOHYDRATE

1. Molisch Tests

This is a general test for carbohydrates. Carry out the test on 0.1 M solutions of glucose and sucrose, and on 1% starch solutions.

1. Place 5 ml. of each of the solutions (glucose, sucrose and starch) in clean test tubes. In another tube also add 5ml. of distilled water (as a control).
2. Add 2 drops of α-naphtol in each tube. Mix the content well.
3. Incline the tubes. Slowly add 2-3 ml of concentrated sulphuric acid down the slide.

A purple of violet ring at the junction of the acid and the solution indicates the presence of carbohydrates.

2. DEMONSTRATE CO_2 PRODUCTION DURING ANAEROBIC RESPIRATION

Yeasts are fungi used in baking and the production of alcoholic beverages. They can respire in the absence of O_2, and oxidize glucose to ethanol and CO_2. TO demonstrate CO_2 production during anaerobic respiration by yeast (fermentation) follows the procedure below.

1. Label five fermentation tubes and add the solutions listed in Table 7.1:

Table 7.1 Contents Of Fermentation Tubes To Demonstrate CO2 Production During Anaerobic Respiration

Solution	Tube 1	Tube 2	Tube 3	Tube4	Tube 5
3M Pyruvate	-	-	-	2.5 ml	2.5ml
0.1 M NaF	-	0.51ml	5ml	2.5ml	-
5.0% glucose	2.5ml	2.5ml	2.5ml	2.5ml	2.5ml
Water	5.0ml	4.5ml	-	-	2.5ml
Mm CO2 after 40 minutes					

2. Fill fermentation tubes 1 to 4 with the yeast suspension provided. Fill tube 5 with distilled water. Your instructor will demonstrate how to tip the fermentation tube to remove air bubbles.
3. Cover the outlet of each tube with a piece of plastic film.
4. Make a pin-hole in the film to release pressure.
5. Incubate the tubes at 40^0 C, and check for the production of CO_2 bubbles every 10 min for 40 min.

6. When CO_2 accumulates in the top of the fermentation tube measure the height of the bubble in millimeters. *Record your results (emphasis added).*

3. Testing for an Unknown

1. Unknown solutions A, and B, will be provided in groups. *Carry out each of the food tests and record your results in the table on the worksheet (emphasis added).*

Source: Kifle Dagne (1998:33, 50, 38) *Introductory Biology Laboratory Manual I.*