

An Evaluation of The Teaching of Biology In Some
Selected Snior Government Secondary Schools of
Addis Ababa Vis-a'-Vis An Enquiry Model

A Thesis
Submitted to
the School of Graduate Studies
Addis Ababa University

In Partial Fulfilment
of the Requirements for the Degree
Master of Arts in Education

by
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June 1992

ADDIS ABABA UNIVERSITY
SCHOOL OF GRADUATE STUDIES

AN EVALUATION OF THE TEACHING OF BIOLOGY
IN SOME SELECTED SENIOR SECONDARY
SCHOOLS OF ADDIS ABABA VIS-a-VIS
AN ENQUIRY MODEL

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Acknowledgement

I am indebted to my advisors Dr. Azeb Desta (Department of Curriculum and Instruction) and Dr. Zemedu Asfaw (Department of Biology) for their help and guidance throughout the study. I would also like to express my deepest gratitude to Ato Solomon Girma and Ato Abeje Birhanu who sacrificed their time and money to enable me produce the research in this form.

Abstract

An evaluation of the Teaching of Biology in Some selected Senior Secondary Schools of Addis Abeba vis a-vis an Enquiry Model.

It has been reiterated that science teaching can by no means be properly accomplished by merely telling students about scientific facts, principles and generalizations. Science educators, school science teachers and scientists have emphasized the need for a problem-solving or enquiry approach to science teaching rather than presenting it as sanctified body of knowledge. To this end, they have stressed and pointed out the preferred way; i.e., science teaching should be based on the nature of science and should help students understand the process of scientific enquiry without which an adequate understanding of any science subject would not be possible.

The teaching of biology, as a science, follows the premises of science teaching. The object of this study was to evaluate the present Biology Curriculum for Senior Secondary Schools of Ethiopia and its implementation against an Enquiry Model for Biology Teaching and thereby see whether or not it is in line with modern trends in science teaching. For this purpose, the questions, practical activities and "Narrations of enquiry" included in 15 even numbered units of the four textbooks (grades 9 - 12) were analysed using various criteria. Evaluation of its

implementation involved questionnaire survey and observation of the actual teaching-learning processes in biology classrooms using an observation schedule designed for the purpose.

Chapter 2 is devoted to a discussion of the rationale for teaching science as enquiry, the nature of a science curriculum suited for enquiry teaching and requirements for the proper implementation^{of} an enquiry science curriculum.

Results of the study, presented in chapter 3, in general show the presence of an immense gap between the actual teaching of the subject and the approach called for by the Biology Curriculum. That is, while the textbooks overall follow a commendable approach with regard to their ability to help students understand the process of biological enquiry, their implementation is very minimal at best (verbalism is to rampant). The reasons vary from those that are general (applicable to the general educational system at this level) to those that are specific to biology. Among the specific reasons, the unrealistic nature of the textbooks and the unfamiliarity of biology teachers with the enquiry approach stand out as the most important ones.

Although the teaching of biology cannot be seen out of the context of the general educational system at this level, the excessive domination of verbalism in biology classrooms has led to what has been called "a dead study of life".

Chapter One

1. The Problem and Its Approach

1.1. Introduction

The effectiveness of science teaching at the Senior Secondary School level lies in designing curricula that reflect the nature of science and their proper implementation. Science could be considered as consisting of two inseparable aspects: the "processes" and "products" of science. The former refers to the mode of investigation by which scientific knowledge is acquired. The latter refers to the accumulated scientific knowledge which results from the investigations. While the traditional approach to science teaching emphasized the product (content) with little emphasis on its processes, at present there is a more or less general agreement that an adequate understanding of science requires understanding of both its processes and product (Marshall, 1965; Romey 1968). What is less general, however, is the means by which this far-reaching objective of science teaching could be achieved.

1.2. Background

Since the early 1960s a teaching approach considered as the most appropriate for achieving the goals of science teaching and consistent with its nature has been to teach science as enquiry (Nuffield Biology Project, 1966; BSCS, 1971). One of the most significant trends in the teaching of science which reflected this basic approach, whether it be in chemistry, physics, or biology, has been an increased emphasis on student involvement in scientific investigation through laboratory work and field study. This emphasis also stems

from the view that science cannot be effectively learnt from books and lectures, or taught by merely telling students about science. To learn science, one must do it. The kind of learning that results from this experience - student involvement in a real (to him/her) scientific investigation - not only gives the student knowledge of the subject but also provides him with some understanding of scientific processes.

In Ethiopia, this approach to science teaching seems to have been recognized long ago. Senior Secondary School Curriculum committees established at different times either to design new or revise existing curricula have emphasized student involvement in science teaching. The provisional Secondary School Curriculum released in 1959, for instance, states that the aims of science teaching are:

1. To encourage enquiry and experiment as a means to greater knowledge and understanding of the environment.
2. To show the importance of experiment as a means of discovery, and of evaluation of theory, and to show the value of experiment and of science in the students everyday life.
3. To train accuracy of observation and recording, and to encourage careful analysis and appraisal of evidence (Ministry of Education and Fine Arts, 1959:70).

In view of achieving these aims of science teaching, the following were among the teaching methods recommended(Ibid):

1. Science teaching must not become merely a recital of connected facts but must emphasize the foundation of science in experiment and application of scientific method and thought to a particular theme.
2. No science teaching is complete without demonstration by the teacher and progressively more difficult experimental work by the student.

The final report of the Science Commission established in January 1967 to evaluate the then Science Curriculum also notes that:

...it must yet again be stressed that science teaching is to a large extent ineffectual if the student doesn't see and do things for himself. Science is observation and experimentation. (Ministry of Education and Fine Arts, 1967:197).

This same commission had also identified the faults of science teaching at that time and gave various recommendation for its improvement. At present also there is a widespread dissatisfaction with, in general, the quality of instruction at the Senior Secondary School level (Tekeste, 1991).

1.3. The Problem

The teaching of biology, as a science, follows the premises of science teaching. However, in spite of this understanding among scientists, science educators and school science teachers, it has not been easy to raise the standard of science teaching, even in the developed world, to the desired level. An important global obstacle in this regard has been and still is the authoritarian teaching of science; i.e., the placing of emphasis on authoritative content with little or no attention to the processes of science. Though not separately reported for biology, overemphasis on content is still a major problem of science teaching in our Secondary Schools today (Ergese Summary Report, 1986:14).

The present Biology Curriculum for Senior Secondary Schools of Ethiopia, apparently in line with its predecessors,

seems to have been designed following what might be called the enquiry approach. This is explicitly stated in the foreword of the course given in its first part (the Grade Nine Biology Text):

The course is similar in approach to the new course for grades 7 and 8. This means that most of the work consists of investigations which you, the pupil, will perform.... Some of the investigations will take a long time to complete. Scientists often have to take readings over many months in order to obtain an answer to a problem. Like these scientists, You must make sure that any investigation is complete.

This shows that emphasis is to be given to practical activities and field study in order to give students experience in scientific processes. Above all, students are supposed to work like research biologists, or "little"scientists.

1.4. An Enquiry Model for Biology Teaching

Among the repertoire of models that may be selected for science teaching, those belonging to the information processing family are preferred. These models, rather than focusing on the acquisition of specific skills, "focus on the process of thinking, enquiry, problem-solving and decision making" (William,1987:101). The emphasis on enquiry teaching (and hence preference for models that emphasize it) is based on one crucial assumption: that if students are given ample opportunity to practice in and develop scientific enquiry skills, they would transfer this skill and enquiring attitude

of mind to the problems they encounter in everyday life.

Joyce and Weil, in their book *Models of Teaching*, describe a model for the teaching of biological science developed by Joseph J. Schwab of the University of Chicago and his associates. The model emphasizes understanding of scientific enquiry using content. Its basic premise is that an understanding of biological enquiry is so crucial for adequate understanding of the nature of the subject. In the words of Joyce and Weil (1980:138) the essence of the model is:

to involve students in a genuine problem of enquiry by confronting them with an area of investigation, helping them identify a conceptual or methodological problem within that area of investigation, and invite them to design ways of overcoming that problem.

Largely based on this model, the Biological Sciences Curriculum Study(BSCS) under supervision of Joseph J. Schwab and in cooperation with the American Institute of Biological Science (AIBS), had developed instructional materials for use in American High Schools.

A summary of the concepts that describe the model is given below (Ibid:142).

Summary Chart: Biological Science Enquiry Model

Syntax (Floats)

Phase one	Phase Two
Area of investigation is posed to student	Students structure problem
Phase Three	Phase Four
Students identify the problem	Students speculate on ways of clearing up difficulty

Social System

The model has moderate structure, and a cooperative, rigorously intellectual climate.

Principles of Reaction

Teacher nourishes enquiry, turning students toward enquiry processes rather than identification efforts.

Support System

The model requires a flexible instructor skilled in the process of enquiry and a supply of problem areas of investigation.

The model was selected as a "standard" for the study due to the following reasons:

1. The model had been developed in such a way that students would be able to understand both the content and processes of the subject - following the emphasis on teaching science as enquiry.

2. The BSCS materials produced based on this model had, at the time, aroused such worldwide interest among educators and biologists; leading to their adaptation in several countries. According to McInerny (1986:25), BSCS textbooks have been adapted for use in over sixty (60) countries. Thus, the selection of this model is partly based on its acceptance as a viable model within the field of biological science.

3. Though one may reasonably expect, given the stretch of time since the model's development, that other model(s) suitable for the teaching of the subject might have been developed, it is still described by Joyce and Weil (1980:138) as one of the best:

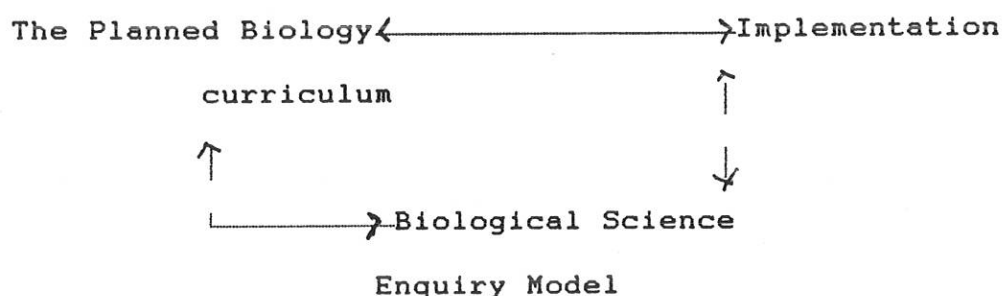
Whereas many of the curriculum materials and instructional procedures...used rather straight-forward, unimaginative teaching strategies.... Some of the curricula used very sophisticated strategies to induce students to practice the methods of the disciplines. Two very articulate exemplars of this approach were taken by the Biological Sciences Curriculum Study...

4. The model could serve, as it did, as a basis for curriculum revision or in new curriculum design. The choice of content and ways and means by which the objectives of the model could be achieved is open, thus leaving ample room for local choice and priority from country to country.

5. As indicated earlier, the present Biology Curriculum has some elements that fit into the model selected. The curriculum capitalizes on student involvement in scientific investigations and enquiry. Thus, the researcher's conviction that the intention of the writers of the curriculum is in accordance with the Biological Science Enquiry Model led to its selection.

1.5. Statement of the Problem

The purpose of this study was to evaluate the present Biology Curriculum for Senior Secondary Schools of Ethiopia and its implementation in light of the Biological Science Enquiry Model described above and thereby see whether or not it is in line with modern trends in science teaching. In essence, it sought to identify aspects of the curriculum that fits into the model and how these relates to its implementation as shown below:



The major basic questions with which the study was concerned are:

1. Irrespective of the content included, does the curriculum place emphasis on the enquiry approach it purports to follow?

1.1. Do the questions included in the Biology Textbooks and their integration into text-discussion facilitate student enquiry?

1.2. Do the practical activities included help students understand the nature of biological enquiry?

1.3. Are the practical activities included in the

textbooks feasible in terms of the amount of time required, materials and equipment needed etc.?

1.4. Is there sufficient material in the textbook developed following the format of "Narration of Enquiry"?

2. Is there adequate provision for the implementation of the investigations in terms of expendable materials, equipment, facilities and the administrative set up?

3. Does the actual teaching-learning process in biology classes create a conducive atmosphere for students to engage in enquiry processes?

1.6. Significance of the Study

Before listing the potential contributions of the results of this study, it is worth mentioning the role of biology in a general education programme.

At present, the world is witnessing the problems of population explosion, poverty, environmental pollution, depletion of natural resources etc., in their most serious form. These problems, directly or indirectly contain a biological element. There are also specific areas of biology that have socioeconomic implications. These include forestry, agriculture, conservation of natural resources, control of vectors and disease transmission, and control of soil erosion. These are more a concern of the developing world; where easily preventable diseases turn out to be plagues, where

malnutrition and under nutrition affect a large part of their population, where measures to check population growth become less effective, and where an astonishing number of children die due to diseases which could have been prevented by simple immunization. All this shows the intimate relationship that exists between biology and everyday life; i.e., biology has immense practical value in the life of every citizen. In addition to this, biology as a discipline contributes a lot in training of the mind. In view of this, therefore, the why, what and how of secondary school biology becomes of paramount importance. We need citizens who are aware of the socio-economic implications of biology and who can contribute better to the solution of bio-social problems through a better understanding of the ideas of biology. This need becomes even more important when we consider the fact that Ethiopia is a country where agriculture forms the basis of its economic life. A closer investigation of the teaching of the subject is, therefore, an essential prerequisite towards improving the quality of its teaching. In addition to this, it is hoped that the results of this study:

- will contribute a great deal in pre-service training of biology teachers.
- will throw light on the teaching of other science subjects.
- may serve as a basis in the effort to improve the quality of biology teaching at the Senior Secondary School level.

1.7. Delimitation of the Study

The choice of teaching of the subject biology at the Senior Secondary School level as the problem of investigation was due to the fact that biology is the researcher's area of specialization and is at present involved in the pre-service training of biology teachers for these schools. Two areas of interest with which the study is not directly concerned are training of biology teachers and student achievement. The study will not attempt to deal with questions pertaining to these areas except by way of showing, where necessary, their relationship to the problem under investigation.

An aspect of this study-implementation of the biology curriculum was limited only to schools in the capital due to the following reasons:

1. The Biology Curriculum, regardless of local conditions and requirements, is the same for all Senior Secondary Schools in the country.

The same textbooks and related materials are used. Thus, it was presumed that, if there is any significant variation it should be in its implementation: particularly in the effort of individual teachers to enrich their teaching.

2. The majority of biology teachers in the schools of the capital are those who have been teaching the subject for several years in the provinces. One may, therefore, reasonably expect a better teaching approach by these teachers based ^{on} one invaluable asset:

experience. In addition, these teachers also have better opportunities for enriching their teaching. Some of these are better access to various local publications of related interest, better availability of community resources and abundance of resource persons. It was, therefore, assumed that implementation of the Biology Curriculum in Schools of the Capital should not be less proper, if not more, than schools in the provinces.

1.8. Definition of Terms

1. Enquiry: The Biology Teachers' Handbook (BSCS, 1971: 21) defines enquiry as "A set of activities directed to solving an open number of related problems in which the pupil has as his principal focus a productive enterprise leading to increased understanding and application."

2. Model of Teaching: "A plan or organizational model which is used to guide the selection of objectives in the curriculum, instructional materials, environmental organization and teacher's action." (William, 1987:99).

3. Senior Secondary School: The highest level of schooling (grades 9-12) in the Ethiopian formal education system.

1.9. Method and Procedures of the Study

The following method and procedure were used in this study:

1. Evaluation of the degree to which the Curriculum emphasized student enquiry was done as follows:

1.1. A total of fifteen even-numbered units were selected from the four (grades 9-12) textbooks. The questions, practical activities and text discussion included in these units were then analyzed based on:

1.1.1. the six categories of questions classified on the basis of Bloom and co-workers categories of instructional objectives.

1.1.2. the "degree of openness" (BSCS: 1971) and the "Structured-unstructured" model (Romey: 1968) for practical activities.

1.1.3. the amount of textbook material developed following the "Narration of Enquiry" format (BSCS:1971).

2. Two methods were used in the evaluation of implementation of the Biology Curriculum:

2.1. A questionnaire consisting of 17 items and dealing with various aspects of the teaching of the subject was developed and administered to 40 randomly selected teachers.

2.2. The actual teaching-learning process in biology classrooms was observed by using a classroom observation schedule developed in order to assess the presence of an enquiry approach to biology teaching or lack of it.

3. Finally, the data from (1) and (2) above were analyzed and evaluated against the model selected.

1.10. Sampling

A two-stage simple random sampling was used to select the sample population of schools and teachers:

1. The total number of Senior Secondary Schools in each Administrative zone of Schools was first determined.

2. In each of the five Administrative zones, one school was randomly selected for the study.

3. In each selected school, two teachers from each grade were randomly selected to fill the questionnaire and were observed while conducting actual lessons.

CHAPTER TWO

2. Review of Related Literature and Research

This chapter presents review of the most significant literature and research findings related to the problem under investigation. The first part deals with ^{the} traditional approaches to science teaching, the nature of science and the process of scientific investigation; thus laying the ground for subsequent discussions. Part two attempts to show how the ideas developed in part one may be reflected in science curriculum development. Basic principles and guidelines that govern implementation of enquiry-oriented science curricula are dealt with in the last part.

2.1. The Need for Teaching Science as Enquiry

Just as when the rationale for teaching science as enquiry is based on a different view of science; the traditional approach to science teaching too, covertly or overtly, rests on another view of science. Thus, before discussing how and why the emphasis on an enquiry-mode of instruction came in to being and the rationale behind it, a brief review of the traditional or conventional approach is in order. This would help justify the need for teaching science as enquiry.

2.1.1. The Traditional Approach to Science Teaching

The conventional approach to science teaching was based

on the idea that science consists of a stable and immutable body of facts; i.e., science had been considered as consisting of a large body of knowledge which is final and absolute. The various facets of science teaching based on this premise (the role of the teacher, the textbooks, the laboratory experiences etc.) fail to convey the true nature of science.

William D. Romey (1968;4), comparing the traditional and modern approaches to science teaching observes that:

...the [traditional] teaching of science can be compared to the teaching of art. Some art schools stress the history of art, whereas others are more concerned with studio art; actual painting or sculpture. The difference between the two approaches is that one produces art historians whereas the other produces artists. The same is true to science.

What are the salient features of the traditional approach? As indicated above, in this approach, the teacher, the design of textbooks, the laboratory strategies and other accessory curricular materials all contribute to the instillment of false and misleading picture of science. At the centre of such an arrangement is the teacher who becomes a figure of authority, whose main function is to dispense knowledge. The course typically constitutes a series of lectures supported by few laboratory demonstrations which are arranged in such a way that they would fit this scheme. The student remains a passive receiver of information who is supposed to reproduce it on demand by the teacher, usually on examinations. The teacher also normally uses the textbook as the central point of focus in his teaching. Often, the textbook constitutes the sole curriculum. Thus, the text,

together with the teacher with the "know it all" attitude who explains what is left unclear, assume the roles of authorities.

Moreover, textbooks in traditional science courses are designed to serve this scheme. Most textbooks to a large degree contain scientific conclusions with few supporting data and references to the original scientific work that led to the conclusions. In addition, the conclusions consist "mainly or wholly of unqualified, positive statements such as" organ A is composed of three tissues," "Respiration takes in the following steps," (BSCS, 1971:22). According to the BSCS, this kind of exposition - called a "rhetoric of conclusions" - has long been the standard rhetoric of textbooks even at the college level. A teacher who strictly adheres to such a textbook and follows it chapter by chapter or question by question leads students to think that science comes from the textbook and the teacher, rather than from observation, experimentation, data analysis and conclusions (Romey, 1968:41). This is because such textbooks divorce the conclusions of science from the data and the conceptual frames that give conclusions their meaning. That is why the student learns, as a consequence, a lesson we never intended to teach. Elaborating further on the harmful effects of teaching science as a "rhetoric of conclusions", the BSCS, (1971:333) states that :

a rhetoric of conclusions has two unfortunate side effects on the student. First, it gives the impression that science consists of fixed, unalterable truths...second, it tends to convey the impression that science is complete. Hence the fact that scientific investigation still goes

on at an ever accelerating rate is left unaccounted for to the student.

Another major defect of this anachronistic approach to science teaching is the way the laboratory is used. The laboratory is commonly considered as a place where students prove the facts and principles presented by the teacher and the text. In other words, the laboratory is often seen as an extension of the formal lecture session where the student performs observations and descriptions of biological phenomena to confirm facts and principles stated by the teacher and text. Although this type of laboratory exercise is still useful, its virtual use has great disadvantages. This illustrative arrangement of laboratory activities does not give the opportunity for the student to formulate and test hypotheses, carefully carry out graded, controlled experiments and generally to become aware of the various processes used by scientists in purposeful laboratory investigations. In short, laboratory work is not organized in such a way that it conveys a sense of science as enquiry.

In summary, the most important drawback of the traditional approach to science teaching is that it fails to recognize and take fully into account the close organic connection between process and content in science. For instance, while it teaches that "vaccines prevent disease," it fails to show why and how it does so. But it is the "how" and the "why" that constitute science. Thus, until curriculum developers and teachers of science thoroughly understand just how enquiry is conducted in the sciences, not much progress towards the teaching of science as enquiry can be expected.

2.1.2. The Process of Scientific Enquiry

Much of the controversy over the use of enquiry teaching stems from a fundamental lack of understanding as to the meaning of "teaching science as enquiry"; as distinguished from enquiry in general. One who is sufficiently familiar with the educational literature on teaching methods and techniques will recognize the lack of consistency in the use of terms or phrases that characterize a given instructional procedure. Most educators emphasize, in contrast to teaching approaches that promote the rote memorization of facts, that teaching should focus on the development of "scientific attitude," "problem-solving ability," "enquiry skills," "discovery skills" etc. In most cases, these various phrases are interchangeably used to refer to the same instructional procedure. Such variations blur the basic assumptions on which a teaching strategy might be based. Some authors such as Dean and Mills (1965:4), use problem - solving as being inclusive of all the others. Others consider "problem - solving," "discovery," and "enquiry" approaches as being the same (Skowronek, 1975:77; Maglathery, 1972: 26). Maglathery, for instance, writes that "this mode of instruction [discovery] focused on equipping the student with tools for problem solving and has been known by such names as enquiry teaching, discovery teaching and problem - solving" (Ibid).

Plowden (in Foster, 1972:5) views discovery learning as resulting from:

initial curiosity, often stimulated by the environment the teacher provides, leading to question and to a consideration of what questions it is essential to ask and how to find the answer...

essential elements are enquiry, exploration and firsthand experience.

Note that in this definition enquiry is given as one of the essential conditions for discovery. In contrast to this, Gagne (in Leaner and Victor, 1971:417) views enquiry as the "terminal capability" the learner is supposed to acquire; discovery being a means to this end: "... the construction of a response by the learner, something that happens every step of the way in the process of learning, is what usually has been called discovery."

The importance of this discussion is not, of course, to call to the attention of the reader the existence of such discrepancies or inconsistencies but to show that, inspite of the differences in terminology, most of these approaches have a similar objective as their intent: that teaching should help students become independent/autonomous searchers of knowledge by equipping them with a mode of enquiry.

The next question, however, is how could this general objective be achieved in science teaching. An added complication arises when we use the phrase "teaching science as enquiry". Joseph J. Shwab, in a book bearing the same title, discusses the meaning contained in the above phrase. According to him, the phrase "teaching science as enquiry" is ambiguous in that it contains two distinct elements (1962:64):

It means, first, a process of teaching and learning which is, itself, an enquiry, "Teaching as enquiry". It means, second, instruction in which science is seen as a process of enquiry, "science as enquiry".

Schwab, elaborating on this, states that the ambiguity embedded in the phrase is deliberate. Both aspects of the approach, he argues, are essential to the attainment of the objective (Ibid):

Both of these meanings are part of the idea in its complete form. The complete enquiring classroom would have two aspects. On the one hand its materials would exhibit science as enquiry... on the other hand the student would be led to enquire into these materials. He would learn to identify their component parts, detect the relations among them, note the role played by each part, detect some of the strengths and weaknesses of the enquiry under study. In short the classroom would engage in an enquiry into enquiry.

Rutherford (in Romey, 1968:265), addressing the question of the distinction between enquiry as content Vs as pedagogic technique in an article entitled "The Teaching of Science as Enquiry" holds a different view. He asserts that "it is possible to learn something of science as enquiry without the learning process itself having to follow the method of "teaching as enquiry" or "enquiry as technique" " The argument is based on his premise that "the concepts of science are properly understood only in the context of how they were arrived at and of what further enquiry they initiated" (Ibid). He understood "enquiry as technique" to mean cases where the student is expected to conduct an investigation to learn about scientific enquiry at first hand rather than vicariously; i.e., the phrase to him is tied to student practical activity. It is this view that led critics to doubt the feasibility of enquiry based approach to science teaching. Notably Ausbel, who has been the most outspoken critic of it, attacks it on

psychological, developmental and practical points of view (in N.Nelson, 1969:260; UNESCO,1966:265 -79).__

Much of the controversy would subside if one acknowledges, as Rutherford strongly suggests, that scientific enquiry is part of scientific knowledge. He holds that "there is a pattern of enquiry characteristic of a given science and that such patterns form what "science" is (Ibid). Connely also, using ecology as an example, convincingly argues how enquiry specific to a given scientific discipline is part of its content (1982:283):

... the resulting forms of knowledge [of ecological research] - the principles of enquiry - are forms of knowledge as experienced. This follows from the fact that the research papers are the recorded experience of people operating on subject - matter to achieve knowledge and understanding. Thus, the principles of enquiry are at once forms of knowledge and forms of experience ... the forms for the research study of ecology and for the logical reasoning required of the student of ecology are one and the same.

In Chapter One of this study, it has been stated that the basic assumption of the model investigated is that an understanding of biological enquiry is so crucial for an understanding of the subject; as these are inseparable, organically linked. The above discussion, therefore, might have helped substantiate the basic assumption or premise.

In conclusion, it is evident that enquiry could be seen at two levels. One is organically linked to scientific content - enquiry specific to a given scientific discipline and indispensable if it is to be understood by students of the discipline. In other words, its isolation either in

curriculum development or teaching would only lead to a superficial understanding of the discipline or, as Rutherford puts it, to the "understanding of neither scientific content nor scientific enquiry". The other - enquiry as an approach to teaching - is a general strategy and could be used in the teaching of other disciplines too. The concern here is with the former type: what actually constitutes scientific enquiry and how could it be used in the teaching of science?

2.1.3. The Nature of Science and the Scientific Method

Scientists and science educators believe that the traditional approach to science teaching is the very antithesis of true science. Again, it had been reiterated that the defects in contemporary science teaching stem from the failure to base it on the nature of science. Thus, if this is to be rectified, the springboard for any science teaching programme should be a detailed examination of what science really is.

The attempt to define science per se is usually difficult. Most attempts to do so are made in terms of what scientists do or based on individuals intuitive judgement of what the business of science is or should be. When science is defined in terms of "what scientists do", it leads to such words as scientists "describe," "explain," "classify," "predict" etc. It has also been defined in terms of what it should accomplish: the business of science is "the establishment of general principles for their prediction and

provision of a system of concepts that assist in their explanation" (Robinson; in Romey, 1968:271). Anderson, on the other hand, defines science as "a process of analyzing experiences to create models of reality as a way of explaining, predicting, and further exploring empirical evidences." (1971:88).

These slight variations in definitions, more in phraseology rather than out of a fundamental difference in understanding, need not bother us so much as finding a working concept on which to base a strategy for science teaching. The model investigated in this study had been developed based on the research methodology or discipline base of biology. It is therefore necessary to note that the review which follows is in essence an elaborated discussion of the background of the model.

2.1.4. Science as Process and Product

A science teaching strategy, as noted earlier, which is not based on its true nature is bound to fail. The search for such a strategy becomes easier and clear if, as Paul F. Brandenwein (1962, 122) notes, we regard science "not merely as a body of information about the world but also as a way of learning more about the world;" i.e., as a body of knowledge and as a way of thinking and investigating. In other words, very few, if any, scientists and science educators would disagree on the view that science is both a "process and

product". Anderson (in Leaner and Victor, 1971: 212) succinctly puts the idea as follows:

The products of science refer to the body of scientific knowledge that accrues from scientific investigation while the processes of science refer to the means of investigation by which the body of knowledge is acquired.

This complementarity of process and product in science leads to the discovery of new knowledge about the universe and the refinement of old and defective knowledge. The two aspects are inseparable, two faces of the same coin.

A related concept to the process-product dichotomy in science is what is called the "structure of science". Like any other field of study science has its own domain in which it operates. This operation is guided by a mode of enquiry specific to the discipline (which might rightly be called the processes) which in turn produces major generalizations (theories, laws etc.) The major generalizations again give focus to the mode of enquiry. This reciprocity thus becomes the framework into which the student of the discipline fits, interprets and evaluates new and existing knowledge. It is to this processes that writers designate the phrase "structure of science" J.D. Novack (in Romey, 1968:122) defines structure of science as " the system of major generalizations or concepts together with the process by which these concepts are obtained and enlarged." Robinson (in Romey,1968:156) uses "structure of science" as being synonymous with "nature" of science. Structure of science is thus, according to the above definition, broader and more inclusive than the dichotomy of

science as process and product. The "major generalizations" or "concepts" referred to above are also known as "conceptual schemes," "themes," etc. Based on this conception of the structure of science the American Association for the Advancement of science (AAAS) had proposed seven conceptual schemes which served as a fabric for the production of curricular materials.

Now, what constitutes the scientific process of investigation or as popularly known the "scientific method" on which to base the design of curricular materials and classroom teaching? As Brandenwein writes (1962:103), "unless we have a clear understanding of the processes in the sense that scientists and students of the scientists way know it, it is unlikely that science will be experienced by young boys and girls." Thus, we shall consider in some detail the processes or "steps" involved in scientific investigation. However, it should be remembered that:

- 1) the process of scientific investigation does not necessarily follow rigidly the steps outlined below.
- 2) there are attitudes that very much influence scientific enquiry, and
- 3) general knowledge and knowledge about the nature of knowledge are crucial for successful enquiry.

2.1.5. Enquiry Factors in Science

The effort to systematize the way of the scientist and apply it in the teaching of science has produced ample

literature. This has generally been known as the "scientific method". However, whereas the disagreement as to what this phrase refers to is minimal, there seems to be much heedlessness and oversight when it comes to applying it in the teaching-learning process. Emphasizing this point Blaydes and Miller (1966:13 - 14) write that:

... many do not fully realize the significance of this expression at least to the point where it can be applied to a method of teaching... one must first decide what elements of the scientific method can be made of specific pedagogical value. After this has been done it is necessary to modify the curriculum so as to permit the free application of these elements in the attack upon subject-matter.

The steps involved in scientific investigation as used by scientists are more complex. In fact one of the commonest errors committed in the attempt to base the teaching of science on its nature had been the reduction of the process involved into rigid and fixed steps. The processes involved in scientific investigation do not occur in a tight, logical progression. It becomes so, according to Brandenwein, only in the scientists reporting of his contributions or findings; i.e., a simple and naive presentation of the " way of the scientist" often confuses "the scientists concise report of his work with the manner of his work" (1962:115). Curriculum developers who loose sight of this may produce textbooks that

reduce the scientific process of investigation to a few statements of procedure. The idea of the existence of any single, definable scientific method has been questioned and viewed as a gross oversimplification and distortion of the methods of scientific enquiry. Such a depiction is misleading, in that, "the role of theory, various methods of problem-solving, intuitive judgement and creative thinking are neglected" (Anderson, 1971:10). It does not also show the role of chance in science (accident in enquiry); a classic example being the accidental discovery of Penicillin.

It is therefore necessary that these facts be borne in mind both in curriculum development and teaching if a success in inculcating a conception of what science is about, how science works, and what the real character of the scientific enterprise is to be achieved. Bearing this in mind, the significant steps involved in the process of scientific enquiry could, for purposes of brevity, be viewed as constituting the following: recognizing and formulating a problem, formulating hypotheses, designing an experiment, and interpretation of data and findings. Subsequent pages elaborate each element.

2.1.5.1. Recognizing and Formulating a Problem

The first step in the process of scientific enquiry is the recognition of the existence of a problem and a desire to solve it. Though teacher-posed problems may usually serve as the springboard of enquiry to students; one may, however, ask

how do they arise? As stated in the BSCS (1971:168):

Scientific problems arise from contradictions, inconsistencies, incoherencies or blank spaces created by bringing our principles of enquiry and other assumptions into connection with already garnered knowledge.

It is when such a "dissonant," "unsettled," or "discordant" situation is created that we say enquiry has commenced. As the above quotation shows, previous knowledge plays a crucial role in the creation of that indispensable "general wonderment". Though there are certain other factors that favour quick recognition of a problem by one person than another; in science, careful observation of the environment is important to recognize problems. However, the realization of this general wonderment alone is not sufficient. After being aware of a problem, as Barry K. Beyer (1971:22) observes, one has to make the "task explicit, to define it in manageable terms and set the limits of the quest ... one cannot enquire successfully unless he has a fairly accurate idea of what he is working for or what he needs to know." This means a general curiosity, which is itself necessary for enquiry to commence, should be converted into a specific enquiry. A generally stated problem does not indicate where and how to look for an answer:

A general "wonderment" is converted into an immediately useful problem when the question is made sufficiently specific to suggest an experiment to be performed or specific data to be sought. (BSCS:172)

For instance, the problem "under what conditions do seeds germinate?" is stated in general terms as compared to "will

seeds germinate with or without light?" The later is an immediately useful scientific problem because it points clearly to what data are required. What the investigator has to do is to compare germination in the light with germination in the dark.

The problem posed in an enquiry, if it is stated in sufficiently specific terms, also serves another purpose. Its primary use, as stated above, is that it makes possible the design of the experiment and thus the conversion of the wonder into a plan of attack. Secondly, a specifically stated problem guides us in interpreting the data. If stated generally, that would mean we are proceeding without a clear idea of what problem led to the particular body of data being dealt with. Thus, a problem stated in manageable and specific terms makes the interpretation easier (Ibid)

2.1.5.2. Formulating Hypotheses

Once a problem has been recognized and stated in specific terms, the next step in scientific enquiry is establishing all available facts concerning the problem, which involves the accumulation of data. The investigator, then, constructs, on the basis of these facts, hypotheses which are logical explanations of the parts of the original problem.

Hypotheses could simply be defined as tentative answers to problems or questions that can be investigated. Hypotheses serve as devices based on which experiments could be designed. Thus, just as an investigator can propose hypotheses based on

available data, it is also possible that he uses hypotheses to generate new data through controlled experiments.

It is worth mentioning here that in biology "not all investigations have stated or even implied hypotheses; this is most likely to be the case in studies conducted in taxonomic mode"(Ibid). Thus, depicting the process of scientific investigation as consisting of sequential and logical steps is even more misleading in that it implies scientific investigations are all of the controlled experiment type. As Anderson (1972:89) points out:

Descriptive studies, such as those performed in natural history and some ecological field studies, are clearly scientific in their orderly search for empirical evidence and their creative analysis of data.... The use of descriptive techniques and creative interpretations of data based on rational judgement should also be recognized as part of scientific investigation.

In most cases, however, hypotheses should be formulated based on incomplete evidence / fragmented data about the problem so as to guide the enquirer in designing an experiment to "prove" or "disprove" it. Indeed, as Harold Steel (1975:35) observes, "hypotheses or "educated guesses" concerning the causes or relationships of phenomena underlie the structure of all experiments."

There are two types of hypotheses that are commonly used in science (BSCS,1971:195 - 207). These are the "glass-box" and "black-box" types of hypotheses. In the former type, which is the most common one, what is hypothesized is something that, at least in great part, can be seen; that is, it is open to direct examination. In the later type, "we

conceive of an underlying mechanism inaccessible to direct observation to account for - give coherence to-a wide variety of visible behaviour... this type of hypothesis cannot, by definition, be verified "directly". Instead we seek necessary implications of the hypothesis."

The most important usefulness of a hypothesis in science is that it indicates how one may proceed to test it experimentally. In both the two types of hypotheses described above the same logical form precedes and guides the experimental test of its value. This is the "If...then..." logical linkage which tells us what data to look for (Ibid,208;Bayer,1971:45). This linkage serves as an arrow by thinking of a situation which will provide positive results if the hypothesis is a "good" one and contradictory results if the hypothesis is a "bad" one. That is why we say hypotheses stated in the "If...then..." logic guide a scientific investigator toward an experiment that would test it. If the hypothesis formulated by an investigator is a "good " one, then the consequences implied in it should happen when the experiment is carried out. If otherwise, another hypothesis could be formulated and the cycle begins again.

In hypotheses stated in the "If...then..." logic, the "If..." is followed by the hypothesis, and the "then..." is followed by the consequences we expect.

It should be pointed out here that hypotheses that have proved to be false could have their own contributions to the advancement of scientific knowledge; for such hypotheses could stimulate a stream of fresh enquiries as to why the contrary

to what had been expected happened. A classic example of a false hypothesis but which produced astonishing results is found in one of Claude Bernard's experiments. He thought that the function of the liver is controlled by the vagus nerve. He then proposed this hypothesis: If the vagus nerve controls the function of the liver, then its damage would result in stoppage or reduction of the glycogenic function of the liver. He then punctured the region of this nerve in experimental animals. But he found that the glycogenic function of the liver was greatly increased, elevating the amount of blood sugar to such an extent that sugar appeared in the urine. We can thus see that, while the experiment disproved the hypothesis, Bernard inadvertently produced diabetes. This illustrates that a discovery or finding contrary to what the hypothesis suggested could indeed lead to fresh and important knowledge.

Hypotheses that hold true under several circumstances could be elevated to the status of theory or even law. In summary, after the recognition of the existence of a problem and its statement in specific terms, the question of "what data to want" (to look for) is solved by the hypothesis. The next step is obtaining the "wanted data". For this purpose, the planned and controlled experiment is the best course; though it does not hold true to all problems in biology.

2.1.5.3. Designing an Experiment

An experiment is the means, par excellence, for obtaining

specified, wanted data. Data are "selected facts" in that only those facts which will answer the question about the problem are recorded. In short, data are the recorded facts, the raw materials, from which we try to derive an answer to a question, a solution to a problem. This is best accomplished, as stated above, through experimentation, Fleibleman (1978: 113 -114) defines an experiment as:

a deliberate action undertaken in order to infer with phenomena in such a way as to compel a decision concerning an hypothesis...by means of experiment a proposed generalization is confronted with the evidence and this requires observations under controlled conditions, where the investigator anticipates there will be a certain conclusion reached, quite irrespective of whether it turns out to be positive or negative.

Thus, we say a student is experimenting when he/she tests a hypothesis under controlled conditions. There are certain concepts in experimentation of which teachers themselves should be aware and help their students grasp them. These, in general, constitute the problem of obtaining wanted data. Some of these, as stated in the Biology Teachers' Handbook (BSCS, 1971:150) include:

1. the existence of error and that it can be reduced but not eliminated.
2. that as many variables as possible should be identified in a problem and a selected one studied;
3. the difficulty of carrying out the plan of an experiment...;
4. that one experiment can rarely, if ever, prove a scientific statement;
- and 5. the need for replication.

2.1.5.3.1. The Idea of Experimental Control

Though there are numerous problems in science that do not require controlled experimentation, many science teachers

prefer to limit the term "experiment" to the type of investigation known as the "controlled experiment" (Steel, 1975:37). A controlled experiment is an experiment in which all factors are kept constant except the one under investigation (Fibleman 1978:308). Experiments in which control groups are used are quite common in biology. In the use of a control group the specimens to be examined are divided into two groups which are equal in all respects, and one is disturbed by the introduction of an extraneous element which is the independent variable. The control group is the one left undisturbed, while an experiment is conducted on the other. The effects of the disturbance are observed by a comparison of the two groups. The choice of the condition to be varied while the others are kept constant is not inherent in the nature of the specimens but is made by the investigator in terms of some hypothesis he wishes to test (Ibid).

2.1.5.4. Interpreting the Data or Findings

The next step in this process brings us to interpretation of the data and drawing conclusions. This step, temporarily, winds up the process of investigation and thus leads to the acceptance, modification or rejection of the hypotheses[?] formulated at the beginning of the study.

During the act of interpreting the data and drawing conclusions, the student learns to use reasoning skills such as deduction (arriving at a particular implication from a generalization), induction (arriving at a generalization from

the evidence or arriving at an interpretation by reasoning from evidence).

The student also learns to analyze (identify component parts, interactions and relationships among the data), synthesize, extrapolate etc. Above all the student will examine his data to determine its relevance to both the problem and hypothesis at hand.

2.2. Curricular Requirements for Teaching Science as Enquiry

Curriculum development in science, or any other discipline for that matter, should be based on a philosophy or theoretical framework. The attempt made in the previous section was to set this framework. If the objectives of teaching "science as enquiry" are to be achieved, the curriculum thus developed should give ample provisions for it. This means the content selected, its organization and the teaching strategies should favour active student engagement in enquiry processes.

This section by no means attempts to give a detailed discussion of the process involved in the development of a science curriculum suited for enquiry teaching. Rather, its major aim is to cite some general guidelines that should be borne in mind by curriculum developers and implementers as well. These include criteria for content selection, organization of enquiry textbooks and the role of the laboratory.

2.2.1. Content Selection

One of the most significant world-wide trends in content selection has been what Meyer (1969:2) calls "a reduction in detailed factual knowledge and an emphasis on broad principles and concepts." This trend has been a result of, at least, two major factors. The first and most important one is the astonishing rate of accumulation of biological knowledge - the so called "revolution in biology" - which led to a huge gap between the contemporary line of scientific enquiry on the one hand and the science curriculum on the other. For instance, it has been estimated that "there will be a 100 times as much biology to "cover" in the introductory course by the year 2000 as at the beginning of the century" (Barthelemy, 1969:2); or, according to a similar estimation, "the issue of Biological Abstracts for the year 2000 will be about 100 feet thick if in the same format as now" (Meyer, 1969:22). As a result of this change, the evolution of the biology curriculum has been towered a highly selective approach in content which combined the most profound achievements of the old biology and the new one. The second reason for the shift in emphasis is the change in the field of biology itself. Biology has changed from a relatively descriptive field to a field in which the invention of concepts and conceptual structures in taking a progressively more important role (BSCS, 1971:333; J. Drobnik, 1966:211). Because of this change, according to the BSCS (Ibid):

the significance of the products of biological research - the meaning of information that has accrued from biological investigations becomes more and more dependent on a grasp of the processes of biological science, the ways (both technological and intellectual) in which the body of biological information has been attained. The word enquiry has been used by the BSCS to designate this process.

It is evident, then, that the rate at which biological knowledge accumulates has had a tremendous impact on the conceptual framework of the discipline which in turn shaped the direction to which the modern biology curriculum developed.

Before citing modern criteria that govern content selection, it is worth mentioning some of the earlier forms of curricula in biology. According to Hurd (1961:183) there were two major approaches to the selection of course content in biology:

1. The use of "objective" procedures to isolate the knowledge according to an assumed criteria (e.s. frequency of biological items in the public press) and
2. the establishment of certain philosophical assumptions which may serve as a unifying theme (e.g. meeting the personal - social needs of young people).

Blaydes and Miller (1962:32 - 34), based on a related classification, also discuss the three most important types of courses that were dominant in early biology curriculum development. The first they mention is the "Morphological or Types course...in which subject-matter is centred around the study of types of plants and animals arranged usually in phylogenetic sequence." The student is made to study representative species (type forms) of the major groups. The

primary emphasis of this course had been an understanding of morphology and taxonomy. The second type is what they called the "Civic or Economic course". This course came into being as a result of the theoretical ideal "education for citizenship". A distinct advantage of such courses had been their minimization of the domination of the morphological course plan and their practical importance to the majority of school leavers who received no further training in the field. These courses, in time, gave way to a third type of course which used a radical approach in content selection. This type, which they called the "principles course", appeared when the importance of understanding the discipline using the opinion of leading scientists gained increasing popularity and acceptance. In other words, this course could be considered a response to the trends outlined above. As a result, the idea that course content should be selected in terms of the significant principles of science gained firm ground. This is, perhaps, the single most important guideline or principle that governs content selection in biology today. Hurd (1961:189) believes that this tendency was an effort to "direct science teaching toward the larger ideas of science expressed as principles or generalizations, and away from an inventory of discrete facts."

This tendency for basing course content on the major principles or generalizations, besides the reasons mentioned above, has tremendous support from studies in psychology too. Ausbel, for instance, who developed the concept of an "Advance Organizer" has shown that understanding and retention of

earning is increased when learning is based on broad concepts and principles (in Anderson, 1971:23). Hilda Taba (in Nelson, 1969:145), criticizing popular teaching - learning procedures, writes that teaching should help students search for "generalizations with which to organize the needed facts and to plan an attack on them". Reinforcing this, Brandenwein (1962:123) also writes that "there is a need to develop curricular frameworks around the major conceptual schemes presently acknowledged in science so that children's questions can lead to sustained enquiry." These broad scientific principles had been known by such names as "conceptual schemes," (National Science Foundation) "Themes," (BSCS) and "Leading Ideas of Biology" (The New Soviet Biology Curriculum).

McInerny (1987:25) elaborates the use of this basic guideline for selecting content in the field of biology. This guideline, or criterion as he calls it; and which has been used by the BSCS in the development of new or revision of existing curricula, is "how well does the information in question illustrate the basic enduring principles of biology?" A careful attention to this question, according to him, saves curriculum developers from the mistake of "incorporating into curriculum new information simply because it is new, absent of

any justification for how it helps students understand major concepts." (Ibid). Further illustrating this point McInerney (Ibid) writes:

One might, in a chapter on genetics, list the human genes that have been mapped most recently to highly localized regions of specific chromosomes. For the average student, however, that is useless information unless it is discussed in the broader context of a major unifying concept such as genetic continuity or applied to a particular problem that has social or personal utility such as the use of gene mapping in the prenatal diagnosis of genetic disorders.

Intentional or unintentional neglect of this guideline or the involvement of "curriculum developers, advisors and writers who do not understand thoroughly the major organizing principles of the discipline" might lead toward production of "encyclopedic, vocabulary laden textbooks" (Ibid). Although the major concepts or organizing principles referred to above appear under different names, their objective is the same: to base the teaching of biology on its major organizing conceptions and theories.¹⁴

The developers of the New Soviet Biology Curriculum, for instance, believe that identification of what they called "leading ideas of biology," (comparable to the "themes" of BSCS) "supplied the basis upon which to select the content of school biology education and to define academic consistency" (Miagkova and Sivoglazove, 1986:69 -70). What makes BSCS approach a bit different is that, besides identifying the "themes" which guided the selection of content, it has also identified the "themes" that defined the structure of the

course thus developed. According to BSCS experts, the first eight themes define the content of modern biology, and the ninth and tenth themes - "science as enquiry" and "history of biological concepts" - defined the "logical structure" of its textbooks. This means, as the developers put it, these two "themes" constitute "the context of data and inference through which their content (of textbooks) is conveyed" (BSCS,1971:14). Thus, the organizational structure of biology curriculum was derived from the structure of the discipline itself and from the process by which biologists conduct research. This is perfectly in keeping with the conviction that science education should be organized on the knowledge base of the discipline and that enquiry-oriented instruction should help students to think and solve problems the way scientists do. This is also the basic premise of the Biological Science Enquiry Model.

What has been said above might perhaps be put in few statements if we summarize it by Shomansky's definition of "new science curricula" (in McInerny,1987:28). He defines new science curricula as programmes which:

- 1) emphasize the nature, structure and processes of science,;
- 2) integrate laboratory activities into course discussion; and
- 3) emphasize higher cognitive skills and an appreciation and understanding of the nature of science.

Having seen the most important trends and the guidelines for developing an enquiry-oriented science curriculum, it is now time to consider how these ideas could be expressed in

various curricular materials. As the textbook is the basic tool of instruction in the secondary school curriculum, it would be appropriate to begin by considering the most important features of a textbook best suited for enquiry teaching.

2.2.2. Enquiry Textbooks

In the discussion of the traditional approach to science teaching, it has been pointed out that the textbooks used consisted mainly or wholly of conclusions/ unqualified statements. The uncertainties built into scientific conclusions remain unaccounted for to the student. Moreover, many of the conclusions treated in such textbooks are frequently outmoded ones which have been replaced by more encompassing conceptions. More importantly, it does not show that scientific knowledge arises from problem posed, planned observations and experiments.

The text we envisage to be suitable for enquiry-oriented instruction should, however, make a radical shift in its presentation of textbook content. The most significant ones are outline below.

Replacing "Rhetoric of conclusions" with a "Narration of Enquiry ": Narration of enquiry involves a step by step description of the enquiry factors involved before a given data is converted into scientific knowledge. Students' ideas on more recent biological subjects such as genetics are best developed in this manner. Thus, whenever possible, textbooks should describe the problem posed in an investigation, the

experiments performed, the data obtained and the interpretations made of them. Depending on the nature of the topic under discussion, whole chapters or major sections of chapters could be developed in this way. Narration of enquiry, however, doesn't lend itself to all topics in biology; especially to those of the descriptive or classificatory fields.

Lal and Johry (in UNESCO - 1969:297) suggest that the most important biological discoveries should be "dealt within a historical perspective to give an idea of how science progresses." Thus, the degree to which a textbook cites prominent scientists who made landmark contributions to the advancement of the discipline could be taken as one of the indices of its shift away from an inventory of discrete facts and conclusions. Traditional textbooks written as compendiums of biological information could, however, serve as educational instruments to the conscientious teacher ; i.e., in so far as the book doesn't determine the method of procedure, the teacher could extract meta-lessons suited for enquiry teaching.

Inserting a "doubt component" in Textbook Exposition: This includes inserting statements and paragraphs showing the uncertainty of knowledge. An enquiry science textbook should include a fair treatment of the doubts and incompleteness of science and indicate the possibility that through the advance of enquiry scientific knowledge can change. Shwab (1962:60) succinctly states the need for such kind of material:

The first component of an adequately enquiring curriculum is the injection into text material and classroom procedure of a substantial component of doubt. I have in mind nothing more than the honest statement of ignorance, uncertainty, and dubiety, where these conditions are, in fact, the conditions of our knowledge.... Each chapter must bear its share of the burden of doubt and ignorance of concrete, important matters.

Giving a "Human Side" to Enquiry: According to Meyer (1969:15) one of the recent trends in modern science teaching had been a development of an understanding of scientists as people with real human problems, difficulties, joys and successes. However, much of the earlier science teaching had been faulty in that it had been impersonal and dehumanized. Drawing up on important biological material together with the people, as indicated above, helps to achieve this objective. When using such a historical approach it is essential to acquaint the students with the way that scientific discoveries are made, the contradictions that arose and were resolved in the process, the influence exercised by society upon the development of science, and above all the contributions made by eminent scientists to the storehouse of scientific knowledge. Students should be helped to understand that there is a human side to enquiry, that discoveries are made by humans; that, just like other individuals, scientists could make errors and that part of science had indeed been concerned with the correction of error.

Textbooks that contain a sufficient amount of narration of enquiry in which the material describes research in terms of the persons, the places, and the incidents involved have a

crucial role to play in the correction of students attitude. The BSCS underscores that such an approach conveys to students (1971:23):

a realistic and understandable view of science and scientists. They can help to mitigate the extraordinarily unreal, antagonistic and fantastic view of science and scientists which repeated studies show to have grown in the minds of many persons.

d) Using Questions in the Text as Challenges to the Student: Traditional textbooks usually have a rigid plan of presenting information. Facts establishing the proof of a conclusion or theory followed by suggested demonstrations/experiments and review questions often constitute the plan. It is also not unusual to find the questions/problems posed answered there by the text. In such cases, obviously, the student misses the training which he should get in problem-solving and enquiry. Blaydes and Millers (1966:41) suggestion would probably serve to summarize this point:

...Questions, especially problematic questions, belong at the beginning of a study. The student should be made to feel that there is an interesting problem ahead, the solving of which is a fascinating procedure as well as a worthy accomplishment.

2.2.3. The Enquiry Laboratory

Modern science curricula place a premium on laboratory and field work as central to the teaching of science. The idea that science is best learnt by doing it is not controversial. Indeed, science teaching can by no means be

properly accomplished by merely telling students about science. Doing science involves giving students the opportunity to find and discover relationships among facts, materials and events; to put them in their own way and come up with their own conclusions and generalizations. The most important means for the achievement of this goal is through investigations, observation and experimentation.

It is during investigations that the student explores ideas, tests hypotheses and raises questions. It is during laboratory and field work that the student begins to understand the frustrations as well as the achievements of scientific investigations. He/she also learns that it is the interpretations of the data generated during investigations that produce the conclusions of science, and that it is this interpretation and conclusion that challenges older scientific knowledge and raises new questions that lead to further enquiry.

Due to these reasons, the general direction of modern biology laboratory exercises has been toward greater emphasis on enquiry or open-ended experience and minimal use of confirmatory or illustrative laboratory sessions.

However, using the laboratory toward these ends necessitates a radical departure from its role in traditional science courses. According to Schwab (1962:152 - 155), there are two fundamental changes that should be made if the laboratory is to be converted from the dogmatic to the enquiry mode. The first change is that a substantial part of the laboratory work is made to lead rather than lag behind the

classroom phase of instruction. This means changing it from its traditional role of illustration of conclusions to illustration of problem situations. The former serves the traditional purpose of making clear material expounded in class or the textbook, thus making it incongruous to the objectives of teaching science as enquiry. If the student is really to understand the nature of the scientific process, ample opportunity for active participation in that process should be provided for. This means the student must investigate enough problems for which he/she doesn't know the answer.

As stated before, classroom teaching itself has to follow an enquiry mode; i.e., it should deal with the statement of a scientific problem, present the data needed for its solution, provide an account of the interpretation of these data and the conclusions drawn from them. But this alone will not convey the real flavour of scientific enquiry in that it doesn't show the difficulties and frustrations involved in such a process. It is in view of providing this experience that we say the laboratory should provide a tangible experience of some of the problems dealt with in science. This discussion brings us to the conclusion that laboratory exercises in which the student is told what to do and what to expect, as found in many cook-book fashion laboratory manuals, will not lead to a meaningful understanding of the process of scientific enquiry. Such laboratory activities, in which the student is given "instructions that lead him through a procedure designed to produce certain specified results" are called structured

activities (Romey, 1968:22). While such activities are beneficial for students initial experience, more open-ended (unstructured) activities should be provided for.

According to Romey, science topics should be introduced in the laboratory whenever possible; and that other activities (lecture, discussion, reading) should be outgrowths of the problem introduced in the laboratory. He also suggests a rough procedure by which effective laboratory activities may be set up (Ibid):

1. Pose a problem;
2. Establish an experiment design aimed at solving the problem;
3. Have students gather data related to solution of the problem;
4. Have students graph, study and interpret their data;
5. Have students generalize on the base of the data;
6. Proceed to a group discussion of the meaning and limitation of the data, the relationship of the data to other problems, and related readings in a textbook (or other references) which may reinforce and augment the student personal experience.

If the nature of the topic under discussion or study is such that it doesn't lend itself to experimental procedure (as often happens in biology) and only observation is necessary, we still have to pose problems-observational this time rather than experimental, and ask the student to gather and interpret data. In summary, what should be stressed in laboratory work is the need for enabling the student to actually experience, on a somewhat reduced level, the various procedures used by scientists in scientific research.

2.3. Implementing an Enquiry Science Curriculum

In the preceding section, it has been stressed that the science curriculum should provide ample opportunities for the development of enquiry processes in students. That is, the textbooks, the laboratory experiences and other accessory curricular materials should convey a "sense of science as a process of enquiry". However, this alone by no means guarantees proper implementation and the attainment of stated objectives.

Factors that influence proper implementation of the curriculum designed are diverse. Some of these are availability of curricular materials in sufficient quantities, teachers capability and willingness to use the materials and willingness of the educational and other concerned authorities to support the programme financially and otherwise. The concern here, however, is with one of these factors concerning the teacher. That is, the question that will be dealt with in this section is what Beyer (1971:122) succinctly asks: "What can we as teachers do to facilitate enquiry in the classroom, and how can we "bring it off?" What should our strategy be, and what techniques can we use to make it work?" The role of the teacher in using the model investigated in this study is explicitly stated in one of its components: "principles of reaction":

The teacher's task is to nurture the enquiry, emphasizing the process of enquiry and inducing students to reflect on it. He or she has to be careful that the identification of facts doesn't become the central issue and should encourage a good level of rigor in the enquiry. The instructor's task is to turn the students toward the generation of hypotheses, interpretation of data, and the

development of constructs, which are seen as emergent ways of interpreting reality (Joice and Weil, 1986:139).

Before discussing specific competencies (strategies, techniques, styles) that an enquiry teacher should possess in order to fulfil the tasks mentioned above, it would be appropriate to rephrase the major premise upon which a reorientation in methods and techniques is to be based. It has been stated that the major objective of teaching science as enquiry is to help students develop the competencies and habits related to enquiry processes; since these processes are the key to understanding the nature of science. It also aims at the development of the ability to carry on self-directed learning and to the development of thinking. The attainment of these objectives, therefore, necessitates a radical shift from the conventional approach to teaching science. Eagleston (in Bennet and McNamara, 1979:83) contends that "enquiry approaches to learning science, compared to more didactic approaches, demand different kinds of engagements between the minds of teacher and taught." Schwab (1962:66), reinforcing Eaglestone's view, also writes that "...an enquiry classroom requires teaching and learning skills which are not the common habits of our schools. Its aim is not only the clarification and inculcation of a body of knowledge but the encouragement and guidance of a process of discovery on the part of the students."

Two major conclusions could be drawn from the foregoing discussion:

- 1) Science teachers committed to or intending to use the

enquiry approach should above all have a thorough understanding of the operations of scientific enquiry.

2) In addition to this, they should also be well versed in teaching strategies and styles that are most conducive to developing the competencies and habits related to enquiry processes in biological sciences.

These essential preconditions are in keeping with the idea that attainment of stated objectives requires using "the most effective means of teaching within specified limitations and structure of the syllabus" (Meyer, 1969:5). In other words, if a given science curriculum gives provision for understanding of enquiry processes in science, then certain methods and techniques of teaching should be encouraged and provided for in the syllabus.

The kind of teacher required by the model, as summed up in the "support system", is "a flexible instructor skilled in the processes of enquiry" (Joyce and Weil, 1986:139). Although the role of the teacher is that of facilitator, as in other enquiry models, it should be remembered that he/she still has a central role to play. As Marshal (1965:82 - 83) points out, however good are the textbooks designed and unique the laboratory experiences provided:

the science teacher still serves as the interpreter of these things to the students, and is at the centre of the teaching-learning situation. Only if this interpretation reflects the philosophy of the course developers it is reasonable to say that the student has taken the course.

Beyer, too, supplements this view (1971:142):

Although enquiry is learner centred, enquiry teaching requires considerable teacher involvement. Enquiry teaching demands that 1) the teacher plan or design a learning experience that will facilitate student enquiry. This includes creating a series of activities designed to put students through the various stages of enquiry as well as collecting and preparing appropriate learning materials and guides. (2) It also requires that the teacher direct or guide the learning experience by asking questions, making comments or suggestions and providing data when is needed.

Beyer also emphasizes that planning an enquiry lesson is not done by a priori determination of the content to be covered, but through a "continuous and conscious reference to the specific mental operations in which the learners should engage"(Ibid). If the teacher, for instance, wants his students to practise how to formulate hypothesis or the concepts of experimental error, experimental control etc., these cognitive operations must first be clearly stated and then experienced through an appropriate content selected for the purpose.

The use of the model in biology teaching requires that the teacher presents an area of investigation or problem at the beginning of the lesson. The problem is supposed to unify the whole, or at least a major part of the lesson. Subsequent activities of the class, depending on the nature of the problem posed, are geared toward solving the problem. It should, however, be noted that teachers, after introducing a lesson through didactic exposition, may pose problems during the development of the lesson or even at its concluding phase. Posing problems may not be as difficult for the teacher as what should follow. After the posing of problems, the next

step is progress toward its solution. And it is here that the greatest demand on the teacher is made. The success of the lesson depends on what the teacher does to sustain the enquiry process thus started. In short, he or she has to create the appropriate classroom environment where ideas can flow freely between the teacher and students and among the students themselves. J. Richard Schushman, one of the proponents of the enquiry approach, states that two conditions, freedom and a responsive environment, are essential and must be provided by the teacher (in N.Nelson, 1969:218).

But how does the teacher provide the climate and conditions necessary? This task may be properly accomplished by acquiring the skills of questioning such as what kind of questions to ask, how and when to ask them; how to deal with student responses and questions, how to lead classroom discussions, laboratory experiences and projects etc. Some of the salient features of these skills that promote achievement of the objectives of the model investigated will be reviewed in the following pages.

2.3.1. Questioning Skills

As questioning is the most important activity in which teachers engage in all aspects of their contact with students (in class, laboratory and field study), and especially since the model investigated relies heavily on problem/question posing skills of the teacher, it would be appropriate to start with and review it in some detail. Questions are commonly

student is required to recall specific facts (structure of organelles in a generalized animal cell), processes (biosynthetic pathways, development of the human embryo from egg to birth), principles (hormonal regulation of reproductive cycles, feedback control in enzyme systems), concepts (ecosystem, adaptation, gene) and theories (Darwin's theory of evolution).

Although this is the lowest level, it serves as the raw material for the more complex levels.

2) Comprehension questions: These include questions of translation, interpretation and extrapolation. Translation questions require the student to change information from one form to another such as mathematical graphs or formulas into verbal form. Examples are asking students to translate a graph relating O_2 production by *Elodea* to photointensity of incident light and questions requiring the student to translate chemical formulas into verbal forms.

Questions of interpretation require the student to discover relationships among facts, generalizations, definitions etc. To summarize and present a central idea or to identify and explain a verbal, pictorial or mathematical presentation constitutes interpretation. Examples are identifying the central concept of biogenesis in Pasteur's experiments using goose neck flasks filled with boiled Broth and Malthus' concept of food limitation obtained from reading one of his essays.

Extrapolation questions require the student to extend trends and sequences in graphs or inferring end points of

certain plant or animal group based on their characteristics.

4) Analysis questions: According to Perrot (Ibid:44 - 45), there are three functions of analysis questions:

1. To identify motives, reasons and causes for a specific occurrence.
2. To consider and analyze available information in order to reach a conclusion, and
3. To analyze a conclusion, inference or generalization based on evidence.

Analysis occurs when the student is asked to look for "underlying reason such as cause and effect", to draw conclusions after the completion of an experiment, to identify the components of a communication such as hypotheses in a theory (analysis of elements), to identify the interactions between parts of a communication such as identifying predator-prey relationships (analysis of relationships). Examples are identifying the hypothesis in Pasteur's study of biogenesis and identifying the relationships and interaction of primary producers and secondary consumers in a fresh water food chain.

5. Synthesis questions: These questions pose problems that require original, creative thinking. They are, thus, crucial for developing the creative abilities of students. Synthesis occurs when the student brings together several diverse content areas to solve the problem posed. Problems that require the student to design an experiment in order to

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5. Synthesis questions: These questions pose problems that require original, creative thinking. They are, thus, crucial for developing the creative abilities of students. Synthesis occurs when the student brings together several diverse content areas to solve the problem posed. Problems that require the student to design an experiment in order to

test a hypothesis, to create a descriptive model of a scientific phenomenon (such as food relationships in a marine ecosystem) or to propose a micro-theory to explain a set of laboratory observations belong to this group of questions. The student is, for instance, synthesizing when he proposes an experimental plan to test the effects of certain drugs on visual responses in mice as a means of testing a hypothesis that the drugs impair visual perception and motor activity. As synthesis questions do not have a single predetermined answer, they allow a variety of original responses.

6. Evaluation questions: Evaluation questions demand the student to make a judgement of good or bad, right or wrong, according to standards he designates. Like synthesis questions, questions at this level do not have one correct response since the student makes qualitative and quantitative judgements based on a certain value or criteria which will not be the same for all students. Examples are assessing the value of a theory by examining how accurately it predicts laboratory data; assessing the effectiveness of antibiotics in producing bacteriostases using inoculated agar plates and antibiotic discs; and critically reviewing an experiment on photosynthesis in *Chlorella* to determine how effectively the experiment was controlled and how efficient were the methods.

In summary, the use of higher order questions that "require students to manipulate information for some purpose" will determine whether or not the students would engage in

higher thought levels. The use of more complex levels of thinking has also been found to relate to "the nature of the cognitive task" presented to the student (Biddle and Dunkin, 1974:296). Biddle and Dunkin also report that "experimental training in Bloom's Taxonomy...appears to be effective in getting teachers to use more higher order categories." In addition, the use of such categories by teachers has, apparently, a similar effect in students (Ibid: 392 - 3); although the use of higher order categories of knowledge is reported to have a complex relationship with student achievement. It should, however, be noted that if teachers are to incorporate these and other relevant questioning strategies into their teaching style, a continuous practice in their usage is essential.

2.3.2 Guiding Classroom Discussion and Invoking Student Participation

The foregoing discussion on the types and uses of questions, have made clear the need for enquiry-oriented science teachers to be cognizant of the fact that the type of questions they pose greatly affects the students' thinking processes. However, in addition to knowing what kind of questions to ask, it is also necessary to develop a good manner of framing and directing questions, and of dealing with student questions and responses. These skills are also crucial for stimulating and guiding classroom discussion. In fact, it should be remembered that the model investigated is a

discussion scheme or procedure that gets right at the heart of the process of science. Thus, even though we have dealt separately with questions as a basis for such a teaching approach, it is obvious that questioning and discussion are closely allied topics, since they reinforce the same class activity. A teacher who mastered the skills mentioned above is, therefore, in a better position to guide successful classroom discussion.

Once again, it should be pointed out that in using the model the teacher is supposed to provide his students with a limited amount of basic data or evidence (background information) and then invite the students to interpret the data or to reason out a solution to the problem posed. Though one reasonably expects that this will start off discussion between the teacher and students and among students, this may not always be the case. As Davis (1981:308) points out:

Sometimes discussion will start with little encouragement from an instructor or group leader. It gets going on its own. At other times, a great deal of prodding is necessary. Even when things have started well discussion can slow down. It has to be refuelled. Otherwise momentum is lost.

It is in the service of this function; i.e., that of sustaining the enquiry processes through invoking student participation that we say the teacher should acquire basic skills of questioning that are indispensable for conducting successful classroom discussion. These skills are briefly reviewed in the following pages.

The first skill is knowing how to frame and direct (pose) the questions. Some of the salient features of this skill which facilitate discussion are the following (Wienberg, 1971:12):

1. Questions would be more fruitful if directed to the whole group of students.
2. Stating each question slowly and emphatically.
3. Pausing, which allows students time to reflect on the problem. If the students do not respond right away, the teacher should be patient. This is because some of the students may think slowly and carefully, some may not have understood the question, some may be reticent to speak up in class because of past unpleasant experiences, etc.
4. Giving time for a student to hesitate and deliberate while he is answering; and
5. Varying the difficulty of questions (lower and higher) order so as to give a chance for both slow and fast learners.

Encouraging students to participate in classroom discussion and allowing them to arrive at their own conclusions and generalizations also necessitates avoiding certain types of questions. These include (Ibid):

1. Vague, indefinite and ambiguous questions such as "What about chromosomes?"

2. Questions calling for one-word answer (closed end questions) such as "What colour result from starch test?"
3. Categorical questions such as "Is protein digested in the stomach?"
4. Double, multiple and involved questions such as "Who was Darwin, tell about his life, and explain his theory?", and
5. Rapid fire questions.

The second crucial questioning skill for the enquiry teacher is knowing how to deal with student responses. How the teacher deals with student responses is, indeed, as important as the questions themselves. The responses that students give to teacher questions may vary from an "I don't know" to a completely correct response that matches teacher's expectations. In between are responses that are "very weak;" "partly or completely incorrect," "poorly organized, lacking in detail or incomplete." (Perrot, 1982:62 - 63). Whatever the case, it is always profitable if the teacher encourages a student for the attempt made with a word of appreciation such as "Good," "That is a thoughtful answer," "An interesting idea," etc., and then evaluate the response offered, ask the class or the respondent to expand, improve, evaluate the response. The important point is that it should be the student who says "Yes, I was wrong." This approach, which Ned Flanders, (in Perrot; 1982:81) calls an Indirect Style of teaching, is known to increase student performance while

minimizing their dependence on the teacher.

Davis and Perrot suggest more specific ways of dealing with student responses in a manner that doesn't inhibit students participation and progress. Davis (1981:170 - 71) suggests that "probing trainee (student) responses" is important to avoid superficial reasoning. He offers four techniques toward this end: seeking further clarification of the answer offered, asking students to be more critical about their responses, prompting students to go further, and refocusing students answers to questions. Perrot (1982:56) suggests somewhat related sets of skills that would enable the teacher to help students: 1. give more complete and thoughtful responses and 2. increase the amount and quality of their participation. The first objective is accomplished by using four related teaching skills: pausing, prompting, seeking further clarification and refocusing a student's response; while the later involves redirecting the same question to several pupils, framing questions that call for sets of related facts (open-ended questions), and using questions that invite the student to use higher cognitive thought levels.

As most interesting lessons elicit student questions, skill in dealing with them is the third area that an enquiry teacher should develop. When a student asks questions, there are three main alternatives for the teacher:

1. give the student a straight answer to his/her question(s).
2. Answer his/her question with another question. Davis

calls such questions " reverse question" and help students to think; and

3. Make a specific suggestion about how the student may find his/her own answer to the problem.

A variant of the second possibility is to turn the question back to the whole class (relay questions). Although which of these possibilities a teacher uses depends upon the specific circumstances, frequent use of the first type (analogous to rapid-fire questioning) is an indication that the teacher has adopted an authoritarian mode of teaching. Effective teachers, however, tend to use the third alternative, which, through the technique of probing and other related skills, could lead to a chain of reasoning which would finally enable the student to arrive at his own conclusion and generalization.

Chapter Three

3. Analysis and Discussion of Findings

In this chapter three aspects of the findings of the study are presented. The first part deals with analyses of the four Senior Secondary School biology textbooks. Part two presents results and analyses of questionnaire survey and interview. This is then followed by results and analysis of observation of classroom interaction.

3.1. Analysis of Textbooks

Analyses of the four Senior Secondary School biology textbooks in use today was made in order to determine the degree to which they reflect the purpose for which they were designed. That is, the analysis focused on whether or not the textbooks promote the development of biological enquiry skills without which, as stressed in chapter two, an adequate understanding of the subject would not be possible. Aspects of the textbooks that had been analyzed were:

3.1.1. Questions¹

3.1.2. Practical activities

3.1.3. "Narrations of Enquiry". The following discussion deals with these aspects respectively.

¹. Only those questions whose answers are to be provided in the corresponding worksheet space have been analysed. Review questions have been excluded because (1) they are few in number compared to the total number of questions in each unit, (2) their pedagogical significance is different and (3) they are repetitions of some of the questions studied.

3.1.1. Description and Analysis of Questions

Analysis of questions included in the 15 units studied, with the exception of those under review questions (grades 10,11 and 12) was based on two major criteria:

a) What is the student required to do in order to answer the questions (problems) posed; i.e., do the questions require performing some kind of activity or not?

b) In what cognitive process is the student expected to engage while trying to answer the questions posed by the text; i.e., the level of cognitive demand required by the questions. For this purpose, classification of questions based on Bloom and Co-workers categories of instructional objectives was used. It is especially based on the more specific elaborations of the categories of questions given in Anderson (1971:7-8) and Perrot (1981:41-47). The categories are (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis, and (6) evaluation. The type of cognitive operations which determine a given question as belonging to one of these categories has been discussed in chapter two.

Classification of questions based on the first criteria revealed two major groups and five sub-groups. It is worth noting here that, in effect, this classification is based on an answer to a single question: How are the questions integrated into textbook discussion?

Type I: Questions: These include questions or problems

the posing or solution of which necessitates performing an activity: referred to as activity-bound questions. These questions have again been classified into two sub-types.

Type I. A : Questions that demand the student to explain why he/she performs a certain step in a series of experimental procedures during an activity: referred to as procedural or methodological questions.

Examples: 1. "Which is your control group in this experiment?"

2. "Why was it necessary to take the bubble into the long arm of the J- tube before taking measurements?"

Type I.B: Questions that ask the student why or how he/she gets a certain interim result before the completion of an activity; and questions presented at the completion of an activity and asking the student to interpret the findings, draw conclusions, design further investigations etc.: referred to as conceptual questions.

Examples: 1. "What were the colours produced in test tubes A and B?"

2. "How much CO₂ was given out in one minute before exercise? After exercise?"

3. "Why did the lungs collapse after being blown up in step 1?"

4. " From your data what do you conclude about the rate of carbon dioxide production by different animals?"

Type II. Questions: This group includes those questions the posing or solution of which requires no practical activities: referred to as activity-free questions. This group, too, has been found to consist three sub-types within it:

Type II. A: in such questions the student is given a description of actual or hypothetical experimental results together with the problem posed and the experimental procedures involved. In some cases, such descriptions make mention of the person who investigated the problem. In the process, the student may be asked to formulate hypotheses, interpret the results, draw conclusion, etc.

Examples: 1. "Given the results of the above experiment what conclusions can you make?"

2. "Do the results of the experiment support your original hypothesis?"

3. "From your observations of the graph, formulate a hypothesis as to what you think is happening...?"

Type II-B: This sub-group includes those questions which are linked to a diagram, chart or table; excluding those of the II-A type above. These questions require the student to look at a figure (diagram, graph or table) and provide the answer by comparing, analyzing, translating etc.

Examples: 1. "Which of the beaks inf Fig 2/12 are suited for sipping nectar from flowers?"

2. "Now look at figure 4/17 to see the position of the nasal cavity. By looking at the diagram answer the following questions....?"

Type II-C: These questions require the student to think from his/her experience (such as to draw upon his/her general knowledge), previous information given in the text (such as that learned in a previous topic, unit or grade) or background information given concurrently by the text before the question is posed.

Examples:1 " You know from your physics lesson that coloured objects look coloured because they absorb some parts of the light falling on them and reflect some other parts. So, when you look at a green leaf, what does the fact that it appears green tell you...?"

2. "Shivering is a response made by the body to cold. When the body cools the muscles under...how does shivering help the body keep warm?"

Table 3.1.1-A: Number of Activity-bound and Activity-free
Questions in Each Unit and Grade

		Type I		Type II			
Grade	Unit	I-A	I-B	II-A	II-B	II-C	Total
9	U2	-	73	-	-	2	75
	U4	2	34	-	2	4	42
	U6	2	65	-	6	8	81
Total		4	172	-	8	14	198
10	U2	1	27	6	1	17	52
	U4	10	59	9	4	3	85
	U6	-	35	6	-	7	48
Total		11	121	21	5	27	185
11	U2	2	28	-	50	34	114
	U4	8	61	7	9	2	87
	U6	-	31	17	10	25	83
	U8	-	12	2	-	-	14
	U10	1	37	27	10	7	82
	U12	9	47	14	-	7	77
Total		20	216	67	79	75	457
12	U14	-	38	3	14	8	63
	U15	1	10	22	15	46	94
	U16	-	-	3	1	51	55
Total		1	48	28	30	105	212
Grand Total		36	557	116	122	221	1052

Table 3.1.1-B: Proportion of the Five-Sub-Types of Questions
in Each Grade and Among the total Number of
Questions

Type	Grade									
	9		10		11		12			
	No	%	No	%	No	%	No	%	Total	%
I-A	4	2.02	11	5.95	20	4.38	1	0.48	36	3.43
I-B	172	86.87	121	65.40	216	47.27	48	22.64	557	52.95
I-A	-	-	21	11.35	67	14.66	28	13.20	116	11.02
II-B	8	4.04	5	2.70	79	17.29	30	14.15	122	11.60
II-C	14	7.07	27	14.60	75	16.41	105	49.53	221	21.00
Total	198	100%	185	100%	457	100%	212	100%	1052	100%

Results of the classification of the 1052 questions included in the 15 units analyzed based on the first criteria is given in tables 3.1.1.-A and 3.1.1.-B.

The results reveal that, of the total 1052 questions 593(56.4%) are activity-bound. The rest, 459 or 43.6%, being activity-free questions. Thus, the fact that more than half of the questions are activity-bound indicates the emphasis given to student investigation as the principal mode of

acquiring knowledge; one of the principal features of a text suited for enquiry-oriented teaching of biology. Comparison of activity-bound questions in each grade to the total number of such questions shows that the largest proportion is found in grade 11 (39.8%), followed by grade 9 (29.6%), grade 10 (22.2%), and grade 12 (8.2%). This figure, as well as the subsequent ones, show that grade 11 takes an inflated share of the various types of questions. This is because six units have been analyzed in this grade, twice more than the number of units analyzed in the other three grades. Other than this, the amount of content included in a given unit and the nature of the unit are important factors that contribute to the variation in the number and type of questions from unit to unit and thus from grade to grade. A more balanced picture would, therefore, be observed if the number of activity-bound questions in each grade is compared to the total number of questions within the grade. Such comparison reveals that, of the total number of questions in each grade, activity-bound questions constitute 88.8, 71.3, 51.6 and 23.1 percent in grades 9, 10, 11 and 12 respectively. In this case grade 9 has the largest proportion of activity-bound questions.

Similarly, when the distribution of the total number of activity-free questions in each grade is compared to the total number of such questions in the four grades, grade 11 contains the largest proportion (48.1%); followed by grade 12 (35.5%), grade 10 (11.5%) and grade 9 (4.7%). However, comparison within a grade shows that, activity-free questions constitute 76.8, 48.3, 28.6 and 11.1 percent of the total number of

questions in grades 12,11,10 and 9.

These figures, the distribution of both activity-free and activity-bound questions, show that, as the proportion of activity-bound questions to the total number of questions with a grade goes on decreasing, the reverse is true for activity-free questions. This seems to be a result of the tendency toward inclusion of more textbook information (text discussion) found in the two upper grades as compared to the two lower grades. This is particularly true in the last two units of grade 12 - Evolution and conservation of Natural Resources - where type II questions account for 93.1 percent of the total questions in the two units. This indicates the existence of a trend or shift from students' concrete experience with biological phenomena (student observation and experimentation) to more abstract (theoretical) engagements by students; i.e., in the lower grades, emphasis is given to student investigations; in the upper grades, this gives way to more abstract reasoning exercises (questions). This is apparently in line with the principle of moving from the concrete to the abstract.

A closer examination of the 593 activity-bound questions reveals that 36(6%) are of the I-A type (procedural or methodological questions). Notwithstanding the fairly low proportion of such questions, they are crucial because students are expected to perform practical activities with conscious knowledge of the reasons for the steps and procedure involved, so that it would not be a cook-book procedure in which students merely follow instructions without

understanding the underlying principles and concepts.

Among the I-B type of questions, 26.5 percent are asked before the completion of an activity. These questions correspond to Taba's "focusing" type of questions which, according to her, "help establish the content or topic and the cognitive operations to be performed." (BSCS: 1971:345). These questions direct the student to look for a certain aspect of an activity so that he would record only the needed data to solve the problem. Students' data collection is therefore guided by such questions. The rest of the type I-B questions (73.5%) are asked after the completion of the activity. As indicated previously, questions that are asked after the completion of an activity require the student to interpret the results, draw conclusion, design further investigations etc.

Breakdown of the 459 type-II (activity-free) questions shows that the II-c type is by far dominant, accounting for 48.1 percent of the total such questions. Types II-A and II-B account for 25.2 and 26.5 percent respectively. Type II-A questions, perhaps the nearest to enquiry-centred teaching of biology next to questions related to laboratory experiences, are utilized more frequently in grade 11; which accounts for 57. percents of all such questions in the four grades.

When the total number of type II-A questions in the two upper grades (11 and 12) is compared to those in the lower grades (9 and 10), 81.9 percent are found in the former. The reasons may be, (1) following the principles of moving from simple to complex and from the concrete to the abstract,

students are gradually introduced to what is called "enquiry" ^{into Enquiry} which is a rather advanced form of the ways by which students may be helped to understand the processes of biological enquiry. And (2), since most of the experiments from which the II-A type questions were drawn are very difficult to duplicate (due to the requirement of elaborate and sophisticated facilities and equipment and/or a prolonged period of time), only descriptions of the problem, the experimental method used and the results obtained are given. The frequent utilization of such questions (and the materials on which they are based) in grades 11 and 12 has been strongly recommended by Roger Baja (in UNESCO, 1966:68).

The II-B type question, with a nearly equal proportion to that of the II-A type, is dominant in grade 11 (70.5%). Among the Six Units in Grade 11, unit two-feeding and digestion - accounts for 44.6 percent of the total such questions in the four grades. Combined the two upper grades account for 89.3 percent of this type of question. Although diagrams are equally abundant in the two lower grades as in the upper grades, their use as sources of questions or problems is visible in the later while serving predominantly as illustrations in the former two grades.

The II-C type, besides being the largest among the three type II questions, is abundant in grade 12 (47.5%) as compared to its proportion in the other three grades. Eighty-one percent of this type of questions are found in grades 11 and 12. The distribution of type-II-C questions reinforces the conclusion previously reached: that there is a tendency toward

more exposure to textbook information as one goes from the lower to the upper grades.

As indicated before, the 1052 text questions in the 15 units have also been analyzed on the basis of the nature of cognitive demand. That is, based on the level of thinking process elicited by the questions while a student tries to answer them, they have been classified into one of the six question categories. The results of this classification are given in tables 3.1.1-c, 3.1.1-D and 3.1.1-E.

Table 3.1.1-C: Classification of Textbook Questions Based on Bloom's Taxonomy of Educational Objectives²

Question Category								
Grade	Unit	Knowled	Comprhen	Applica	Analysi	Synthe	Eval	Tot
9	U2	51(0)	14(0)	6(2)	1(1)	1(1)	2(0)	75
	U4	26(4)	13(2)	-	3(0)	-	-	42
	U6	45(3)	16(4)	8(2)	12(3)	-	-	81
	Total	122(7)	43(6)	14(4)	16(4)	1(1)	2(0)	198
10	U2	17(5)	10(3)	9(7)	11(3)	1(0)	4(0)	52
	U4	21(1)	20(8)	11(2)	23(2)	6(5)	4(2)	85
	U6	13(4)	20(4)	5(1)	7(4)	2(0)	1(0)	48
	Total	51(10)	50(15)	25(10)	41(9)	9(5)	9(4)	185
11	U2	50(36)	32(22)	22(21)	7(2)	3(3)	-	114
	U4	27(2)	25(9)	15(4)	20(3)	-	-	87
	U6	13(5)	32(25)	26(17)	11(5)	1(0)	-	83
	U8	4(0)	6(1)	-	4(1)	-	-	14
	U10	26(11)	28(18)	6(2)	15(10)	5(3)	2(0)	82
	U12	25(1)	32(8)	7(7)	10(2)	2(2)	1(0)	77
	Total	145(55)	155(83)	76(52)	67(23)	11(8)	3(0)	457
12	U14	32(11)	16(8)	3(1)	9(3)	1(0)	2(2)	63
	U16	6(5)	10(9)	24(19)	22(20)	27(26)	5(4)	94
	U18	14(14)	2(2)	10(10)	23(23)	5(5)	1(1)	55
	Total	52(30)	28(19)	37(30)	54(46)	33(31)	8(7)	212
Grand								
Total		370(102)	276(123)	152(96)	178(82)	54(45)	22(11)	1052(459)

². Numbers in brackets indicate the proportion of activity-free questions to the total number of questions in each question category. For instance, 26 (4) (G 9, U 2, column one) means of the total 26 knowledge questions in this unit, 4 are activity-free.

Table 3.1.1.C: Proportion of the Six Categories of Questions in Each grade and among the total number of questions

Grade											
		9		10		11		12			
Quest											
categ	No	%	No	%	No	%	No	%	Tot	%	
Knowl	122	81.62	51	27.57	145	31.73	52	24.53	370	35.17	
Comp	43	21.72	50	27.02	155	33.92	28	13.20	276	26.23	
Appli	14	7.07	25	13.51	76	16.63	37	17.45	152	14.45	
Analy	16	8.08	41	22.16	67	14.66	54	25.47	178	16.92	
Synth	1	0.50	9	4.87	11	2.40	33	15.57	54	5.14	
Eval	2	1.01	9	4.87	3	0.66	8	3.78	22	2.09	
Total	198	100%	185	100%	457	100%	212	100%	1052	100%	

Table 3.1.1.E: Proportion of Activity-bound and Activity-free Questions in Each Question Category

Question Category	Question Type					
	Activity-bound		Activity-free			
	No	%	No	%	Total	%
Knowledge	268	45.20	102	22.23	370	35.17
Comprehension	153	25.80	123	26.78	276	26.23
Application	56	9.45	96	20.92	152	14.45
Analysis	96	16.19	82	17.87	178	16.92
Synthesis	9	1.51	45	9.80	54	5.14
Evaluation	11	1.85	11	2.40	22	2.09
Total	593	100%	459	100%	1052	100%

Among the total number of questions analyzed in ~~the~~ 15 units, the largest (35%) are knowledge questions, followed by comprehension questions (26.%). Application and analysis questions have a more or less similar proportion, 16 and 14 percent respectively. The last two categories share a comparatively low proportion, 5 and 2 percent respectively. With the exception of analysis questions, the total number of questions in each category decreases as one goes from the lower to the higher order. Disregarding few exceptions (analysis in grades 9 and 10, comprehension in grade 11 and application and analysis in grade 12), this trend also holds true when considered grade wise or within a grade. However, contrary to this, the number of questions requiring the student to engage in higher-order cognitive processes go on increasing as one goes from the lower to the higher grades (grade 12 is an exception to this trend).

The dominance of knowledge questions (both in the lower

grades and among the total number of questions in the four grades) is, perhaps, fair when one considers that a knowledge of biological facts, principles, processes etc., forms the raw material for the other (higher-order) categories of questions. In other words, the proportion of each category within a grade and among the total number of questions is in accordance with the idea that students should first have sufficient knowledge or information on a given content area before beginning to manipulate information at a higher level (Perrot, 1986:46).

The proportion of activity-bound and activity-free questions in each category has also been determined (table 3.1.1-E). The emphasis here is on the percentage of activity-free questions in each category, as this might have a special significance. Among the 370 knowledge questions, 102 (27.5%) are activity-free. In comprehension, application, analysis, synthesis and evaluation categories; activity-free questions account for 44.5, 63.1, 46, 83.3 and 50 percent respectively. It is worth noting here that in three of the categories (application, synthesis and evaluation), activity-free questions account for 50 percent or more of the total number of questions. The fact that a significant number of questions in each category are activity-free could have a distinct advantage. That is, should a teacher fail to help his students exercise the more complex types of cognitive skills through practical activities, activity-free questions provide the opportunity. And there is every reason to doubt the practicality of activity-bound questions; i.e., unless the respective activities are carried out, the questions remain unanswered by the student. It is, of course, possible for the teacher to provide the correct answer or solution via lectures, or for the student to search for the correct answer through his own reading, which is better than the former. This probable drawback could, therefore, be compensated by activity-free questions. But this holds true if the teacher is skilful enough in dealing with such questions. In other words, the fact that a given text question is not bound or linked to practical activities does not guarantee that it will

be properly experienced by students; as this depends on the teacher's skill, expertise as well as commitment in the use of questions.

In summary, the writer believes that the distribution of the various types of questions and the way they are integrated into text discussion facilitates student enquiry. This, however, holds true if and only if the teacher helps his students experience the various enquiry and cognitive skills in exactly the way, or in a better way, the texts require. But this again is possible if all the requirements of the curriculum for its proper implementation could be fulfilled.

3.1.2. Analysis of Practical Activities

As pointed out in chapter 2, laboratory experiences play a significant role in helping students acquire or develop the various scientific enquiry skills. The student of biology becomes aware of the various processes involved in biological investigations by conducting purposeful laboratory activities. It is the nearest to "doing science" than any other approach. However, not all types of laboratory experiences are equally important in helping students grasp the processes involved in scientific enquiry.

Analysis of practical activities included in the 15 units examined was thus done in order to determine, as it was done for questions, the degree to which they serve the purpose for which a laboratory experience should be used in an enquiry biology curriculum. This was done by using the

following criteria:

i) The "degree of openness" involved in each activity: the "structured-unstructured" model (Romey, 1966:22 - 24).

ii) Time of conducting the practical activities; i.e., whether or not the activities are conducted before or after the students' coverage of the specific principle, concept or theory to be investigated: the "Illustrative-investigative" model (BSCS, 1971:337), and

iii) The type of practical activities; i.e., whether they are experimental or observational in nature.

In addition to this, feasibility of the practical activities was also investigated by considering the amount of time required to complete each activity in relation to the amount of time allotted for biology in each grade. Feasibility was also determined by taking into account the laboratory procedures used to conduct the activities (e.g. teacher-demonstration VS student experimentation) and the availability of materials and equipment necessary to conduct the investigations.

Before evaluating the practical activities against the first three criteria, it is first necessary to examine the model or models used by the texts for practical activities.

There are 167 practical activities included in the 15 units analyzed. Almost all of the activities follow one basic model with slight variations (Figure 3.1.2.1). A detailed description of the phases of this model is given below.

The practical activities begin with an introductory paragraph or statement which set the stage for the enquiry (investigation). A typical example is given below:

Activity: "Does Soil Hold Water?" Plants which live on the soil require water. Different soils contain different quantities of water, and so are suitable for different plants. You are going to do an investigation in which you will compare the amount of water which can be held by three different types of soils (Grade 9 Biology Text, P.60).

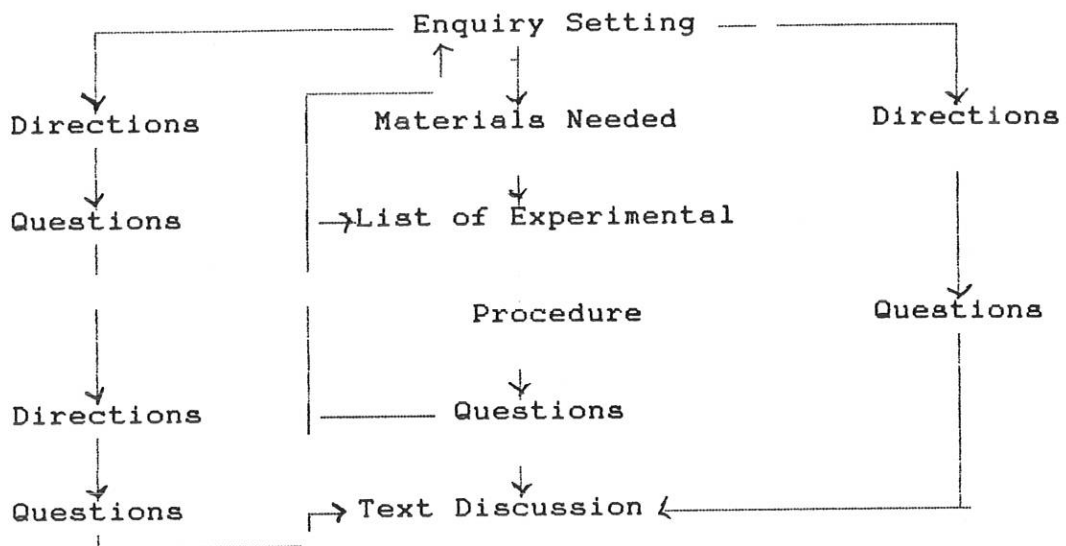


Figure 3.1.2.1: Basic model used for Laboratory Activities by the Biology Textbooks

Such introductory statements, which are termed here as "enquiry setters" and which pose the "area of investigation" to the student, are analogous to Ausbels' "advance organizers". According to Ausbel (in Anderson, 1971:43) advance organizers, which are statements containing "general or inclusive concepts that will serve as anchor points for the specific facts," will later help the student to relate new knowledge acquired to existing knowledge. Acquisition and retention of learning could thus be enhanced. But such statements, either written or orally introduced by the teacher, are important in so far as they do not provide or hint-off possible answers to the problem to be investigated.

The introductory statement or paragraph is then followed by a list of materials and equipment needed to perform the investigations (variant 1) or directions telling the student to look at a specific feature of a biological specimen in observational activities (variants 2 and 3).

The third phase constitutes a list of detailed procedures for the investigation (variant 1). The list of procedures is often interspersed with questions of the I-A type - which ask the student to state why he/she performs a certain step in the activity. The possible significance of such questions has been mentioned in the previous section. In the other variants, the directions are followed by questions which end the activity temporarily (variant 3), or the directions could be interspersed with questions before the completion of the activity (variant 2).

In variant one, the list of experimental procedures is followed by a series of questions asking the student to interpret, analyze etc., his data or findings. To some of the investigations, model "Results Tables" or graphs are given in which the student is supposed to enter the results of the investigation in the corresponding work sheet space (see table 3.1.2-C).

When one asks the question: Does a laboratory experience based on this model really help students grasp the basic processes involved in biological investigations?, the answer depends on an answer to another question: Are students made to do the investigations in just the way, or in a better way, the texts require?

As one can see from the way in which laboratory activities are integrated into text discussion a new concept or principle (content area) is introduced to the student through practical activities; i.e., the activities are to be conducted before the corresponding concept or principle is covered in class. This is also explicitly stated in the Teachers' Guide for Biological Science, Grade 9:

....In this sense they [activities] are "programmed" or "structured" enquiries, but they are not extended, as is the case with programmed instruction, to give the correct final answer. The pupils' answers will depend on their findings.

Thus, the proposed activities are of the investigative type. Investigative in that the student is provided with the problem (area of investigation) and is told how to proceed, but does not know what the conclusions would be. The pedagogical significance of the activities, however, rests on two conditions: (1) teacher allows students to perform the activities and proceeds to the corresponding concept, and (2) the student doesn't know the conclusions of the activity through lectures or his own reading.

To stress once again an important point, the activities to be performed by students are investigative because, among the various steps involved in the process of biological enquiry, the last phase - interpreting data and drawing conclusions - is left out to the student. There are, however, other types of investigative laboratory activities depending on their "degree of openness" (criteria I) or the degree of student freedom involved. As described above, practical activities included in the textbooks, excluding those of

teacher demonstrations, are what Romey (1966:22) calls "structured activities," in that the student is given "instructions that lead him through a procedure designed to produce certain specific results." Obviously, this type of laboratory activity is more open than activities in which the student confirms a concept or principle which is already known to him.

Although these two types of laboratory activities have their proper place in any biology curriculum, their virtual use to the exclusion of other more open types of laboratory exercises will in the end lead to a distorted view of the subject. As stated in Chapter One, the major objective of the model used as the basis of this study is to enable the student understand the process of biological enquiry so that a true understanding of the subject could be achieved. This is also the major objective of the writers of the biology curriculum. The "Biological Science: Enquiry Model" was thus developed as the proper means for the achievement of this objective. Except phase one in which the teacher "poses an area of investigation", the responsibility of finding a solution is left to the student.

There is, therefore, incongruence between the "Biological Science Enquiry Model" and the model used by the textbooks for practical activities. Instead of the student, the "structuring of the problem" and the method of "overcoming the problem" are done by the texts. As a result the student misses the training involved in the process of biological enquiry. A student who exclusively experiences laboratory

activities of the type included in the textbooks will not follow in the foot steps of "research biologists" or scientists, as claimed in the foreword given for the Senior Secondary School biology course. A research biologist does not find a ready-made biological problem or a clear-cut method of investigating it. To offset the unwanted effect that emanates from the exclusive use of such laboratory activities, experts recommend that other more open types of activities should have a place in the Biology Curriculum (66:24;BSCS,1971:336). These are (1) laboratory activities in which the student is given the problem and hypothesis. The task of designing the experiment and the subsequent steps is given to the student. (2) Activities in which the student is given just the problem, the rest being his responsibility; and (3) activities in which the student is provided with a general area of investigation, such as a biological specimen (an aquarium for instance), in which he is interested to work. In the last case the student is completely at liberty and close to the manner in which biologists conduct research.

Before looking at how the texts attempt to provide provisions for the student to recognize problems, formulate hypotheses etc., it would probably be appropriate to say few statements on these more open types of laboratory exercises. The reader might perhaps feel that inclusion of such exercises is irrelevant given the Ethiopian school situation. And more so when considered against the ability of high school students to conduct such investigations with the most minimum teacher guidance. If so, the writer believes that the scepticism is

justified. However, if the question is limited to the theoretical level, without such experiences a school leaver will not have achieved one of the fundamental objectives of biology teaching. Fortunately, laboratory experiences are not the only means to help students understand the processes of biological enquiry (see section 2.1.3).

The biology texts give an extremely inadequate provision for the type of experience outlined above in two ways. The first is through questions that ask the student to peruse an investigation beyond the point where the text left it:

Example: "Describe one experiment you would do in each of the following cases: a) to find out if a green plant formed starch in absence of light, b) in absence of carbon dioxide, (Grade 11 Biology Text, P.224).

In the second, along with text discussion the texts introduce the student to an area of investigation and ask him to find a solution:

Example: "When investigating the activities of a crop pest, it is necessary to know as much about the pest as possible....Design and carry out an experiment to find out whether bean weevils will attack other seeds than beans....Write a report of the method you used on your work sheet. Include all your observations and conclusions." (Grade 10 Biology Text,P.174).

However, the amount of material and questions related to the methods of science (biological enquiry) in which the student is made to experience through his own involvement is insignificant. Instead of allowing the student to engage in the more open types of laboratory experiences, for which there are very few provisions, the texts try to accomplish this more through the use of type I-A questions. Some of these questions, for instance, ask the student to identify the

"control" and "experimental" groups while the student is conducting the investigations, or to formulate a hypothesis for an experiment already completed. Although such questions are better than none, they are not as effective as allowing the student to pass through the process with conscious knowledge of each enquiry factor involved.

Perhaps the greatest jeopardy that can spoil even what may be benefitted from conducting the activities included arises from the fact that laboratory activities are integrated into text discussion, which is different from integrating laboratory activities into classroom discussion. The latter is a recent trend in science teaching, the importance of the former hinges on one critical assumption: that text discussion following a given practical activity (where given) doesn't provide the conclusions which the student is supposed to arrive at after the completion of the activity. But this is usually difficult due to the nature of such textbooks. If the interpretations and conclusions of an activity, incorporated into subsequent text discussion, are not given; then it stops to be a text. It is a guide for practical activities or a laboratory manual. If the conclusions are given, what guarantee is there that the student does not read them before conducting the activity?, especially if he/she has the opportunity to read it. Should this happen, it would be contrary to what Romey (1966:24) strongly recommends: That "the student's⁷ initial generalization should be the result of his own reasoning. He must have no preconceived ideas forced on him by textbooks or teacher."

The Senior Secondary School Biology Curriculum also clearly states that the activities are to serve as a basis on which a student's understanding of a concept or principle would depend. This is indicated in the Teachers' Guide for Biological Science (Grade 9):

....Biology is a subject which is very well suited to such [Discovery or Enquiry] an approach. In fact the process of discovery is as important to a child's development as the actual knowledge discovered. As a result the class work has been structured so that the pupils approach a topic with an open mind and are not in possession of any final or correct answer before they begin their activities.

True to word, and as indicated previously, the texts do "structure" each and every topic in such a way that they begin with a problem situation, followed by activities, whenever there are, which are supposed to be the source of the solution for the problem. The teacher is expected to follow the procedure as given in the texts. One may thus say that the instructional procedure which a biology teacher is supposed to follow has been transplanted into the design of the biology course.

The effort by the authors and editors of the textbooks to initiate a given topic or unit with observation and experimentation is of course, a commendable approach. As Richardson (1957:42) stresses, this would help to "integrate the actual textual material with the (direct) experience of the learner." However, for reasons mentioned above, this approach could as well be fruitless unless some conditions are met. In other words, the fact that laboratory experience have been integrated into text discussion doesnot guarantee that

they would be so during actual classroom teaching. This obviously depends on the teacher.

The 167 practical activities have also been analyzed in terms of the amount of time required to complete them, their type and whether "Results Tables" are given or not (tables 3.1.2-A, 3.1.2-B and 3.1.2-C).

Table 3.1.2-A reveals that among the total number of practical activities, those which take either less than an hour (68) or 1-2 hours (30) are by far dominant. Together, they account for 58% of the activities. This is fortunate in that these activities could somehow be performed, if other conditions are fulfilled, within the time allotted for biology.

Table 3.1.2.A: Amount of Time Required to complete the
practical activities included in the 15
Units Analyzed

		Time Required						
Grade	Unit	<1hr	1-2 hrs	1-2 days	3-7 days	8-14 days	>14 days	Total
9	U2	8	2	1	2	1	-	14
	U4	9	1	2	2	1	-	15
	U6	8	-	2	7	-	-	17
Total		25	3	5	11	2		46
10	U2	7	3	-	-	-		10
	U4	1	3	2	12	-		18
	U6	-	3	1	1		5	10
Total		8	9	3	13		5	38
11	U2	10	4	-	1	-	-	15
	U4	5	6	4	-	-	-	15
	U6	3	2	-	-	-	-	5
	U8	3	1	-	-	-	-	4
	U10	10	4	2	-	-	-	16
	U12	-	-	7	2	3	8	20
Total		31	17	13	3	3	8	75
12	U14	4	-	1	1	-	-	6
	U16	-	1	-	-	-	1	2
	U18	-	-	-	-	-	-	-
Total		4	1	1	1	-	1	8
Grand Tot.		68	30	22	28	5	14	167

Table 3.2.2.B: Type of Activities Included in the 15
Units Analyzed

Type of Activity					
Grade	Unit	Controlled	Uncontrolled	Observation	Total
9	U2	2	-	12	14
	U4	7	4	4	15
	U6	5	5	7	17
Total		14	9	23	46
10	U2	6	3	1	10
	U4	12	5	1	18
	U6	-	-	10	10
Total		18	8	12	38
11	U2	4	4	7	15
	U4	2	13	-	15
	U6	-	4	1	5
	U8	-	4	-	4
	U10	2	13	1	16
	U12	14	4	2	20
Total		22	42	11	75
12	U14	-	1	5	6
	U16	1	1	-	2
	U18	-	-	-	-
Total		1	2	5	8
Grand Total		55	61	51	167

Table 3.1.2.C: Number of Activities for which "Results Tables" (RT's) are Given

Grade	Unit	Activities for which RT's are given		Total No. of activities
		Nº	%	
9	U2	2	14.3	14
	U4	7	46.7	15
	U6	4	23.5	17
Total		13	28.3	46
10	U2	9	90.0	10
	U4	14	78.7	18
	U6	5	50.0	10
Total		28	73.8	38
11	U2	1	6.7	15
	U4	3	20.0	15
	U6	-	-	5
	U8	-	-	4
	U10	-	-	16
	U12	1	5.0	20
Total		5	6.6	75
12	U14	-	-	6
	U16	1	50.0	2
	U18	-	-	-
Total		1	12.5	8
Grand Total		47	28.2	167

While those requiring below an hour could be carried out within the allotted class time (40 minutes), those taking 1-2 hours could be performed by arranging double periods, which is possible in grades 11 and 12. However, a significant number of the activities require more than this. Sixty-nine (42%) of the activities require time ranging from 1-2 days up to more than 14 days. Added to the overcrowded time schedule in the High Schools today, carrying out practical activities that require longer periods of time seems to be extremely difficult.

It is worth noting here that the requirement of long time to carry out a given practical activity does not necessarily mean inconvenience in as long as the teacher makes careful planning beginning from the pre-lab phase. An activity that requires long time does not mean that it will be conducted continually. For instance, if students are to investigate a given property of bacteria; the time required for incubation of bacteria is not as important as the time of actual investigation. That is to say, the indispensable steps in activities of the above type are those in which students make the actual inoculation of the culture, regular visits of the cultures and the final result of their investigations.

In short, many of the activities include a pre-lab phase involving preparation of solutions, growing of seedlings,

setting up of apparatus etc. Such pre-lab activities could be done if there is a competent laboratory assistant, thus minimizing the amount of time required. Thus, unless there are specific reasons to involve students in this phase, the time needed during the pre-lab period could be discounted.

Table 3.1.2-B presents the type of activities included in the 15 units analyzed. Practical activities are basically either experimental or observational. In the former type an experimental variable is manipulated while all others are kept under control. In the later, students find out characteristics and features of biological objects and phenomena without influencing or destroying objects or processes. In this study, however, a third group - the uncontrolled type - has been included. While activities classified as either controlled or observational are those which fall into the definitions given above, the uncontrolled type is mid-way between the two. As used here, it refers to activities in which a given variable is not manipulated, but the biological object or phenomena being investigated is profoundly affected in the process of the activity. It should be noted here that there is no clear demarcation between the uncontrolled and observational types. One might as well consider them as belonging to the same group. The significance of dividing them into two lies in the fact that it has implications in amount of time required, materials needed and the amount of student involvement.

As the table reveals, each type of activity is fairly represented in the texts. What is interesting is that as one goes from the lower to the upper grades, excluding grade 12, the number of controlled experiments increases, while the reverse is true for observational activities. Observational activities account for 50, 31.5 and 14.6 percent in grades 9, 10 and 11 respectively. There seems to be a tendency or movement from more experience in skills of observation, which are basic to the other types of activities, in the lower grades to the more complex types of activities in the upper grades.

It has been pointed out that one of the skills which a

high school biology student should acquire is the ability to present his findings in various concise and understandable ways. The Biology Textbooks analyzed try to accomplish this in two ways. In the first, a 12-page section entitled "presentation of data" is devoted to this skill in unit 1, grade 10 of the biology text. In the second, the texts suggest "model" methods of recording and presenting the results of some of the activities (table 3.1.2-C). As the table shows, grade 10 has the largest number of activities for which model "Results Table" is given. Eighty-seven percent of the activities in the two lower grades, where fifty-percent of the activities are found, have model results tables compared to thirteen percent in the two upper grades. This shows the emphasis given to this skill in the early stages of the course, the task of choosing the best ways of recording and presenting data being given to the student in the upper grades.

3.1.3. "Narrations of Enquiry"

The presence of materials descriptive or explanatory of scientific enquiry was the third major criteria by which the suitability of the textbooks for enquiry-centred teaching of biology was determined. The phrase "Narration of Enquiry" refers to such materials. In such topics or sections of textbooks, a given concept, principle or law is developed through descriptions or narrations of the work(s) of a scientist (whose name(s) may or may not be mentioned) stretching from the problem posed to the conclusions reached (see Chapter Two, section 2.2).

For this purpose, every textbook topic in the 15 units analyzed was read to identify the topics (passages) related to certain aspects of scientific enquiry. As indicated above, such descriptions may be done by the textbook writer together with the person (scientist) who made the investigation. Another aspect of narration of enquiry is, therefore, the

degree to which the texts cite the works of prominent biologists who made landmark contribution to the development of the discipline.

Table 3.1.3-A. shows list of topics developed in the manner described above. Table 3.1.3-B. also shows list of biologists whose original works are used by the texts. The work cited may vary from passing remarks or few statements to major parts of units such as that found in unit 16 Evolution.

The largest number of such topics are found in Grade 11, where the names of only two biologists is mentioned. Grade 9 has no such topics or sections. A closer examination of the topics reveals that, except those in Grade 10, they are either physiological, photosynthesis or evolution.

Table 3.1.3-A: List of topics Developed Following the
Format of "Narration of Enquiry"

- Grade 10:
1. The function of vitamins
 2. The theory of spontaneous generation
 3. Where do microorganisms come from?
 4. Controlling harmful microorganisms
 5. Microorganisms and disinfectants
- Grade 11:
6. Evidence of gas exchange in lungs
 7. Constant temperature and variable temperature in animals
 8. Maintaining water balance

9. How the urinary structures work
 10. The kidney as a regulatory organ
 11. The knee jerk reflex
 12. Observation of frog Nervous system
 13. Constancy of O₂ and CO₂ in the atmosphere
 14. CO₂ exchange in plants
 15. Proof of CO₂ uptake by green plants
 16. Plants and Oxygen
 17. Plants and light energy
 18. Tracing the carbon atoms in sugar formation
 19. Tracing the origin of O₂ given off by plants
 20. Model to demonstrate the effect of size and number of stomata on...
 21. Effect of different concentration of Auxin in the development of plants
 22. Effect of photoperiod on short-day plants
 23. Effects of photoperiod on long-day plants
 24. Plant growth hormones
- Grade 12:
25. Sexual reproduction in fungi
 26. Darwinist theory of evolution³

³. The writer believes that + unit 16 (evolution) is the most complete unit developed following the narration of enquiry format. The other specific descriptions of enquiry (27-30) are included so as to reinforce the evidences (arguments) on which Darwin's theory is based.

27. Discontinuous variation
28. Natural selection in *Biston betularia*
29. Phenotypic variation
30. Mutations
31. The origin of life
32. Freshwater conservation

Table 3.1.3-B: List of Biologists to Which References
are Made by the Texts

- | | |
|-----------|--------------------------|
| Grade 9: | 1. Linnaeus |
| Grade 10. | 2. Stanley Miller |
| | 3. Lois Pasteur |
| | 4. Francisco Redi |
| | 5. Lazaro Spallanzani |
| | 6. Robert Koch |
| | 7. Eduward Jenner |
| | 8. Antony Van Leewenhook |
| | 9. Van Helmont, J.B. |
| | 10. Alexander Fleming |
| Grade 11: | 11. William Harvey |
| | 12. Pavlov |
| Grade 12: | 13. Lamarck |
| | 14. Kettlewell |

15. Darwin
16. Canon
17. Lysenko
18. Lederberg
19. A.I. Oparin
20. E.L. Tatum
21. Harold Urey
22. Stanley Miller

In most of the narrations, the problem, experimental procedure and the results (data) are given. Very few have no stated experimental procedure. These correspond to the "uncontrolled" type of experiment (activity) mentioned in the previous section. For 28 of the topics listed in table 3.1.3-A (except numbers 12,27,31,and 32), the experimental procedure is diagrammatically illustrated to the student.

It would be recalled that questions based on such materials - type II-A questions - have been found to be abundant in the upper grades. This is consistent with the relatively large number of such topics found in the two upper grades as compared to those in the lower grades.

Now, the question is how much such material should be included in a given text to be labelled as suited for enquiry-centred teaching of biology. As this is only one aspect of the issues of the approach it should not, of course, be taken as the sole criterion. However, the writer believes that the best rule with regard to inclusion of such materials is, if the topic or content area selected to be included in a biology course is well-suited to be developed in a historical manner,

it should be so. The detail into which the treatment should go depends on the nature of the topic and the specific needs of students for whom the course is designed. Thus, when the number of topics developed in this manner (table 3.1.3-A) is compared to available content area for which such an approach could have been taken, and not the total number of topics included in the 15 units studied, one could say the texts (especially those for grades 11 and 12) share a fair share of narrations. Due to their very nature, such topics are available only in some content areas (such as genetics, physiology and evolution).

As indicated in section 3.1.2., the biology texts determine not only the content but also the organization of the course, and thus dictate the instructional procedure to be followed by the teacher. The topics listed above are no exceptions. A problem is posed, followed by the experimental procedure and the results found. This is then accompanied by question of the II-A type and text discussion. Viewed against the model by which the texts were evaluated, such topics are perhaps the most suited for its use. This, however, depends on how the teacher conducts lessons based on such topics; since, as Romey (1968:89) points out, while it is "entirely possible to lecture" in the enquiry mode; "teachers who stress activity and discussion may or may not teach" in the enquiry mode.

As pointed out in the literature review, this specific way of helping students understand the process of biological enquiry is probably the most effective of all the ways when

considered from a practical point of view or against the practical situations in our secondary schools. In view of this the writer feels it deserves more elaboration.

It has been reiterated that investigations (observation and experimentation) form the heart of science teaching. Referred to by some science educators as the "active method" of science teaching (Oria, M. and Baja, R., in UNESCO, 1966, 77-78), it involves the actual gathering of data by students as part of their search for a solution to a problem posed by the teacher or text. However, due to several reasons among which time and equipment requirements are the most important ones, conducting practical activities as required becomes very difficult and at times virtually impossible. This is perhaps nowhere more true than in our own country. This problem could partially be overcome by including enough material, in texts, of the type described above on which a biology teacher may base his teaching. We must not, however, lose sight of the fact that this approach, sometimes called the "historical method" of science teaching (Oria and Baja, Ibid; Berger, M; in Romey, 1968:227-232), doesn't replace the actual gathering of data by students. Nonetheless, since the procedure followed when a class engages in such topics is truly "scientific", Oria and Baja (Ibid) argue that "contrary to frequent assertion, it is possible to be "very experimental" and perfectly dogmatic; the active method could be used without materials." Elaborating on their position, they add that:

It [the historical method] follows in the footsteps of scientists who contributed to solving these [biological] problems. In most cases, these footsteps stretch out in a logical fashion: from simple to complex, from observation to hypothesis, from hypothesis to experiment, and from experiment to law. The student thus participates in the difficulties and demands of research in biology by stepping in the footsteps of those who have made headway in biological research. He sees the research mentally instead of being satisfied with just approaching its results....The historical method, which dissects the mental processes of the scientist, is thus applied logic.

This particular method could thus have an invaluable advantage in that it helps students understand the scientific spirit of enquiry without the material, equipment and long time requirements that arise when students are made to engage in direct laboratory experiences.

In addition to its practical advantage, research studies have also shown that students taught following this method had changed their wrong conception of science and scientists (Baumel and Berger, in Romey, 1968:235). As reported by the researchers, a typical comment received from one of the students who participated in the study was ""I got to feel as if I was in the scientist's shoes, making all the experiments and decisions."" (Ibid)

3.2. Teachers' Opinion on the Practicality of the Present Biology Curriculum

The proper implementation of the Biology Curriculum for Ethiopian Senior Secondary Schools Vis-a'-vis the objectives and the nature of the course thus developed was evaluated in two major ways. These were (1) survey of teachers' opinion on

the practicality of the Biology Curriculum through a questionnaire and (2) observation of the actual teaching-learning process in biology classrooms by using a classroom observation schedule designed for the purpose. This section presents analysis and discussion of data collected through the first method. Results of classroom observation are presented in section 3.3.

A questionnaire consisting of 17 items was distributed to 40 teachers in the five schools where the study was conducted. The questionnaire was completed by two randomly selected teachers from each grade, making a total of eight teachers per school. Among the 40 respondents, 36 were males and 4 females. Usable returns were received from all the respondents. A more detailed information on the respondents characteristics is given in tables 3.2.A and 3.2.B.

Table 3.2.A Number of Respondents in Each School and
Average Number of Years of Service

No	School	Number of		Year of service				
		Teachers						
		Male	Female	1-5	6-10	11-15	16-20	21-25
1	Addis Ketema	7	1	-	3	4	1	-
2	Nefas Silk	7	1	-	-	8	-	-
3	Kokebe Ts	6	2	-	-	8	-	-
4	Entoto	8	-	-	2	4	2	-
5	Medhanialem	8	-	-	1	6	1	-
Total		36	4	-	6	30	4	-

Table 3.2.B Academic Qualification of Respondents

No	School	M.Sc	B.Sc.	Diploma	Other
1	Addis Ketema	1	5	4	-
2	Nefas Silk	-	4	1	-
3	Kokebe Ts	1	6	3	-
4	Entoto	1	4	1	-
5	Medhanialem	-	5	4	-

The above two tables indicate a reasonably qualified staff-mix in the schools studied and a rich experience in the teaching of the subject. Seventy-five-percent of the respondents have served for 11-15 years. Although table 3.2.A. does not show the number of years of teaching experience for each individual teacher, it varied from 6 years (in Medhanialem) to 19 years (in Entoto).

Items 5, 6 and 7 of the questionnaire sought to find out teaching load of respondents. The results are summarized in table 3.2.C.

Table 3.2.C. Teaching Load of Respondent

No	School	Average No of Periods/week	Average No of Section/ teacher	Average class size
1	Addis Ketema	25	6	82
2	Nefas Silk	24.5	6.5	78
3	Kokebe Ts	24.5	6	87
4	Entoto	22	6	75
5	Medhanialem	23	7	82

The rest of the items in the questionnaire were designed to survey the presence of an enquiry approach to biology teaching or lack of it. The questionnaire especially focused

on practical constraints related to implementation. Teachers' conception of the objectives of biology teaching, their use of the enquiry approach and/or problems limiting its use, and the types of other methods were surveyed through items 8-13. Items 14-17 deal with specific aspects of the textbooks, practical activities and teachers' suggestions on ways of improving biology teaching at the Senior Secondary School Level.

Item 8^{of} the questionnaire asked respondents to list the objectives of biology teaching at this level. The following were mentioned with varying degrees of frequency:

- a) develop interest in and appreciation for plants and animals.
- b) understand the importance of maintaining ecological balance; i.e., conservation of natural resources.
- c) develop better food habits based on scientific understanding of foods and their composition;
- d) understand the causes and methods of disease control.
- e) avoid beliefs that are not scientific.
- f) develop rudiments of medicinal and agricultural concepts.
- g) produce researchers that could work in the Ministries of Agriculture and Health.
- h) produce future biology teachers.

It is clear that unless the approach or basic assumption that underlies a given curriculum is properly understood by

the teachers who are the real implementers, any effort geared toward achievement of the objectives might be in vain. It is worth noting that no objective was mentioned by the respondents related to the development of scientific enquiry skills. All the objectives listed are practical; objectives that have personal and social significance. Although these have no less importance for the biology student, especially for the majority of school leavers who do not have the opportunity for further study at a tertiary level, teachers' failure to mention objectives related to the development of scientific enquiry skills and attitudes has a crucial implication. That is, the objectives which are accepted by the classroom teacher are more likely to "describe the actual direction of biology teaching than those postulated by National Committees" (Hurd, 1961:181). While the present Biology Curriculum has been designed following the enquiry approach, albeit some deficiencies, the respondents do not seem to be sufficiently familiar with it. As a consequence, the instructional objectives formulated, the teaching procedures selected and the evaluation techniques might be faulty. Rutherford's observation on this issue will help sum up this point (in Romey, 1968:270):

.....From this there follows an inescapable conclusion regarding the feasibility of teaching science as enquiry: science teachers must come to understand just how enquiry is in fact conducted in the sciences. Until science teachers have acquired a rather thorough understanding in the history and philosophy of the sciences they teach, this kind of understanding will elude them, in which event not much progress toward the teaching of science as enquiry can be expected.

Table 3.2.D: Teachers' Use of the Enquiry Approach

Alternative	No of respondents	percent
Often	8	20.0
Occasionally	13	32.5
Seldom	5	12.5
Never	14	35.0
Total	40	100.0

Table 3.2.D. shows that the largest proportion of teachers (35%) never use the approach. The writer believes that the proportion of teachers who said they use the approach either "often" or "occasionally" is highly doubtful for two reasons. The first is that among the eight teachers who said they use the approach "often", five had been observed by the writer while conducting actual lessons. Although the lessons observed were lecture sessions, they were not even remotely close to what might be called enquiry teaching (see section 3.3.). Secondly, in response to item 12 of the questionnaire, 34 teacher (85%) said student laboratory work (virtually in the form of demonstrations) follow, and not precede, the classroom coverage of a principle or topic. This shows the existence of discrepancies between teachers' responses to the above item and other items that indirectly surveyed the use of the enquiry approach.

For the item which asked respondents to list reasons for not locating the enquiry approach frequently, a total of 13 reasons were given with varying degrees of frequency. These are listed in table 3.2.E.

Table 3.2.E: Reasons Given by the Respondents for Not Using the Approach

Reason	No of Times Mentioned	Percent
1 large class size	32	18.3
2 excessive teaching load	24	13.7
3 the approach, as presented in the textbooks, is tied to practical activities	12	6.9
4 the answer to most of the questions in the texts could not be found easily (would take much time).	8.	4.6
5 shortage of time for pre-lab preparation demonstrations and experiments	9	5.1
6 shortage of expendable materials and equipment	27	15.4
7 inefficient utilization of already available materials and equipment	6	3.5
8 capacity of the laboratories	9	5.1
9 absence of competent laboratory assistants	14	8.0
10 vast content to be covered	18	10.2
11 failure to take into account the ability of teachers to use the texts as required	4	2.3
12 failure to take into account the practical constraints related to implementation	4	2.3
13 students' low intellectual ability and their ever diminishing interest to learn	8	4.6
Total	175	100.

The reasons listed in table 3.2.E as being the principal factors for impeding the proper implementation of the biology curriculum vary from those that are general; i.e., applicable to the general educational system at this level, to those that are specific to biology or, as the case may be, to other science subjects too. Each of the reasons are discussed together with their supporting data.

1. **Large Class Size:** According to the writer, this is the single most important factor responsible for the huge gap between the envisaged standard of biology teaching and the actual practice. Large class sizes are a result of Student Overpopulation or as some people prefer to call it "Student Population Explosion" (Table 3.2.C).

2. **Heavy Teaching Load:** This is reflected by class size, total number of periods per week and the total number of sections which a teacher has to handle. A glance at table 3.2.C. raises the question of how the overburdened teachers can effectively use the various methods, principles and techniques of teaching called for by the biology curriculum; i.e., appropriate for achieving the objectives of teaching biology as enquiry. Can a teacher properly use, for instance, principles related to individual differences when he is responsible for six or seven sections each containing 80-90 students? Can he get enough spare time to plan his lessons carefully when he has to teach 23 or more periods per week? At the same time teachers are often criticized for failing to make the necessary effort to enrich their teaching. The

result seems, however, a combination of such insurmountable problems which created a feeling of helplessness and thus indifference in our teachers. It is probably possible to justify most teachers feelings that they are fighting a losing battle.

3 and 4. Presence, in texts, of too many practical activities and questions linked to them: This has already been discussed in section 3.1. while the present conditions in our Senior Secondary Schools have virtually hindered any modest teaching of science, which requires more than the indispensable chalkboard and desks, the unrealistic nature of the textbooks has contributed in aggravating the problem. If students are not given the opportunity to seek answers to the questions by performing the corresponding practical activities, it would be difficult to say students have taken a biology course.

5. Shortage of time for pre-lab preparation of demonstrations and experiments: As the teachers are heavily overloaded during their normal teaching shift, the necessary preparation before the commencement of a practical activity may not be done unless the teacher is willing to sacrifice some time during his free shift. This also depends on the cooperation of and proper coordination with the laboratory assistant.

6. Shortage of expendable materials and equipment: In all the schools where the study was conducted, expendable materials such as chemicals, test tubes are chronically short. No school has annual budget allocated for purchase of

materials and equipment. All of the respondents, in fact, said that they are not sure whether their schools have annual budgets or not. What seems a realistic response came from laboratory assistants and biology department heads. According to them, there is no fixed annual budget; but whenever a certain material or equipment is found necessary or when some of the expendable materials run out, the laboratory assistant requests the administration for funds to purchase what is required. This seems a poor procedure for the writer, since the acquisition of new materials and facilities on a regular basis would be impaired.

7. Inefficient utilization of the already available materials and equipment: Granted, teaching biology without some kind of laboratory would not be effective. However, the mere presence of a laboratory doesnot at all guarantee its use. At times, shortage of expendable materials and equipment (other factors being constant) could cripple the practical aspects of biology teaching. The case in the schools studied, however, seems that even if the laboratories are well-furnished, it is possible to safely doubt their proper utilization. There are three evidences for this assertion: (1) as the number of students per section and the number of sections is very high, individual and small group experiments are extremely difficult to conduct, leaving teacher demonstration as the most viable option. This is apparent in most teachers response that they use teacher-demonstrations as the principal procedure for practical activities (32 or 80%). Only 5 teacher (12.5%) said they use laboratory activities in

which 4-5 students are assigned per group. No teacher employs individual student experiments or students paired for activities. 2) 25 (62.5%) of the respondents said that there is not a regularly scheduled period for laboratory work. According to these teachers, it is not the specific topic or content area (as required by the curriculum) that dictates conducting practical activities, but the availability of the required material and equipment, time and the presence or absence of the laboratory assistant. 3) In section 3.1. of this chapter, it has been shown that only 68 (40%) of the practical activities included in the 15 units analyzed could be completed in less than an hour. As a result, the time factor immediately rules out the possibility of conducting practical activities that require more than an hour. Although activities that require 1-2 hours (18%) could be conducted by arranging double periods, no such provision was found in all the schools. One can therefore conclude that, because of these problems, the question of how well the laboratories are equipped might be secondary, when seen against the little use made of what is available at present.

8. Capacity of the laboratories: Except Entoto, all the schools have biology laboratories. Each were made to accommodate 30-35 students at a time. If they are used at present, they will have to accommodate more than twice their normal capacity. This immediately rules out the use of individual student experiments and students paired for activities.

9. Absence of competent laboratory technicians: All

the schools have an employed laboratory assistant. However, they are responsible for the three laboratories: biology, chemistry and physics. This practice is obviously inappropriate both on grounds of qualification and availability of time for pre-lab preparation of demonstrations and experiments. Moreover, according to information obtained from biology department heads of the schools, there is no good rapport between the biology staff and the laboratory assistant. The following were mentioned as the responsibilities of a laboratory assistant:

- a) handling laboratory facilities with care.
- b) being available at any time during working hours (it seems that the labs sometimes get locked when teachers want to use them).
- c) providing full cooperation whenever requested by teachers in the following ways:
 - i) lending the necessary materials and equipment for teachers; such as when teachers want to make in-class demonstrations.
 - ii) helping the teacher in setting up apparatus for demonstrations or student experiments.
 - iii) cleaning and ordering materials and equipment used at the end of an activity.
 - iv) informing the Administration about the status of materials and equipment in the lab.

v) guiding members of the biology club (in schools where they exist) and

vi) writing annual report to the administration.

10. vast content to be covered: While the number of periods available for biology is inadequate, the amount of content to be covered, especially in grade 11, is too much. Teachers of grades 9 and 10 have only two periods per week and approximately 45 hours of contact per year. In grades 11 and 12, there are three periods per week and approximately 60 hours of contact. This estimate includes public holidays and unforeseen interruptions in the schools' normal schedule. In connection with item 14 of the questionnaire, which asked respondents about coverage of content, the majority of respondents (62%) affirmed that time is not at all enough to cover the allotted content. Among these eight (33%) were teachers in grade 11. Ten teachers (25%) said there is enough time. What is interesting is the proportion of teachers (6 or 15%) some of whom made additional comments, who said that time is not enough to finish the allotted content but there has never been backlog of content at the end of every normal semester or year. These teachers asked: how much content can be covered if we were to follow the enquiry approach as required by the curriculum when finishing it is very difficult even in the present way of teaching it? One may therefore conclude that the vast amount of content to be covered, coupled with the small number of periods available, pressures teachers to disregard student learning; their emphasis being toward coverage of content.

11. Failure to take into account the ability of teachers to use the texts as required: Although the composition of Senior Secondary School biology teachers with regard to years of experience exists along a continuum, the number of those who begun teaching before the present biology textbooks were released is not insignificant. The present textbooks were issued for use between 1974-1980. As a result, unless teachers who completed their college work before the textbook(s) they are using now were written have had the opportunity to be oriented toward the best ways of implementing them, together with the rationale behind, their implementation would definitely be short of the desired standard. This would hold true even if all the other necessary conditions are fulfilled. There are two ways of doing this: (1) to involve teachers during the development and tryout phase of the new curriculum and/or (2) by organizing workshops and seminars on a regular basis. Although the writer is not exactly sure about the first mechanism, opportunities for professional rejuvenation through participation in programmes designed for the purpose has been meagre. Except for a total of 5 teachers (12%), one of whom had the opportunity to participate twice, the rest have never participated in such programmes ever since they left college. Considering the experience of the writer in the pre-service training of biology teachers, the Senior Secondary School biology curriculum has not also been used as a basis in their training. This is perhaps one of the major issues that should be considered by future researchers in the effort to improve pre-service training of biology teachers at A.A.U.

It is worth noting here that teachers have indeed been unable to implement the curriculum as required due to reasons out of their control. However, as the above discussion might have suggested, teachers may not be sufficiently familiar with the rationale and objectives of the biology course. This indicates teachers may not employ the appropriate strategies and techniques. This means many teachers employ whatever method they have been exposed to. This assertion has partially been substantiated by teachers' responses in connection with item 15 of the questionnaire, which asked the type of methods used by the respondents. The following were mentioned in decreasing order of frequency:

- a) pure lecture (involving no visual aids).
- b) lecture involving teacher-made diagrams.
- c) explanation in connection with models and charts.
- d) textbook recitation and in-class exercises.
- e) demonstrations which can easily be made in class.
- f) demonstrations in which, whenever possible, students are taken to the laboratory.

12. failure of curriculum developers to take into account the practical constraints related to implementation: This is perhaps one of the most important reasons for the deplorable state of biology teaching at present. At the time when the biology curriculum was designed, the school situation might not have been as worse as today; particularly with respect to student population (class size) and the number of periods available for the subject. However, since then school working conditions have progressively deteriorated making the

curriculum ever unrealistic or irrelevant. As the respondents have properly put it, the individuals involved in its development had failed to project possible future problems. And as if to make things worse, the texts have not been substantially revised ever since they were released.

13 The last reason is too general a problem and could be an area of interest for further research. What is important here is that the problem has had a tremendous negative impact on the performance of teachers, leading to an "I don't care" attitude. Coupled with other problems teachers have to face, this problem has significantly contributed in sapping what little motivation they have.

The last item of the questionnaire asked respondents to give their opinion on what should be done to improve the quality of biology teaching at Senior Secondary School level. These suggestions are summarized below:

a) The available amount and quality of materials and equipment necessary to effectively implement the biology curriculum is below the minimum requirement. Moreover, the amount of content to be covered compared to the available time has made effective implementation very difficult. Therefore, the concerned authorities should either try to fulfil the conditions necessary for effective implementation or, if this is not possible, design a new curriculum that takes into account the present practical problems with regard to the student population, shortage of materials and equipment etc.

b) Any such endeavour toward revising or changing the present curriculum should by no means be done without the participation of biology teachers.

c) The amount of content to be covered should be reduced, This could be done by discarding unrealistic experiments from the texts and including, instead, more textbook information.

d) As far as possible, biology laboratories should be reasonably well-equipped and should have their own highly skilled laboratory assistants.

e) Arrangement should be made in such a way that students can use their free shift for practical activities.

f) The number of periods per week allotted for biology in each grade should be raised by at least two periods from the present.

g) Every effort should be made to reduce teachers' load.

h) Teachers should be given regular opportunities to participate in workshops and seminars.

3.3. Analysis of Classroom Interaction

The third and last, but perhaps the most important, method used to assess the presence of an enquiry mode of biology teaching was observation of the actual teaching-learning process using a classroom observation schedule.

It is known that several observation instruments have been developed to study classroom interaction since this mode of classroom research became the vogue some three decades ago. Developing a new or revising an existing instrument would thus

be unnecessary if one can find an instrument developed for similar purposes. However, among the very few observation instruments known to the writer, none have been found to be best suited for the specific purpose which this part of the study set out to accomplish: assessing the presence of an enquiry-cantered teaching of biology within the confines of the four walls of the classroom. In other words, what is required was an observation instrument designed to assess specific properties of classroom verbal and non-verbal behaviour that could indicate the presence of an enquiry-cantered teaching of biology or lack of it. In the search for such an instrument, Eggleston's "Science Lesson Observation Schedule" (in Bennet and McNamara, 1979:88) was found to be the closest to the purposes of this study. However, as the instrument was designed for, and used in, British Schools, it was found necessary to prepare an improved observation schedule, based on the ideas of Eggleston, that would be realistic in the Ethiopian context.

The first step in the development of such an instrument involved an extensive review of the literature to locate teacher and student verbal and/or non-verbal behaviours which are features of classrooms that engage in enquiry teaching and learning. From this effort emerged several tentative categories based on which a preliminary schedule was designed.

A pilot study conducted using this schedule, however, necessitated a substantial revision. Since the categories originally included in the observation schedule were only those related to an enquiry mode of teaching, it was found out

that the instrument was not inclusive enough to describe what actually happens in the classroom. In other words, the writer at this stage was convinced that if an enquiry mode of teaching is not to be found, it should be able to describe what actually exists in its place. The schedule was thus modified in such a way that it will be possible to record behaviors that are not related, or even opposed, to features of enquiry teaching. As a result, a classroom observation schedule consisting of 5 major categories and 36 minor-categories emerged. The final schedule is given in appendix III.

In an attempt to establish the reliability of the observation schedule, the writer trained ^a colleague graduate student in the department of Biology to use the instrument. This involved detailed discussions and sample observations until the coefficient of agreement (ratio of the number of categories on which the observers agree to the total number of categories marked) reached 0.8 or above.

The actual coding of verbal behaviour was done every minute. During each minute of classroom discourse, a mark is placed in the appropriate space when an utterance is heard belonging to that category. If during ^a particular interval, no relevant utterances are made that can be classified in one of the categories, then the space remains empty. It is also possible that teachers and/or students make one or more utterances in any given minute. In such instances the observer makes two or more marks in the corresponding category.

The sample consisted of 20 randomly selected biology teachers from the five Government schools. Except three teachers who were observed only twice due to unforeseen interruptions in the schools' normal schedule, each teacher was observed three times. Every observation was made by the writer himself; i.e., no trained observers were involved in the actual collection of data. Since five teachers were observed in each grade (one in each of the five schools), a total of 57 lessons of approximately 40 minutes duration were available for analysis at the end of the observation period.

As indicated above coding was done every minute, and since a total of 57 lessons were observed, the total number of minutes observed, the total number of minutes observed was 2280 (57×40). However, not all this time was spent in classroom verbal interaction or non-verbal behaviour (activities in which verbal interaction is halted) indicative of enquiry teaching. Breakdown of the amount of time spent in different activities is given below:

Table 3.3.1. Amount of Time Spent in Different Activities

Behaviour/Activity	No of minutes	Average No of minutes/lesson	% of Total
Note giving/taking	682	12	30.0
Time wasted	227	4	10.0
Verbal interaction	1371	24	60.0
Total	2280	40	100.0

In table 3.3.1, "time wasted" refers to unused time usually ranging from the first 3 - 6 minutes. This happened in those observations conducted during the first period of the afternoon shift or those coming just after break (the 4th period). There were also few instances in which the teacher was late. Thus, an average of 4 minutes/lesson were wasted.

Since the objective of this part of the study was to describe the pattern and nature of verbal interaction that occurs in biology classrooms, the total average frequency of use of the various categories are expressed in terms of percentages. The results are then compared between categories and among the grades. This would then be evaluated against the Biological Science Enquiry Model. However, before a discussion of the dominant pattern and nature of interaction in the observed classrooms, it would be in order to depict a hypothetical flow of classroom interaction expected to occur if the teaching were to follow an enquiry mode similar to that of the Biological Science Enquiry Model. This is shown in figure 3.3.1.

Figure 3.3.1. Expected Pattern of Classroom Interaction
Based on the Biological Science Enquiry
Model

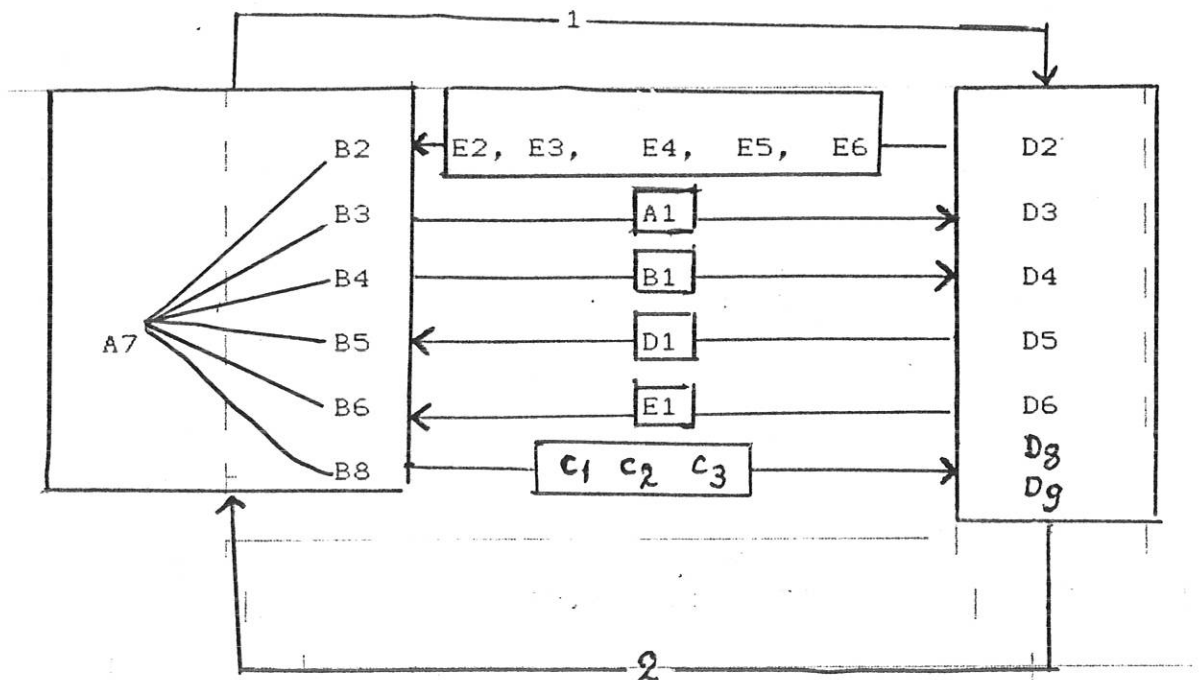


Figure 3.3.1. depicts the pattern of classroom interaction expected to occur if teachers were to follow an enquiry mode of teaching similar to that of the Biological Science Enquiry Model. In this pattern of classroom discourse, teacher poses a problem (A7) which may require students to formulate hypotheses (B2), interpret/analyze given or generated data (B3), draw conclusions/generalizations (B4) etc. Students would

then react depending on the nature of the problem posed (D2 - D9). In the process of solving the problem posed, it is possible that teacher asks knowledge questions (B1), students seek teacher's help on factual information (E1) and teacher provides essential information (A1) necessary to solve the problem as required. Teacher's efforts to sustain the enquiry process thus started would then be accomplished by a proper use of categories C1, to C3. A correct use of these categories would help the teacher create what is called an appropriate "classroom environment".

It is worth noting here that this pattern of interaction is not expected to occur under all circumstances and in all kinds of lessons. For, this would mean enquiry teaching should completely replace didactic teaching. What is required is, as R. Shushman (in Nelson, 1969:219) point out:

to find ways of keeping enquiry alive without discarding the invaluable accumulation of knowledge...and there are many times and situations where didactic instruction is more appropriate and other times when enquiry would best serve the needs of the learner.

Thus, the pattern shown above might be used throughout a given lesson; i.e., the teacher may present an area of investigation or problem at the beginning of the lesson, all subsequent activities of the class (discussion, laboratory activities etc.) being geared toward solving the problem. It is also possible that this pattern of interaction may not occur at all or may

be used several times during a single class period interrupted by didactic teaching.

Tables 3.3.2 - 3.3.5. present the average frequency of occurrence of the various categories. As mentioned earlier, note that the figures presented in the following tables are averages of all the lessons observed in a given grade.

Table 3.3.2: Average Frequency of Occurrence of
"Teacher Talk" and "Teacher Question"
Minor Categories

Category						
Grade	A1	A2	A3	A4	A5	A6
9						
(N=14)	102	3	7	8	14	2
10						
(N=15)	132	-	2	13	2	-
11						
(N=13)	58	6	16	19	-	4
12						
(N:15)	90	7	7	32	5	2
Total	382	16	42	72	21	8
% of total	70.60	2.96	7.71	13.31	3.88	1.48

II) Teacher Question

Category								
Grade	B1	B2	B3	B4	B5	B6	B7	B8
9								
(N=14)	108	2	-	-	12	1	-	-
10								
(N=15)	58	-	-	2	9	-	-	-
11								
(N=13)	30	4	2	3	24	5	-	-
12								
(N=15)	47	11	8	7	16	2	-	-
Total	243	17	10	12	61	8	-	-
% of								
Total	69.24	4.84	2.84	3.42	17.38	2.28	-	-

Table 3.3.3: Average Incidence of the 9 Minor
Categories Under " Student
Talk/Activity"

Category									
Grade	D1	D2	D3	D4	D5	D6	D7	D8	D9
9									
(N=14)	276	3	-	-	23	-	-	-	-
10									
(N=15)	158	-	-	1	16	1	-	-	-
11									
(N=13)	63	2	2	1	32	4	-	-	-
12									
(N=15)	28	5	6	2	10	4	-	-	-
Total	525	10	8	4	81	9	-	-	-
% of									
Total	82.41	1.56	1.25	0.64	12.72	1.42	-	-	-

A close inspection of the above two tables reveals that the most frequently used categories for all teachers observed were A1 (teachers' statements of biological information), B1 (teachers' questions belonging to the knowledge level) and D1 (student talk

predominantly in the knowledge category). Of the total instances of recorded verbal behavior under "teacher talk", 382 (70.6%) were teachers' statements of biological information. The other five minor-categories (A2 - A6) together accounted for 159 (29.4%) of the instances. In addition, the relatively high incidence of A3, A4, and A5 compared to A2 (hypotheses) and A6 (experimental procedure), suggests that teachers tend to make statements containing interpretation/analysis, conclusion and application without showing the data from which they were derived.

The tables further reveal that 243 (69%) of the problems posed by the teacher were to be answered by mere recall of information (B1). Among the other minor-categories (B2 - B8), B5 was the next most frequently used. The high incidence of this minor category (B5) is explained by the fact that teachers asked several questions that require students to give examples to a concept, principle etc., discussed by the teacher. Tables 3.3.2. and 3.3.3. also reveal an important relationship between the nature of the problem posed by the teacher (B categories) and student talk made nearly in response to the problems posed (D categories). Prominent in this relationship is that the frequency of D1 and D5 categories exceeds the frequency of B1 and B5; i.e., the number of responses offered by students (D1 and D5) is by far larger than the corresponding number of questions. This relationship exists because to every teacher question requiring recall of information or

application of facts and principles to new situations, 2 - 3 students respond at a time. This again is a result of the fact that the questions (1) have been open-end and in the knowledge category (e.g. What are the methods used to control the spread of flies?), (2) required students to give several examples to a single teacher question (e.g. Can you name plants whose leaves serve as food for man?), or (3) the response offered by a student was wrong, the teacher thus inviting the class for the correct answer. Contrary to this, a comparison of the total occurrence of B2, B3, B4 and B6 categories to the corresponding total incidence of D2, D3, D4 and D6 categories shows that, on average, almost one response was offered to each teacher question. The relationship between B2 (teachers' hypotheses questions) and D2 (student statements of hypotheses), and B6 (teacher questions of experimental procedure) and D6 (student talk in response to such questions) is particularly striking. That is, few responses were offered by students compared to the total number of questions in each corresponding category. This indicates teachers tendency to give answers/solutions to questions/problems posed by themselves when the problems happened to be just those which would have initiated an enquiry mode of teaching. It also shows teachers' failure to probe/seek clarification (C2), the use of which would have been a step further in this direction. Even more importantly it shows that while few teachers begin their lessons by

posing problems which, if pursued, would have resulted in an enquiry mode of teaching, they failed to sustain it.

As for practical activities, it hardly had a place in the teaching of the subject. This is evidenced by the near absence of instances in which sub-categories B7, B8, D7, D8, D9 and E7 were used.

As the above discussion might have suggested, the teaching of biology is far from the actual methodology suggested by the Biology Curriculum. The classroom teaching (verbal interaction) is marked by a majority of factual questions leaving little or no room for enquiry and problem-solving. This form of instruction relies heavily on rote learning and passive comprehension of factual information.

Teachers' attempts at creating what is called an appropriate classroom environment could be discerned by a close examination of tables 3.3.4. and 3.3.5.; although the reader might have already formed an opinion on this aspect of classroom interaction from the foregoing discussion.

Table 3.3.4: Average Incidence of the Five Minor-Categories under "Teacher's Direction of Enquiry Processes"

Category					
Grade	C1	C2	C3	C4	C5
9					
(N=14)	196	2	-	11	22
10					
(N=15)	94	-	-	7	17
11					
(N=13)	52	-	1	5	12
12					
(N=15)	39	3	-	7	3
Total	381	5	1	30	54
% of					
Total	80.54	1.06	0.64	6.34	11.42

As table 3.3.4. shows, among the (c) categories, C1 is by far the most frequently used. Comparison of the frequency of use of this minor-category with B1 (table 3.3.2.) and D1 (table 3.3.3.) minor-categories reveals the existence of a relationship between the

frequency of occurrence of the former and the latter two. This relationship is explained by teachers' use of category C1 (praises/encourages) with an invariable "yes!", or "good!" following correct response of a student. However, note that the average frequency of use of C1 is by far lower than the number of responses offered by students. This is a result of (1) teachers' criticism/disapproval of a wrong answer (C5), (2) teachers' failure to give any form of feedback following a correct or wrong response of a student, and (3) teachers' repetition of correct responses of students, which only confirms that their responses have been right.

Attempts at probing/seeking clarification (C2) and evaluation of student responses (C3) were extremely rare. This would not be difficult to understand given teachers' tendency to ask knowledge questions which usually have predetermined answers. In those instances in which student responses had been wrong or partially incorrect, criticism/disapproval (C5) had taken the place of C3 (evaluation of student responses) and C2 (probing) seeking clarification).

Table 3.3.5. also shows that the majority of questions asked by students were in the knowledge category (E1). To few of the questions that needed explanation (E2 - E6) teachers responded by giving straight answers (C4) instead of reversing (e.g. "How would you find out ?") or relaying it back to class.

Table 3.3.5: Average Incidence of the 7 Minor-categories under "Student Questions"

Category							
Grade	E1	E2	E3	E4	E5	E6	E7
9 (N=14)	8	1	-	-	-	-	-
10 (N=15)	6	-	-	-	-	1	-
11 (N=13)	1	1	1	-	-	4	-
12 (N=15)	5	3	-	-	-	-	-
Total	20	5	1	-	-	5	-
% of Total	64.51	16.51	3.23	-	-	16.13	-

The classroom climate/pattern of interaction described above clearly shows the absence of two important components of the Biological Science Enquiry Model: "Social system" and "principles of reaction". It is also possible to say that, depending on ones perspective, these components are present but in highly misdirected way; i.e., contrary to the requirements of the model.

Chapter Four

4. Summary, Conclusion and Recommendations

4.1. Summary

4.1.1. The object of this study was to evaluate the Present Biology Curriculum for Senior Secondary Schools of Ethiopia and its implementation in light of the Biological Science Enquiry Model and thereby see whether or not it is in line with modern trends in science teaching.

4.1.2. For this purpose, the questions, practical activities and "narrations of enquiry" included in even-numbered units of the four textbooks were analysed. Evaluation of its implementation involved questionnaire survey on various aspects of the teaching of the subject and observation of the actual teaching-learning process in biology classrooms.

4.1.3. Among the 1052 questions analysed, 593 (56.4%) were activity-bound (questions to be answered by performing an activity), the rest, 459 (43.6%) being activity-free (questions which do not require conducting practical activities). Again, among the total number of questions analysed in the 15 units, 370 (35%) were knowledge questions, followed by comprehension (276 - 26%), analysis (178 - 16%), application (152 - 14%) and synthesis (54 - 5%) questions respectively. Evaluation questions shared the least proportion (22 - 2%).

4.1.4. The total number of practical activities included in the 15 units was 167. Among these, the largest (68) - 40% could be completed in less than an hour. Thirty-one (18%) activities could be completed within 1 - 2 hours. The rest, 68 (42%), require time ranging from 1 - 2 days upto 14 days or more.

Except few cases, the practical activities included in the units analysed help students little to understand

the process of biological enquiry. This is because the texts use a laboratory model in which the amount of student involvement has been reduced to a minimum.

4.1.5. Except the two lower grades (9 and 10), grades 11 and 12 contain sufficient material developed following the "narration of enquiry" format. In such topics and sub-topics, the texts describe actual or hypothetical experimental results followed by questions which ask the student to formulate hypotheses, interpret/analyse the results or draw conclusion.

4.1.6. The majority of teachers surveyed responded that they scarcely use the enquiry approach in their day-to-day teaching. The reasons given for not using the approach vary from those that are general; i.e., applicable to the general educational system at this level, to those that are specific to biology or, as the case may be, to other science subjects too.

4.1.7. The verbal interaction is marked by a majority of factual questions leaving little or no room for enquiry and problem solving. For all teachers observed while conducting actual lessons, the most frequently used categories were A1 (teachers' statements of biological information), B1 (teachers' questions belonging to the knowledge category), D1 (student talk predominantly in the knowledge category) and C1 (teacher words of praise/encouragement). There was no recorded instance of use of categories B7, B8, D7, D8, D9 and E7.

4.2. Conclusion

Based on the major findings of the study presented in the preceding chapter, it is possible to safely conclude that the teaching of biology at this level is strictly subject-matter-centered and is far from the kind of pedagogy suggested by the Biology Curriculum. In other words, it has drifted very much further away from the standard envisaged or stipulated by the developers of the Biology Curriculum.

It has been shown that the biology textbooks, which literally serve as the sole curriculum, overall follow a commendable approach with regard to their ability to help students understand the process of biological enquiry. The texts could serve as "a supply of problem areas of investigation" for a teacher who uses them. However, their implementation has been found to be very minimal at best (verbalism is too rampant). Indeed, the immense distance between real (actual) and mythical pedagogy could hardly be better illustrated. Three major interrelated reasons have been found to be responsible for this.

The first, and probably the most important reason is related to the state of the general educational system in Ethiopia. At present, the student population, compared to available number of teachers and classrooms, is astounding. Teachers of most subjects are heavily overloaded and students, especially those in grades 9 and 10, are required to take up to 14 subjects. These problems that apply to the general educational system at this level have had a direct impact on the quality of biology teaching. Improvement in the other problems specific to the teaching of biology, the writer believes, is subject to changes in problems that affect the general educational system. In other words, even if we are able to produce good biology teachers, design an excellent curriculum, equip well the biology laboratories etc., these general problems are bound to reduce their

contribution in improving the teaching of the subject.

Secondly, the unrealistic nature of the texts (despite their being overall good in as far as they go along with the enquiry approach) with regard to I) the total number of activities included, II) the amount of time required for their completion, III) the amount and quality of materials and equipment needed for their implementation, and IV) the amount of content to be covered (especially in grade 11), has severely compounded the already delicate problem. That is, the curriculum itself has, in part at least, been responsible for the low status of biology teaching.

Thirdly, teachers' unfamiliarity with the enquiry approach, the rationale and objectives of the curriculum, and lack of orientation on the best ways of implementing it seem partially responsible for the state of affairs. Especially, lack of effective modes for classroom discussion, laboratory and questioning strategies, and teachers' unfamiliarity with the most conducive classroom climate for enquiry-centered teaching of biology stand out as the most important reasons among those pertaining to issues related to competency of teachers.

This huge gap between the planned Biology Curriculum and its implementation has, thus, made the actual curriculum students experience totally different from the former. According to Jones and Sherman (1980:554) the "actual curriculum is the one the teacher employs in the classroom. That is the one students

encounter." If the curriculum is the one actually experienced by students, then the existing curriculum for any given subject is the "sum total of decisions made about which activities are included in each classroom" (Ibid).

Based on this concept of the "actual curriculum", one might as well ask, "what constitutes the actual curriculum in biology?" According to the writer it consists of lectures and sporadic demonstrations. Lectures conducted not in the enquiry mode but marked by passive transmission of information. Most of what has been included in the Planned Curriculum remains unexperienced by students. McInerny's aptly described observation (1987:26) on this point will probably sum-up what the above discussion tried to convey:

The best curriculum material is worthless unless it is used effectively by teachers and students. Many well-conceptualized curriculums quickly attain state-of-the-shelf-status because they fail to attend to the realities of the classroom and the background of teachers for whom the materials are developed.

4.3. Recommendations

4.3.1. Meeting the requirements necessary for effective implementation of the present Biology Curriculum seems to be far-fetched. Therefore, either rigorous revision of the present curriculum or developing a new one seems to be an urgent need. In any

case, such an endeavour should take into account the practical problems in schools, teachers' capability to implement them and the needs of students. Bearing this in mind, the revised or new curriculum could take the following form:

4.3.1.1. Prepare a single separate text for grades 9 - 12 containing all the necessary biological information. It is also possible to divide the text into two parts: Part I (volume I) for the two lower grades and part II (volume II) for the two upper grades. If the texts retain their present form (one for each grade), a separate reading material could be prepared.

4.3.1.2. Prepare a separate guide for practical activities. This may also be either single or in two parts depending on which of the above forms have been chosen. The practical activities guide could be prepared in such a way that it contains ample practical activities in a given content area (concept, principle etc.), from which teachers may choose the most feasible ones according to their local conditions and requirements (students' needs)

4.3.1.3. Integration of text discussion and student practical activity could be done by a meticulously planned and

written teacher's guide.

4.3.1.4. It would be highly profitable if a "Biology Teachers' Handbook" encompassing the rationale and objectives of the "Revised" or "New" curriculum, philosophy of science, history of biological ideas, suggestions on teaching specific units etc., is made available to teachers.

4.3.2. If the enquiry approach (teaching biology as enquiry) is still chosen to be the basis of the "Revised" or the "New" curriculum; prospective teachers need to be trained in the major principles of biology, philosophy of science etc., and must understand the process of teaching using the enquiry approach. And if this background is to be provided during Pre-service training of biology teachers at A.A.U., the subject and professional courses offered should be reorganized. This may be worked out by a joint effort involving University biology instructor, school biology teachers and professional science educators.

4.3.2.1. In this regard, establishment of a permanent sub-committee within the Biological Society of Ethiopia composed of the groups mentioned above would be a great step forward. This would permit a continuing exchange of ideas, information and materials relative to the improvement of school biology teaching.

Until changes in the above mentioned directions

become practical, which are, of course, long-term objectives, the following short-term measures will be necessary.

4.3.3. Teachers' guides, student worksheets and curriculum guides should be available in enough quantities.

4.3.4. The present 2 periods per week for grades 9 and 10 and 3 periods per week for grades 11 and 12 should be raised, at least to 3 and 4 periods per week respectively. This would allow arrangement of double periods for practical activities, thus minimizing the effect of time factor as an impediment to good biology teaching. This could be done by reducing the number of subjects offered, especially in grades 9 and 10.

4.3.5. The practice of employing one laboratory assistant for the three science subjects: biology, chemistry and physics, is inappropriate both on grounds of qualification and availability of time for setting up apparatus for laboratory demonstrations and experiments. Thus, properly trained assistants for each science subject should be made available.

4.3.6. Biology teachers have not been provided neither the incentive nor the mechanism to upgrade their professional qualification. Workshops, conferences, seminars and refresher courses during the long summer vacations are thus in order.

4.3.7. A provision for follow-up study of implementation seems to be an urgent need. This would

probably be best done if the MOE assigns a "regional (zonal) science education supervisor" who oversees the proper implementation of science curricula together with a school committee involving the director (unit leader), the biology department head and the laboratory assistant.

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Appendix I

Units analysed for the study

Grade	Units No	Unit title
9	2	One kind of animal: The fly
	4	Soil and plant growth
	6	The growth of plants
10	2	Human nutrition
	4	Micro-organisms
	6	Insect pests of crops and foods
11	2	Feeding and digestion
	4	Breathing
	6	The regulation of the body
	8	The nervous system in mammals
	10	Plants and the atmosphere
	12	Responses in plants
12	14	Reproduction
	16	Evolution
	18	Natural resources and their conservation

Appendix II

Addis Ababa University, Faculty of Education
Department of Curriculum and Instruction

Questionnaire to be filled by Senior Secondary
School biology teachers

Objective: The purpose of this questionnaire is to gather information on biology teachers' opinion regarding the practicality (feasibility of implementation) of the present Curriculum for Senior Secondary Schools of Ethiopia. Since the reliability of the survey depends on the objectivity of your responses, you are kindly requested to be as frank as possible.

- Directions:**
- 1) Do not write your name
 - 2) Check [✓] on the space provided corresponding to the item of your choice.
 - 3) In places where your response is to be given in writing, please try to be brief.
- 1) Sex A) Male [] B) Female []
 - 2) Academic Qualification:
 A) M.Sc. [] B) B.Sc. []
 C) Diploma [] D) Other []
 - 3) Years of experience in teaching, _____ years.
 - 4) How many periods per week do you teach, _____ periods.

- 5) How many sections do you have at present?
 _____ sections.
- 6) On average, how many students do you have per section? _____ students.
- 7) What do you think are the objectives of biology teaching at the Senior Secondary School level?
- a) _____
- b) _____
- c) _____
- d) _____
- 8) The biology textbooks in use today have been written followign what might be called the "enquiry approach". How frequently do you use this approach in your teaching?
- A) Often [] B) Occassionally []
- C) Seldom [] D) Never []
- 9) If your response to the above item is C or D, please mention your reasons?
- a) _____
- b) _____
- c) _____
- d) _____
- 10) Does your school have annual budget allocated for purchase of materials and equipement necessary for conducting practical activities?
- a) Yes [] b) No []; if yes, how much? _____ Birr.
- 11) Is there a regularly scheduled period for biology laboratory work?

- a) Yes [] b) No []; if yes, is it,
c) Double period? d) Single period? []
- 12) Does the laboratory exercise provided to students:
a) Follow class coverage of the corresponding content? []
b) Precede equivalent classwork? []
- 13) which of the following procedure (s) do you use when conducting laboratory activities?
a) Individual student experiments []
b) Students paired for activities []
c) 4 - 5 students per group []
d) Teacher demonstration []
- 14) Is the amount of content to be covered in the grade you teach:
a) Much [] b) Average []
c) Little []
- 15) What other methods do you use in your teaching?
a) _____
b) _____
c) _____
d) _____
- 16) Have you ever participated in workshops and seminars designed to improve your professional qualification?
a) Yes [] b) No []; if yes, how many times?
c) Once [], d) Twice [],
e) Thrice [], f) Four times [], g) More than four times []

- 17) What, in your opinion, should be done in order to improve the teaching of biology at the Senior Secondary School level?

Appendix III

Classroom Observation Schedule

School _____

Grade and Section _____

Name of teacher observed _____

Class size _____

Observer's name _____

Date of observation _____

Number of observation 1st _____

2nd _____ (circle one)

3rd _____

Lesson topic (s) _____

I. Introduction

This observation schedule is designed to record verbal and non-verbal behaviors of both teacher and students which may indicate the presence of an inquiry mode of teaching in biology classrooms at the Senior Secondary School level. Non-verbal behavior as used here does not refer to teacher gestures, postures etc.; it rather refers to situations where students and/ or teacher perform activities where verbal transactions may be

halted for some time. The observation schedule has four major parts: 1) Nature of teacher's verbal statements. 2) Nature (type) of problems posed by the teacher; 3) Nature of student response, activity and initiation; 4) Teacher's direction of inquiry process. Each part contains 5 - 9 categories, with a total of 36 categories in all. Read the following directions carefully.

II. Coding Directions

- 1) Complete the information given in the book at the top of this page before, if possible, beginning the observation.
- 2) The teacher to be observed should be informed of your coming at least one day before the observation date. Subsequent observations could be made on mutually agreed dates.
- 3) If a selected teacher teaches in more than one grade (say grades 9 - 10) choose either of the grades (i.e., grade 9 or grade 10) for observation.
- 4) Teacher's reprimands, jokes; short periods of silence (excluding those before a student (students) attempt (s) to answer teacher posed questions) and teacher's statements of rules of conduct are not recorded.
- 5) Behaviors are coded every minute.
- 6) If verbal transactions in the classroom are discontinued (other than those in which students and/or teacher engage in practical activities), say due to students engagement in class work or teacher's engagement

in correction of class work, indicate the cause and number of minutes spent on a separate piece of paper.

7) Detailed suggestions for coding together with illustrative examples are given next to the observation schedule. Read it very carefully.

I. Teacher Talk, Initiation and Guidance

A. Teacher makes statements of :

- A1. Facts, Principles, Processes etc.
- A2. Hypotheses
- Teacher A3. Interpretation/Analysis of actual or
talk hypothetical data
- A4. Conclusions/Generalizations
- A5. Application
- A6. Experimental Procedure
- A7. Problems

B. Problem posed by the teacher requires students to:

- B1. Recall facts, principles etc.
- B2. Formulate Hypotheses to account for
given or generated data
- Type of B3. Interpret/Analyse given or
Problem generated data
- Posed B4. Draw conclusion/ generalization from
given or generated data
- B5. Apply facts and principles to new
situations

B6. Plan/design an experiment

B7. Observe biological specimens, charts,
models etc.

B8. Perform an activity

C. Teacher:

C1. Praises/encourages

C2. Appraises a wrong/incomplete response

Teachers' and probes further

direction C3. Evaluates, or asks the class to

of evaluate response of a student

enquiry C4. Gives straight answers to student

processes questions

C5. Criticizes/disapproves student
responses

II. Student Talk, Activity and Initiation

D. Students:

D1. Make statements of facts, principles
etc.

D2. Make statements of hypotheses

Student D3. Make statements of
response interpretation/analysis of given or
generated data

D4. Make statements of
conclusions/generalizations

D5. Make statements of application

D6. Make statements of experimental
procedure

Student
Activity

- D7. Perform an activity: observation
- D8. Perform an activity: confirmatory
- D9. Perform an activity: investigative

E. Students ask questions pertaining to:

E1. Facts, principles, concepts etc.

E2. The formulation of hypotheses

Student initiation E3. the interpretation/analysis
 of data

E4. Conclusions/generalizations

E5. Application

E6. The plan/design of an experiment

E7. Observation/activities [experiment]

III. Suggestions for Coding and Illustrative Examples

The use of the model in biology teaching requires that the teacher presents an area of investigation or problem at the beginning of the lesson. The problem is supposed to unify the whole, or at least a major part of the lesson. All subsequent activities of the class (discussion, laboratory activities etc.) are geared towards solving the problem posed at the beginning of the lesson. However, this may not always be the case. As often happens, teachers may start of lesson by importing information-statements of facts, principles, generalizations and the questions asked usually require lower-order cognitive processes. Even so, note that teachers, after introducing the lesson through didactic

exposition, may pose problems during the development of the lesson or even at its concluding phase. Thus, the critical distinction to be made by the observer is to note carefully whether the teacher's verbal statements are statements of problems (category A.7) or whether they are statements belonging to any of the other categories (A1 to A6).

If the teacher's verbal statements belong to the later categories, the observer continues coding in the appropriate category until the teacher makes statements of problems.

If a problem is posed, the observer codes category A7 and any of the categories in (B) depending on the nature of the problem posed. We shall now see examples of how the different kinds of problems (categories B1 to B8) may be posed by the teacher.

For purposes of brevity, the types of problems posed by the teacher could be divided into two groups: those bound to some kind of activity performed (or to be performed) either by the teacher or students (activity-bound problems) and those problems which simply involve verbal transactions between teacher and students (activity-free problems). There is, however, no distinct line which differentiates the two types of problems. Activity-bound problems also involve verbal transactions at some stage in their solution. A more detailed discussion of these two types of problems and how they may occur is given in the following pages.

Activity-free Problems

Problems belonging to this group are those that involve no independent student activity (laboratory exercises, workbook exercises, teacher and student demonstrations). They simply refer to problems the posing or solution of which requires no activity. Major portions of chapters and a lot of specific topics in our biology textbooks (grades 9 - 12) are developed following the "narration of inquiry", made and are best suited to engage students in enquiry processes if so directed by the teacher. Problems belonging to categories B2, B3, B4, B5, and B6, if presented without involving activities. We shall now embark on the discussion of the coding categories and their illustrative examples beginning with the simplest type of problems.

Examples. The following questions if asked at the end of a lesson or after their discussion (coverage) in class belong to category B1.

- I. "What are the four stages in the life cycle of the housefly?" (Details are given in the literature review.)
- II. "What are the three distinct groups of bacteria?"
- III. "Define carrying capacity and productivity?"
- IV. "What is the function of Ptyalin?"

In general, teacher questions that begin with words such as "What", "Where", "Define", "Name?" or phrases

such as "Do you remember what we said about...?, have the purpose of determining what students do and do not remember and belong to the category of recall questions (B1).

Questions that require students to apply facts and principles to problem-solving or to new situations, posed usually at the concluding phase of a lesson or given as homework, belong to category (B3).

Examples:

I. After a discussion of blood groups and the concept of agglutination, the teacher may ask: "Why is a doctor careful to transfer to an injured person blood from the right type of individual?"

II. After a lesson on digestion (its processes and products), the teacher may pose this problem: "A man in a hospital has had a serious operation on the digestive tract, making it impossible for him to eat food for many weeks. The doctors decided to give him food by injection directly into the veins. What kind of food should they inject and why?"

The following two more examples have been taken from Biological Science (grade 11 student's text):

III. "Why do athletes take salt tablets after intensive exercises in training?" (p. 97)

IV. "Human babies have been known to die in unheated rooms where an adult was sleeping comfortably. How do you account for this?" (p. 97)

In problems of this kind, where the student cannot get the answer directly from his textbook, the observer codes category (B5). Note, however, that if these problems were posed at the beginning of a lesson, they would have belonged to category (B2) (formulating hypotheses) where students speculate on possible reasons for each problem.

The teacher can also pose problems which require students to formulate hypotheses (B2), analyse and interpret data (B3), draw conclusions from data (B4) and plan an experiment (B6) without actually being involved in the gathering or generation of the data necessary to test or formulate the hypotheses. However, if these problems require gathering of data, they become activity-bound problems. As indicated before, the biology textbooks (especially those for grades 11 and 12) provide several opportunities that lend themselves well to these kinds of problems. Before such problems are posed, the teacher has to present the necessary background information to students either orally, on the chalkboard or by means of projection equipment. Here again, as in (A) categories, the important distinction to be made is to note carefully whether the teacher himself is making statements of hypotheses (A2), the design of experiments (A6), analyses and interpretations of data (A3), conclusions and generalizations (A4) or whether he is posing them as problems, in which case the observer codes categories B2, B6, B3, and B4 respectively

depending on which of them had been presented as problems.

Examples:

i) The following two examples have been taken from grade 11 Biological Science (Student's text).

Teacher to Students" "In experiments concerning the movement of food substances in the problem, it can be shown that:

a) movement can take place in both directions,

b) the speed of movement is greater than can be accounted for by diffusion. On the basis of this knowledge what hypothesis can you make about the nature of transport in the problem?" (p. 247).

For such problems, the observer codes category B2.

-Teacher presents to class" "a graph showing the variation of the concentration of CO₂ over a period of 24 hours,." and asks them to formulate hypotheses to account for the data (category (B2). If, on the other hand, the teacher directs students to some aspects of the data through selected questions such as "At what time of day is the CO₂ concentration highest? At what time is it lowest? Why? etc.", the observer codes category (B3) , questions requiring students to analyse and interpret data).

Another kind of activity-free problem that may be posed by a teacher is that which requires students to describe how they may design an experiment in order to investigate a biological problem. Note that it does not

require the actual carrying out of the plan or design. The following examples illustrate problems of this kind.

Examples:

Teacher to Students:

i. "how can you find out if a green plant formed starch a) in the absence of sunlight? b) in the absence of carbon dioxide?" (Grade 11 Biology Text: p. 244)

ii. "Suppose you wanted to know what percentage of raw materials for the growth of a plant comes from the soil in which it is planted. Suppose you also wanted to know what percentage of those raw materials comes from the air that surrounds the plant. Plan a simple experiment that would begin to solve this problem?"

iii. "If you wanted to know whether the nucleus of cells is necessary for life, or whether cells could live without a nucleus, how would you show this experimentally?"

When problems of this kind are posed by the teacher, the observer codes category (B6). Here again, note that the teacher can also describe actual or hypothetical experimental results and ask students to formulate hypotheses (B), analyse and interpret the data (B3) etc. It is also possible that the teacher, after posing the problem, describes the experiments done and the data thus found (A6), makes the analyses and interpretations himself (A3) etc.

Activity-bound Problems

If a teacher has not used demonstration for purpose of illustration or for collecting evidence on a problem, he may pose them as problems in manner illustrated below.

i) At the beginning of a lesson on circulation, the teacher may show to his students a "working model of the circulatory system with valves included" and ask the students: "what enables the blood to flow in the right direction?".

ii) In a lesson on digestion, the teacher may demonstrate the effect of diastase on a thin suspension of starch and ask his students: "Where did the starch go?"

iii) In a lesson on enzymes, the teacher may demonstrate the effect of adding a few drops of blood in a beaker containing hydrogen peroxide and ask his students "Where did the released from the from the hydrogen peroxide?"

In all such cases, the observer codes category (B2). If the teacher presents biological specimens, charts, models and other visual aids and directs student attention to some aspect of the materials through selected questions, the observer codes category (B7).

Student activities (investigations) for the purpose of collecting evidence/data in order to test hypotheses or solve problems also belong to this group of problems. After the teacher has posed problems orally, he directs

students to perform a pre-determined activity-simple experiments, controlled experiments, further reading etc., in order to come out of the difficulty (problem) posed. It is also possible that teacher directs students to such activities for the purpose of confirming or illustrating something learned in class. In such cases, as the following examples illustrate, the observer codes category D8 or D9 respectively.

Examples:

i) The teacher may, after briefly introducing the topic "Breathing", pose problems such as "How do we breath in and out?, What are the forces that cause it? What are the structures involved? etc." and provide students with a guineapig, frog or other mammal to dissect and investigate, or if students perform this activity in order to investigate the alimentary canal, the observer codes category D9.

ii) If the teacher allows students find out for themselves, instead of telling them, the components of exhaled air contains CO₂ (i.e., water vapor and heat) and poses this problem. "We have seen that exhaled air contains CO₂. What other components does it contain?" He may now instruct either to devise their own means of investigating the problem (category B8) or provide them with a structured procedure of investigating the problem. The observer codes category (D9) for the later case. It is also possible that the students perform these activities after the respective lessons had been covered

in class; i.e., as illustrations of the facts they learned. In such cases, the observer codes category (D8).

Another possibility is that the teacher himself may make these and other such activities by way of demonstrating to students the facts and principles already learned. Student behavior in this observation schedule has three possible parts: verbal responses to teacher ;osed problems, investigations of some kind to solve problems that require practical activities, and student initiation (student questions) directed to teacher and pertaining to any of the categories listed in (E). The observer will not have difficulty in identifying student behavior either as response, activity or initiation and coding each behavior in the corresponding category.

Posing problems may not be as difficult as what should follow for the teacher. After posing problems, the next step is progress toward its solution. And it is here where the greatest demand on the teacher is made. The success of the lesson depends on what the teacher does to sustain the inquiry process thus started. In short, he has to create the appropriate classroom enviornment where ideas can flow freely between him and the students or among students. Part (C) of the observation schedule is designed to measure this aspect of the model.

Declaration

This thesis is my original work and has not been presented for a degree in any other University.

Name Mervin Kelen

Date 17 June, 1982

Signature 