The State of Problem Solving Skills in General Secondary Biology Laboratory Activities

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Abstract: Though current education & training policy advocates problem solving approach in secondary school curriculum, no subsequent document is available to translate experiences into a material that develops such skills. Hence, curriculum developers and commissioned writers employed differently their own intuitions of the concept. This paper inquires into the state of problem solving skills in general secondary biology curriculum materials. All the laboratory activities suggested were taken as the source of information. A conceptual framework and different content analysis schemes were employed to determine the types of problem, degree of openness and their demands for problem solving skills. It was found that all the activities suggested (N=79) were well structured and well- defined problems. In almost all the cases, students were required to suggest only brief responses and the most important problem solving skills were not represented at all. As a conclusion, it can be argued that it is difficult to expect high school students to transfer such skills into their real life situation that requires biological literacy. This paper recommends the need to re-conceptualize the concept, revise and refine general secondary biology curriculum through developing a workable problem-solving framework.

Introduction

Different models have been used in the past as frameworks or structures around which experiences and perspectives could be organized. Such models had brought major changes in the basic ideas of knowledge and learning that guide the kind of education we design, particularly the curriculum we develop and teach (Elizabeth 2001). Problem solving, in educational literature, is one of such

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expressions. It means all things to many people. As an educational activity; it is not new, as there is a large and detailed body of research that extends over many decades, exploring both the characteristics of school problem solving and problem solver. What was new according to Bentley and Watts, (1989), was the type of problem under consideration.

Education in Ethiopia in general and science education in particular exhibits changes in curricular and instructional approach due largely to the type of imported materials. Since the inception of modern education, the framework used to guide the imported material has affected the orientations of school curriculum (Akalewold 2001). Though we were politically independent, the nation was, as Allosp (in Woolnough 1991) states it, under the influence of the metropolitans. Between 1950s and 1980s science education in Ethiopia had changed from concept-led to process-led and then back to concept-led curriculum (Berhanu 1996, 1999). With the appearance of new education policy in the early 1990s' (TGE, 1994), emphasis was given back to the process (method) of science. Bybee and Deboer (1994) stated this goal statement as:

"Method is a manner of acting, a predisposition to behave, perform, and think in certain ways towards an object or objects of study. Of particular importance here are scientific methods as they have been variously described in the history of science education. Emphasis on inquiry, discovery and problem solving are further example of the method goal of science education"(p.357).

The important focus of science education in this goal statement was the development of understanding of the methods of science and abilities in applying these methods. Scientific methods have been taught as a way to develop the intellect, as a general method of dealing with social problems, and a means for acquiring scientific knowledge. These goals in science curricula have taken a form of method, with steps such as *defining the problem, making observations, forming a hypothesis, performing an experiment, and presenting conclusions* (Bybee and Deboer, 1994).

The New Education and Training Policy (TGE, 1994) implies a shift in educational paradigm and declares Problem-solving as a guideline for framing curriculum development. Though educators respond differently to the nature of school problem, the policy never dares to operationally define the term (Berhanu, 1999). Besides this, no coherent framework was made available to curriculum developers by subsequent official document to translate this intent into the desired materials (Akalewold 2001). The skills and processes required by the problem solver are not identified and thus not used as a criterion for selecting and building curriculum experiences. As a result, curriculum writers shifted to their intuition of the term in developing the material (Akalewold 2001).

In the absence of all these sequential steps in curriculum development, it is difficult to accept the lofty claim made by content analysts of the formative curriculum evaluation (ICDR 2000, 2001) and the commissioned curriculum material writers (MOE 2001) which argues that the present biology curriculum will develop problem solving skills. (Akalewold, 2001). With this general introduction, this paper tries to evaluate the practical activities suggested in light of the new paradigm and the extent to which they provide experience in problem solving skills. Specifically, the following research questions employed were:

1. What kinds of laboratory problem/ exercise are available in the materials?
2. What level of openness and intellectual demand is placed on the stated practical activities?

3. What is the state of problem solving skills with regard to the skill of planning, performance, analysis, and application?

Literature Review

What is Problem in Problem Solving Approach?

Problem solving has become a major focus of science curriculum during the past decades. A major difficulty in discussing problem solving seems to be lack of any clear-cut agreement as to what constitutes a 'problem' (Krulik & Rudnick 1987). There seems enormous variety in the type of problems. Several attempts have been made to categorize them in the past (Bentley & Watts 1989; ICDR 1999). In Bentley and Watts opinion (1989), a person has a 'problem' when s/he has a goal which cannot be achieved directly. Problems are taken as any activities (explanation of phenomena, applied science problems, theoretical problems and investigation) that require a pupil to apply his understanding in a new situation (Gott and Duggan, 1995).

Science, according to Gott and Murphy (1987), is about the solving of problem in everyday and scientific situation. They define problems as a *task* for which the pupil cannot immediately see answer or *recall a routine method of finding it.* A problem is also conceived as *situation*, quantitative or otherwise, that confronts an individual or group of individuals, that requires resolution, and for which the individual sees no apparent or obvious means or path to obtaining the solution (Krulik & Rudnick 1987). The key to all definitions suggested above lays in presenting a challenge to which no apparent or obvious path was adopted.

A problem would no longer be considered as a problem if it can easily be solved by algorithms that have been learned previously. Thus, as students pursue their courses, what was a problem at an early age becomes exercise that can eventually be reduced to mere questions. Problems are considered as a basic medium for problem solving. Good problems, according to Krulik & Rudnick (1987), can be found in every aspect of daily living and have attributes such as (1) the solution to the problem involves understanding of a distinct concept or the use of skill, and (2) the problem can be generalized or extended to a variety of situations. They also made distinctions among three commonly used terms:

(A) **Question**: a situation that can be resolved by mere recall.
(B) **Exercise**: a situation that involves drill and practice to reinforce a previously learned skills or algorithms.
(C) **Problem**: a situation that requires thought and a synthesis of previously learned knowledge to resolve.

Problems as Curriculum Framework

Solving a problem is an active process of trying to change the original state of situation into a desired state. Hence, understanding the processes and knowledge involved in problem solving has a practical importance for educational decision and training programs. The problems and problem solving processes become the curricular and instructional methodologies. When this approach is dedicated to curriculum, problems can be classified as 'open' or 'closed', 'formal' or 'informal' (Bentley and Watts 1989) and 'ill-defined' and 'well-defined' (Bentley and Watts 1989; Clark and Agne 1997; ICDR 1999). In practice, they range from 'IQ tests' to 'egg-race' activities, from puzzles to 'real-life' problems. They are all, however, seen as problems to be solved. The OPEN project, (Simon and Jones in Gott and Duggan 1995), defined such problems as 'open work'. According to them, 'open work' is an activity which gives the initiative to students for finding the solutions to problems. Thus they give emphasis to students' autonomy in making decisions on the integration of knowledge and skills.

On the other hand, Watts and Gilbert cited in Gott and Duggan (1995) classified problem solving in science into two kinds: the paper and pencil tasks that are well defined and have little or no redundant information. There are a wide variety of 'ill-defined' problem solving tasks. By ill-defined they mean tasks where only relevant information and materials are supplied. The classification of problems into well-structured, semi-structured and ill-structured is based on the amount of information available and the means required to transform the current state into one or more forms of the desired state (Mac Crimmon & Tylor cited in ICDR, 1999). Kahney cited in Bentley and Watts (1989) also makes a distinction between well-defined and ill-defined problems as follows: "Well-defined problems are ones in which the goal, the possible move (possible route to a solution) and strategies are all given at the start. Ill-defined problems are ones in which the goal and the permissible moves have to be supplied by the problem solver (p. 81).

Such definitions make distinction between '**given**' problems, where the solver is given the goal and strategies, ***goal*** problems, where the solver is given the goal and nothing else and ***own*** problems, where the solver decides both the goal and the strategies (Bentley and Watts, 1989). Such tasks (own problems) grow out of the search for making science relevant to allow students to apply scientific principles (Gott and Duggan, 1995) and generate enthusiasm. This means that students use multiple talents to solve a 'real' or authentic problem. They use the facts and skills they have mastered (Clarke and Agne, 1997). The shift in school problem solving has been away from the 'given' type of problem towards what is labeled as 'goal' and 'own' types (Bentley and Watts, 1989).

Problem Solving in the School Science Curricula

Problem-solving has been used in science education for many years, mainly as a vehicle to enable teachers to evaluate students' ability to transfer concepts and understanding from the classroom to real-life situations. With the onset of a more process-based science curriculum, however, 'problem-solving' has taken on completely new meaning and it has become the embodiment of the 'scientific process', the 'real-method' of investigation (Howlett, 1989).

Different authors have examined the role of such approach in education (Howlett, 1989; Young, 1979; ICDR, 1999; Krulik & Rudnick, 1987; Arends, 1997; Clarke and Agne, 1997; Glasgow, 1996) by coining different names such as problem-based learning/ instruction, project-based, experience-based education, authentic learning and anchored instruction (Arends, 1997; Clarke and Agne, 1997; Glasgow, 1996). What is central and common to these terminologies is the students are presented with authentic and meaningful problem situation that serves as a springboard for investigation and inquiry.

Problem-solving can be defined as a *process* of producing or closing a perceived problem gap. When a solution is proposed, its effect on reducing the gap can be evaluated and adjustment made accordingly (ICDR, 1999; Krulik & Rudnick, 1987). Young (1979) describes problem solving in science education as a very powerful technique for three important reasons: (a) a problem catches student's attention and it is a good way to begin a lesson; (b) a problem solving approach that can be related to the real world; (c) a problem solving approach can be stresses processes (or skills) rather than facts. Problem leads students to pose hypothesis and hypothesis may lead to an experiment.

Problem-based curricula, according to Glasgow (1996), engage students in proposing solutions that are as real for the adult community as it is for any group of high school students. Ross cited in Clarke and Agne (1997) also argued that problem-oriented curricula are curricula in which (1) problems are used as selection criteria for content (and methods); (2) students work on problems as (part of) the course; and (3) students are given specific training (or development experiences) for solving problems. Bill Stephien cited in Clarke and Agne (1997) described problem-based learning as a pair of scissors with process and knowledge as opposing blades. Students are required to have the complete tool, and with only half of the scissors, all they can do is to stab at the solutions.

According to Glasgow (1996) learning from problem situation has been and continues to be a condition of human existence and survival. It is a basic human process founded in patterns of reasoning that allows early humans to survive in their environment. Reducing this concept and approach to specific classroom practice is a natural extension of a basic human process. In this approach, the students take on problems or projects related to science subjects as a stimulus for learning in the content areas, subjects or disciplines.

The New Secondary School Biology Curriculum

According to Solomon (1998), the policy of education made curriculum reform one of the top priorities. He stated that the existing curriculum has served the country for more than 25 years. This led to a need to improve significantly in areas like biotechnology, biodiversity, biological conservation, population issues, health and environmental education, etc. It was claimed that the new biology curriculum was prepared based on the stated objectives and profiles of the policy (Solomon, 1998). The trend in the new biology curriculum followed, according to Solomon (1998), was to integrate biology with community biology. Emphasis was also given to human biology. More attention was given to issue studies than knowledge studies. An attempt has also been made to make the right mix among scientific, descriptive and community approaches. Solomon (1998) states this as follows:

"In the new Biology Curriculum, at all grade levels, stress is given to the relevance of Biological knowledge for understanding issues affecting people as individuals and for understanding human's interaction with society and the environment. Topics of pure Biology are expanded to applied fields and to the solution of problems affecting the individual and society by integrating current societal issues that are related to environment, population, health and disaster in the Biology Curriculum" (p.31).

A number of methods were also suggested in the guide to make mastery of the content identified, among which was a laboratory activity. Teachers can use suggested methods based on the nature of the learning environment, class population and teachers' own competence. The new biology curriculum starts in a linear approach starting from grade 7. At grade 7 and 8 a general overview of the basic biological problems are presented in a simple and elementary fashion and at grade 9 and 10 both breadth and depth is given to the topic dealt within the preceding grades (Solomon, 1998).

Laboratory Activities and Problem Solving Skills

Laboratory activities promise so much in terms of enabling students to solve problems and construct relevant science knowledge. Tamir and Lunetta (1978) indicated that the main purpose of laboratory in the science curricula of the 1960s was to promote students inquiry and allow students to under-take investigations. This emphasis was in marked contrast to using the laboratory primarily as a place to illustrate, demonstrate, and verify known concepts and laws. According to Hofstein and Lunetta (1982), laboratory activities can be effective in promoting intellectual development, inquiry and problem-solving skills. Furthermore, laboratory activities have the potential to assist in the development of observational and manipulative skills and in understanding science concepts.

In the Ethiopian context, textbooks define the school curriculum. Both teachers and students ardently follow what is found in the textbook to guide their teaching and learning respectively. The issues of practical work/laboratory activities are not new to the Ethiopian school science. For example, the resolution passed (30 years ago) by the science department in the Final Report of the Curriculum Seminar held at Menelik II School (Sene 24-25, 1964 E.C.) was: 'the whole science curriculum should be revised by giving more emphasis to practical work' (58).

In the new biology curriculum, laboratory activities are considered an integral part starting from grade seven (Akalewold 2001; 2003). When laboratory activities were taken as part of the curricula, they often took the form of cookbook recipes (verification labs) in which students follow prescriptions to obtain predetermined outcomes. As a result, laboratories fall short of achieving the potential to enhance students' learning with understanding.

Research work in laboratory is very rare in the Ethiopian context. Bogale (1983), Mekuanent (1992) and Akalewold (2001) evaluated practical activities in biology. Bogale cited in Solomon (1998) criticized the suggested activities as they (1) are too many and they do not necessarily help students acquire the subject matter, (2) can not be performed largely due to the material condition imposed, (3) require much time and (4) require a special place called laboratory, which is not found in Ethiopian schools.

Mekuanent (1992) also analyzed the practical activities included in high school biology curriculum materials based on the degree of openness through the 'structured-unstructured' model; time of conducting the practical activity, and the type of practical activities i.e., observational/experimental. He further states that except in few cases, the practical activities analyzed help students little to understand the process of biological inquiry.

Akalewold (2001) analyzed the nature and purpose of practical activities in the grade 8 biology textbook. His study noted that 65% of the activities included are devoted to enquiry, 30 % to illustrative and 5% to observation activity. Hence, unlike the physical sciences given at the same grade level, the activities in biology for grade 8 helps students to collect data for suggested answer to the activity.

Methodology

The research methodology used in this study was content analysis. Content analysis is defined as a systematic quantitative analysis of learning materials such as textbooks, worksheet etc., according to categories which represent educational objectives (Tamir and Pilar-Garcia 1992. Content analysis can be applied to study the content of any book. Tamir and Pilar-Garcia (1992) also emphasized the benefit of this method for checking the lofty claims of curriculum developers.

Data Gathering Instruments and Sampling Procedure

All practical activities (N=79) included in grade 9 and 10 biological science textbooks (MOE, 2000, 2001) were taken for analysis. Each activity was taken and checked across the OPEN continua (Fig 2**)** developed by Simon & Jones (1992) and Tamir and Lunneta (1978) scheme. To study the nature of the problem and determine its degree of openness, each activity was analyzed through the OPENS continua (Simons and Jones, 1992). The scheme developed by Tamir and Lunetta (1978), was used to indicate the type of intellectual skills involved. The two materials were analyzed with the group of biology year IV education stream students. Each activity was analyzed, and an item with disagreement was discarded from the analysis. (See Appendix 1 for definition and example of the categories).

Conceptual Framework of the Study

Different models of problem solving are available in the literature (Carin and Sund 1989; Welford, 1990; Gott & Duggan, 1995; Woolnough 1991). In Science-Technology and Society framework to science education, students are required to make humanistic decisions on a host of social, economic, political and technological problems (Carin and Sund, 1989). Similarly, in the new biology curriculum; according to Solomon (1998), emphasis is given to the relevance of biological knowledge and understanding of the solution of problems affecting the individual and society and to those issues that are related to environment, population, health, and disaster.

For the purpose of this study, the model developed by the Assessment of Performance Unit in UK, as shown in Fig 1, was used. This problem-solving model was used widely in science and other subjects. It provides a more detailed description of what is going on when pupils perform laboratory activity/investigations. The Model represents a list of things that *can be* done, not necessarily in that order and not necessarily doing all of them (Gott and Duggan 1995; Welford 1990). Though the model is organized into a sequence of steps that has a logical progression, students in practice move back and forth among the steps to work the problem (Carin and Sund 1989). This model is used to analyze practical problem-solving behaviors (Murphy and Gott 1984; Gott and Murphy 1987) in Welford (1990).

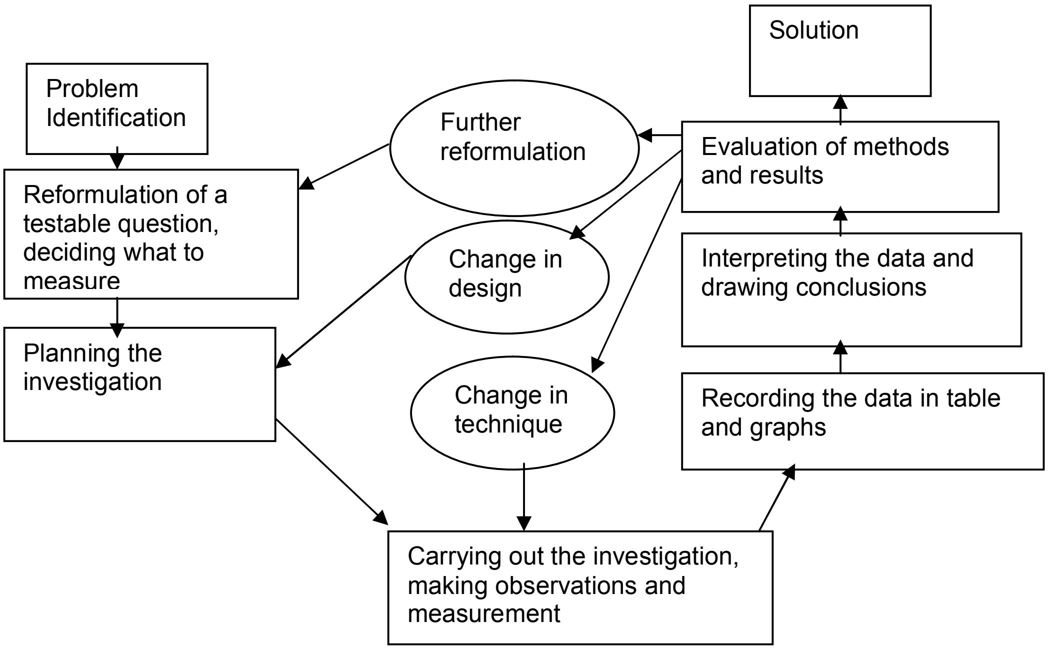

Fig. 1*: Model for Problem solving activity*
Source*: Welford (1998), Gott and Duggan (1995)*

Presentation & Discussion of the Findings

Students spend a great deal of time in classrooms and laboratories exposed to and working with tasks or activities. Research on task structures provides useful insights into the fate of curriculum within laboratory. Blumenfeld et al. cited in Doyle (1996), Mekuannent & Akalewold (2001) distinguish between *task content* (learning objectives, the perceived appeal, familiarity and difficulty of subject matter) and *task form* (the nature and procedural complexity of activities). Blumenfeld et al. argued that task form has important consequences for motivation and task completion. This section analyzes the degree of openness of laboratory tasks, which is determined by the task structure and the cognitive demand for problem solving skills. This in turn is dependent on task content.

The Degree of Openness of the Practical Activities *(The Nature of the Task or Task Structure)*

The curriculum that individual students encounter in laboratories represent the tasks/activities to be accomplished (Doyle 1996). A student must interpret what the task means and struggle with the work itself. The degree of difficulty a student encounters depends upon the way the task is presented and the fit between the task and the student's preconceptions and level of competence. In order to analyze the laboratory tasks suggested in the textbooks according to their degree of openness, the scheme developed by Simon and Jones (1992) was employed. Simons and Jones assigned a stage by reading the script or outline of the activity and noted the level of openness on the basis of the freedom the activities give to students to engage in the central process of scientific inquiry.

The scheme provides three stages in doing the activity: (a) *defining the problem, (b) choosing the method, and (c) arriving at a solution*. In analyzing the activities, the first two stages (defining the problem and choosing the method of investigation) range from 'closely defined' to 'not defined' and the third stage (arriving at solutions) is positioned from the activity that has only one solution to those having several alternative solutions. Hence, any activity labeled as open will appear usually at the right side of the continuum in one or more of the stages (Gott and Duggan 1995). Activities that lie to the left of the continua (activities that are closely defined both at problem and method levels and that have only one solution) cannot qualify for the status of open problems and hence they severely limit the opportunity of pupils to use and apply procedural understanding and problem solving skills. (See Appendix 3(1) for an example of how this was used).

Defining the problem
Closely defined--Not defined
Choosing the method
Closely defined--Not defined
Arriving at solutions
One---Many

Fig 2: *The OPEN Continua*
Source: *Simon and Jones (1992)*

When the structure of the activities was analyzed, it was found that all the laboratory tasks investigated had similar structure (see Fig 3). There is no difference (in terms of their structure and organization) in the presentation of the activities across grades. As shown in Fig 3 each activity was made up of four parts: aim of the activity, material suggested, procedure followed, and a set of questions to organize the experience.

ACTIVITY 6: To see the type of image formed

MATERIALS: Microscope, a small piece of paper with the letter ‘b’ typed on it

PROCEDURE: Mount a small piece of paper with the letter ‘b’ on it and observe it under the low power objective

RESULT: Your answer to the following questions will lead you to the expected results

A) Is the letter inverted from top to bottom?
B) Is the letter inverted from left to write?
C) If you were to mount the letter ‘p’, what would the image look like if seen under the microscope? Show with the help of a drawing what it would look like if it stands in front of a mirror
D) From your observations, how does the image of an object under a microscope differ from its mirror image?

Fig 3: Typical structure for practical activities in the three-grades biology textbooks (Source: AACAR 1999).

All practical activities (N= 79) suggested were analyzed through the above scheme. The laboratory tasks suggested were characterized by *well-defined* problems where both the goals and permissible moves are well presented by the text. The laboratory tasks present a structured problem in that the problem is stated with sufficient information about how to start and reach the solution. All the required information was presented in each topic before the treatment of the activity/investigation. Students, in almost all the cases, are required to suggest a piece of information/skill. In addition, all the activities are well 'sketched'. All the procedural demands expected of students are also suggested.

The activities made a minimum cognitive demand on students and most tasks observed in the text could be accomplished by following simple procedures or reproducing information previously encountered. Moreover, tasks with potentially high cognitive demand were procedurized so that the actual work students did was simplified. The descriptive treatment demonstrated by the text made most of the activities confirm and verify the biological concept/ principle studied earlier. This generally reduces the challenge of the activities, hence, the use of procedural understanding and problem solving skills.

Gott et al. (1988) and Gott & Duggan (1995) classified practical activities into skill, observational inquiry, illustrative and investigative practical (see also Akalewold 2001; 2003). These structured activities presented in the texts could be anything other than investigative practical. (For example; the above activity could be illustrative or inquiry based on the treatment of biological principle in advance of the activity. Investigative practical, on the other hand, offers several alternative ways of reaching a solution and the design is much less controlled than the other practical types. The main aim for their inclusion in the science curriculum was to allow students to use concepts, cognitive processes and skills in solving problems (Gott and Duggan 1995; Mekuannent and Akalewold 2001)). In general; the exclusive use of such activity across grade levels is considered antithetical to the spirit of developing understanding of the scientific method and problem solving skill.

The Nature of Task Content

Problem solving is an active process of trying to change the original state of situation into a desired state. Understanding the processes and knowledge involved has a practical importance for educational decision and training programs. Though problem solving is seen as a natural way to learn, students do not just naturally become expert in the techniques of problem solving. Besides the help of the classroom teacher, students also require to be challenged by suitable problem of the task- task content. In order to identify the opportunities given to the intellectual and practical skills that will allow them to explore and investigate, the scheme developed by Tamir and Lunetta (1978) was used.

Consistent within the theoretical framework identified, Tamir and Lunetta (1978) identified a list of problem solving skills under four broad categories: planning, performance, analysis and application (see appendix 2 for the description and appendix 3(2) for an example of how it was used). Scoring using the task analysis checklist was done on a simple Yes/No basis, i.e. the script for the activity is read and decision was made to determine whether each listed intellectual skill in each category is required. Hence, the evaluator marks either 1 or 0, based on the presence or absence of the required skill. All the activities were analyzed using this scheme. Table 1 and 2 present the result of content analysis of laboratory tasks.

Table 1: Analysis of Laboratory Activities in Grade 9 Biology Textbook

CHAPTER & No. OF ACTIVITY	CH 1 N=5	CH 2 N=12	CH 3 N=5	CH 4 N=5	CH 5 N=4	CH 6 N=3
1. PLANNING**						
1.1	0	0	0	0	0	0
1.2	0	0	0	0	0	0
1.3	0	0	0	0	0	0
1.4	0	0	0	0	0	0
1.5	0	0	0	0	0	0
2. PERFORMANCE**						
2.1a	15*	15	6	6	2	1
2.1b	1	0	1	0	1	0
2.2	0	0	0	0	0	0
2.3	0	6	1	5	4	1
2.4	0	0	0	2	2	1
2.5	0	0	3	2	0	3
2.6	0	0	0	0	1	0
3. ANALYSIS**						
3.1a	0	0	0	1	2	1
3.1b	1	0	0	0	0	0
3.1c	5	0	0	2	0	0
3.2	3	6	6	2	4	1
3.3	0	1	0	0	0	0
3.4	0	0	0	0	2	0
3.5	0	1	1	0	0	0
3.6	4	2	2	3	2	2
3.7	0	1	0	0	0	0
4. APPLICATION**						
4.1	0	7	2	1	5	0
4.2	0	1	0	0	0	0
4.3	0	0	0	0	0	1

* Number is assigned to the number of times each skill (behavior) is demanded by the activity.
** The description for each category is found in Appendix 2.

Table 2: Analysis of Laboratory Activities in Grade 10 Biology Textbook

CHAPTER & No. OF ACTIVITY	CH 1 N=7	CH 2 N=12	CH 3 N=11	CH 4 N=3	CH 5 N=5	CH 6 N=3	CH 7 N=2	CH 8 N=2
1. PLANNING								
1.1	0	0	0	0	0	0	0	0
1.2	0	0	0	0	0	0	0	0
1.3	0	0	0	0	0	0	0	0
1.4	0	0	0	0	0	0	0	0
1.5	0	1	0	0	0	0	0	0
2. PERFORMANCE								
2.1a	5	11	9	0	11	1	2	1
2.1b	2	1	0	0	0	0	4	0
2.2	0	0	0	0	0	0	0	0
2.3	5	1	2	3	2	0	0	0
2.4	1	1	1	1	0	2	1	0
2.5	2	11	1	0	0	0	0	2
2.6	0	0	0	0	0	0	0	2
3. ANALYSIS								
3.1a	0	0	1	1	1	0	0	0
3.1b	1	0	0	2	0	0	0	0
3.1c	2	8	2	1	5	1	1	0
3.2	4	8	8	1	1	1	0	1
3.3	0	1	0	0	0	0	0	0
3.4	0	0	0	0	0	0	1	0
3.5	0	0	0	0	0	1	0	0
3.6	8	6	9	2	1	1	1	1
3.7	0	0	0	0	0	0	0	0
4. APPLICATION								
4.1	1	2	2	0	5	1	1	0
4.2	0	1	0	0	0	0	0	0
4.3	0	0	1	1	0	0	0	0

Planning

"Tell the pupils too little and they will not be able to proceed. Tell them too much and it will no longer be an investigation" (Drive et al. in Mekuannent and Akalewold 2001).

Careful planning was considered essential in order to maximize from the experimental work (Mekuannent and Akalewold 2001). In all practical activities (N= 79) included, planning received the least attention by the textbook writer. Only one activity in grade 10 has demanded one specific skill of planning (category 1.4 and 1.5). This finding was consistent with the above in that all the practical activities were well-structured activities. All the time, the planning part of the practical was explicitly defined by the text and thus the problem was stated with sufficient information about how to start and reach a solution. Unlike investigative practical that gives much freedom, here the students will never formulate a question, predict experimental results in advance and never make hypothesis, and design experiment, which is central to the whole notion of biological problem solving.

Performance

As a group, performance has received attention by the designers of these activities. In most of the activities, students carry out observations (category 2.1a) and record results of their performance (category 2.3). They are sometimes required to explain and give reasons for the procedure employed by the text (category 2.5). Students are left to work according to their own design (category 2.6) in a few activities.

Analysis

Analysis is the second group that received attention. In most cases, students are expected to determine relationships (category 3.2), explain the relationship observed (category 3.6) and make drawing based on their observations (category 3.1c). The most important skill of communication (category 3.1a, b) in science (students' ability to transform results into table and graph) is not treated sufficiently. Determining accuracy of experimentation (category 3.3), defining assumptions (category 3.4), formulating generalization/ model (category 3.5) and formulating new questions based on the results of analysis (category 3.7) are treated the least.

Application

Application as a group is treated the least next to planning. Too often students are called to predict based on obtained result (category 4.1). The skill of making hypothesis based on obtained result (category 4.2) and applying finding in new context (category 4.3) were not treated adequately. Since students are only exposed to problems whose solution involves a straightforward application of a given knowledge, they can easily fail to appreciate and that is one of the most important and challenging aspect of problem solving in real scientific situation.

Generally, academic demands were found to be minimal and few opportunities were provided for divergent thinking or reasoning. The texts almost all the time simplify the task demand by defining specifications clearly, emphasizing procedures for completing activities, providing prompts and resources. When this happens, students' attention will shift from meaning and the underlying operation with content. They strive to obtain correct answers and complete the task. As a result, the basic academic purpose of the laboratory activity is circumvented.

Summary of Findings

From the above discussions, the following important points are taken as a summary of this paper:

1. All practical activities identified in the three students' textbooks are characterized as well-defined problems. The problem always states everything required with little or no redundant information. Problems in student textbooks are always tightly structured to present the aim of the activities, material required, procedures to be followed and sometimes, even the possible answer. Open ended problems that require the student to change the problem into the desired state that might involve a series of actions were not part of the student's laboratory experiences.

2. Content analysis of the activities across the different schemes revealed also that due to their structured and predominant nature (demonstration practical), the activities emphasize the lower cognitive levels. The challenge level of the activities was significantly reduced. In some cases, students are required only to put a phrase or a 'yes' or 'no' response.

3. In general, the skill of planning the practical activity is the least provision given followed by the skills of application. The essence of any scientific inquiry, i.e., designing of an experiment, is totally absent. The text book provides the design to be followed by the student. Performance, as a group, received a relatively more attention followed by analysis.

4. There is a strong movement elsewhere in the direction of open-ended problem solving in science education (Fairbrother, 1991). Well structured activities in the texts deterred students from designing experimental procedure which is central to biological

investigations. There is no indication of moving from 'given problems' to 'goal problem' and 'own problem'. Student progress in their laboratory skills and understanding of major biological principles will be at risk. The nature of the problems presented define biology curriculum right from grade seven to university level (see Akalewold 2001; 2003).

Recommendations

Textbooks have long been considered major factors in shaping instructional program. They are integral parts of many science classrooms, and in many cases, they define the school curriculum. This remains valid in the Ethiopian context where textbook learning is the most important element of biology instruction. Efforts at improving the quality of textbooks and reform the curriculum stems, in part, from the widespread belief that students have difficulty in learning from science textbooks (Tobin, Tippins and Gallad 1994). Finley (1991) also noted that students encounter obstacle to learn from textbooks because of fundamental contradictions "between the nature of science textbooks and the educational goals that texts are meant to serve".

Because teaching from and with textbooks is the dominant method of instruction in many science classes, research is needed on how students learn to use textbooks in order to become independent learners, how teachers should use textbooks, as well as how to write textbooks in order to promote efficient learning. In designing activities, one important factor must be considered- providing optimum balance between challenge and security. Too much challenge makes students withdraw and if too much security is given they will never grow. Woolnough (1991) identified that the majority of students were found to welcome the security of tightly structured lessons. On the other hand, when given the opportunity for challenge in their work, under supportive conditions, students welcomed and responded well to it. Students need both security and challenge. They need enough confidence in their own ability and in the supportive structures to be able to explore further, to test themselves out and to grow and learn through responding to challenges.

In choosing or designing activities for a certain grade level, variety should be taken into consideration through monitoring the levels of openness of the activities. Genuine enquiry should be addressed where students design materials, methods or both. One approach is to use restricted inquiry, where materials available will be restricted but students are required to design the experimental approach and thus both method and answer are open. Such activities retain some of the advantages of well structured activities: materials can be planned in advance and costs controlled and time needed for the activity can be adequately estimated. (See Appendix 3B). In subsequent revision of the curriculum materials, textbook writers must give sufficient care in designing the practical activities. There is a need for a framework to design the whole textbooks and practical activities. Specific problem solving skills and behavior need to be identified in advance and their balance of treatment should be maintained in the planned curriculum materials.

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Appendix 1

Types of Problem Solving and their examples (Welford, 1990)

CATEGORY	EXAMPLE
Recognize and define problem	your task will be to learn as much as you can about the organs in the frog.
Formulate hypothesis	On the basis of your observations; make a hypothesis about the possible function of cork in the living tree.
Predict	What is likely to happen if glycerinated muscle fiber is exposed to salts as before and then ATP is added drop by drop?
Design observation and Measurement procedures	What control would you suggest for this enquiry?
Design experiment	Device an experiment to test tolerance of vinegar eels to pH changes.
Carry out observations,	Place it in a drop of 5% solution and observe with the microscope.
Measurements, experimental Procedure	Measure the size of the organ for all sets of experimental conditions
Record results, describe	Record results for the effect of temperature on rate of heartbeat.
Transform results into Standard format	make a graph of the data.
Analyze, interpret, make inferences	Analyze your data and determine the mean generation time of the organism
Explain; conclude	What explanations can you give for the different cork cell shape in your presentation?
Define limitations or assumptions	Is an identification of a spot on a chromatograph such as this proof that it is the same as one of the known amino acids?
Formulate generalizations, Models	On the basis of your inquiries into the nature of cells, prepare a statement about your investigation of cell theory.

Categories for analyzing students' tasks in laboratory scripts (Boud, Dunn and Hegarty-Hazel (1989: 118) adapted from Hegarty 1978a and Tamir and Lunetta 1978).

Appendix 2

Summary of results of the Laboratory activities with respect to the Tamir and Lunetta Scheme.

	BIOLOGY G 9. N= 34	BIOLOGY G. 10 N= 45	BIOLOGY G.11 N= 38
PLANNING			
1.1 FORMULATING A QUESTION.	0	0	0
1.2 PREDICTING EXPERIMENTAL RESULT.	0	0	0
1.3 FORMULATING HYPOTHESIS.	0	0	0
1.4 DESIGN OBSERVATION/ PROCEDURE.	0	0	1
1.5 DESIGN EXPERIMENT.	0	1	0
PERFORMANCE			
2.1A CARRIES OUT OBSERVATION.	45	41	26
2.1B CARRIES OUT MEASUREMENT.	3	7	3
2.2 MANIPULATE APPARATUS.	-	-	-
2.3 RECORD RESULTS.	17	13	6
2.4 PERFORM NUMERICAL CALCULATIONS.	4	7	7
2.5 EXPLAIN PROCEDURE.	8	16	8
2.6 WORKS ACCORDING TO OWN DESIGN.	1	2	5
ANALYSIS			
3.1A TRANSFORM RESULTS TO TABLE.	4	3	1
3.1B TRANSFORM RESULTS TO GRAPH.	1	3	1
3.1C MAKES DRAWINGS BASED ON OBSERVATION.	7	20	10
3.2 DETERMINE RELATIONSHIPS/ CONCLUDES.	22	24	13
3.3 DETERMINE ACCURACY OF EXPERIMENT.	1	1	-
3.4 DEFINE ASSUMPTION/ LIMITATIONS.	2	1	-
3.5 FORMULATES GENERALIZATION/ MODEL.	2	1	-
3.6 EXPLAIN A RELATIONSHIP.	15	29	13
3.7 FORMULATE NEW QUESTIONS.	2	-	-
APPLICATION			
4.1 PREDICT BASED ON OBTAINED RESULTS.	15	12	10
4.2 HYPOTHESIZE BASED ON OBTAINED RESULTS.	1	1	-
4.3 APPLIES FINDING IN NEW CONTEXT.	1	2	-

Appendix 3

A) The method of analysis through the OPEN continua and Tamir and Lunetta is exemplified taking activity shown below.

1) Classifying activities through OPEN continuum. *(Simon and Jones, 1992)*

1. *Activity 1: carbohydrates-Testing for Starch*
   Materials: iodine or Potassium Iodide Solution, Dropper; potato.
   Procedure:
   1. *Cut a thin slice of potato from a tuber.*
   2. *Add a few drops of dilute iodine or Potassium iodide.*
   3. *Note the color change.*

   Result: What color change do you see? Iodine is an amber-colored solution that turns blue-black in the presence of starch. (Grade 9 Biology, MOE, 1999)
2. *How does the amount of light affect the number of seeds that germinate?*
3. *What factors affect germination?*

Level	Defining the Problem	Choosing the Method	Arriving at solution
1.	*Closed*	*closed*	*open*
2.	*Closed*	*Open*	*Open*
3.	*Open*	*Open*	*Open*

Fig 3 Classifying tasks on the OPEN Continuum

Activity 1 is a typical structure for laboratory activities in the high school biology. Its aim (to see the type of image formed), the material and methods are clearly specified. Such activities are commonly called 'controlled activities,' 'set activities', 'recipes' and 'cook books' (Woolnough 1991; Boud, Dunn and Hegarty 1989).In essence, this is an activity designed for observation. They have many advantages, includes: (1) they are almost certain to 'work'; (2) they usually occupy about the right amount of laboratory time, neither too long nor too short. However, they do not involve students in the act of problem solving except in the sense of consciously 'copying' an investigation conducted by other scientist. These activities do not involve students in designing the material or method to be used.

Activity one is a closed task in all the continua. It is carefully structured to enable all pupils to reach the same endpoint. Each activity in the students' textbook was analyzed at three points: defining the problem, method and solution sought. Hence, both the problem and methods are well defined and directed, always looking for one solution: to suggest answer to what is stated as aim- to determine the presence of Carbohydrate-for example.

Activity two is an investigative activity. It define the dependent variable (the number of seeds that germinate) but open both at method chosen by the pupil and the solution, which could be one or many. Investigative activity, according to Gott and Duggan (1995) is a specific type of problem solving and is defined as 'a task for which a pupil cannot immediately see an answer or recall a routine method for finding it'. Activity three is clearly an open task at all the continua. No activity was found in the analyzed textbooks with the level of two and three.

2) Analysis through the Tamir and Lunetta Scheme

The method of analysis is shown by taking the activity suggested in Fig 4.1 (Pp.17). To start with, according to Gott & Duggan (1995), such activity is an observation practical- activity that train observational skill. There is no opportunity for a student to employ the skills of **planning** the activity. Under **performance**, students are required to make *observation.* Under **analysis**, students' makes drawing based on observation and determines relationships/

conclude. And finally, under **application**, students make predictions based on obtained result.

B) To remedy the existing excessive emphasis on the structured investigation, an alternative approach can be a restricted inquiry. An example of such inquiry can be shown from Bentley and watts (1989: 81) where students are provided with problem context, and material available is restricted and students are required to design the experiment, hence both method and solution is open.

> You are lost in the wilds of a tropical country. You have not drunk anything for 3 days. All you have around you is swamp water, some coconut trees and some bamboo trees. You have a sharp knife, some matches and a spare shirt. Find a way of producing pure water from the swamp. You must also find a way of producing it is pure.