Analysis of the Science Process Skills in High School Chemistry Textbooks

Temechegn Engida*

Abstract: *The processes of science have been an integral part of school Science, although science educators differ in their conception of the term 'processes'. Based on this premise, this study attempted to analyze the experimental activities included in the Ethiopian high school Chemistry textbooks (grades 9 to 12) in terms of certain criteria. The study showed that, although most elements of the science processes skills were included in the texts, they were not balanced activities seen in the light of the criteria used.*

Introduction

The term `processes´ has been given different meanings by different science educators, and each meaning is with its associated claims (Millar and Driver, 1987). This might be due to the fact that *any definition of separate skills is a convenience rather than an attempt to describe reality* (Harlen, 2000: 73). However, most agree that the process of science, in general and Chemistry in particular, is the ways of thinking scientists use in discovering and ordering scientific knowledge--the product of science. It refers to the resemblance between what is taught to students and what scientists do.

It has been argued that a Science curriculum in general, and a Chemistry curriculum in particular, should pay attention to both the processes and the products (concepts, principles and generalizations) of science. That is to say, the Science/Chemistry curriculum should aim at mastery or understanding of principles and generalizations in chemistry as well as the development of abilities to observe, classify, use numbers, measure, communicate, predict, infer (data

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interpretation), formulate hypothesis, control variable, experiment and so on (Pendaeli, 1976). These skills are exemplified by the following activities that require the student to engage himself/herself in the identification of the chemical processes. Almost all activities are taken from our high school Chemistry textbooks (Curriculum Division, 1983a, b; 1989a, b).

Observe: Can you see the iron fillings and sulfur separately? (9^{th} grade, p. 37)

Classify: Make a list of the substances which are conductors and another list of substances which are non-conductors (11^{th}, Vol. I, Unit III, p. 6)

Using Numbers and Symbols (Mathematical Operations):

- Using the above rules for oxidation number, find the oxidation number of each element in the given compounds (11^{th}, Vol. I, Unit III,p.56).

Measuring: - Note the temperature at which the solid substance melts. Record your result for each substance (9^{th}, p.11).

Communicating (for example, by drawing graphs):

- Draw the shape of copper sulfate crystals you see under the microscope (11^{th}, Vol. II, Unit IV, p.48).

Predicting: - Which reactant would you add to make the reaction mixture neutral? (11^{th}, Vol. I, Unit I, p. 55)

Inferring (Data Interpretation):

- Was there a change in the PH of the solution? If so, how would you account for this? (11^{th}, Vol. I, Unit III, p. 27).

Formulating Hypothesis:

- Mix some sodium carbonate or sodium bicarbonate and citric acid crystals in a dry watch glass. Does chemical change take place? How can you tell? (9^{th}, p. 42).

Controlling Variables:

- How can you maintain a constant pressure in order to show the direct relationship between volume and temperature of a certain gas?

Experimenting:

- Suppose the powders the following elements are given to you. The elements are Fe, Cu, Zn, S, and I_2. These elements are mixed together. I_2 is soluble in ethanol. S is soluble in CS_2. Zn reacts with dilute HCl. Iron fillings are magnetic. Thus the elements can be separated. Suggest the procedure for the separation (9^{th}, p.17).

The above mentioned science process skills should be organized in such a way that the student can exercise the intellectual/practical skills in a meaningful way. In order to achieve this goal a science program should provide a range of activities from the close-ended activities (answers known in advance) to the completely open-ended ones (answers to be learned through the activity). Such an arrangement, Pendaeli (1976) argues, allows for different levels of intellectual participation and abilities. For instance, an activity that requires a student to verify a law or principle is close-ended. On the other hand, an activity that requires the student to investigate, say, the properties of chlorine, or to find out what is obtained when lead bromide is electrolyzed, is open-ended.

A science program should also organize the intellectual/practical activities in such a way that they take two different and perhaps opposite forms: (1) structured activities, (2) unstructured activities. In a structured activity the student is given written instructions that lead him/her through a procedure designed to produce certain specific results. Inserted among these instructions must be questions requiring the student to analyze why he/she is performing a specified operation and why he/she is to do it in a certain way. Nevertheless, the student doesn't know in advance what his/her results will be (Romey, 1968; Gega and Peters, 1998).

Example: Measure out 10 ml of hydrochloric acid using your pipette and put it in a 50 ml beaker. Using a different pipette, measure 10 ml of sodium carbonate solution and add it to the beaker containing the acid. We will call this the reaction mixture. Observe what happens and put your ear close to the mouth of the breaker and listen.

Q.1. What kind of substance produces this type of effect? What do you think this gas is?

Q. 2. Write two cases, you saw at your house, in which bubbles of gas are produced. (11^{th} grade, Vol. I, Unit I, pp. 50-51).

In the above structured activity, there are detailed instructions in which the students interact with the materials. Among the process skills that are included in the instructions, measuring and observing changes are dominant. The questions (Qs) also require the student to predict the type of substances and to hypothesize about the nature of the gas. Moreover, the second question (Q2) requires the student to apply what has been taught in the laboratory to his/her home situations.

On the other hand, an unstructured activity merely poses a problem and then allows the student complete freedom to devise his/her own procedures, organize his/her own data, and arrive at his/her own generalizations. In such activities the student comes closest to following methods a scientist might use, and the possibilities for student discoveries are greatest (Romey, 1968; Gega and Peters, 1998).

Example: When air is moving, sometimes air pressure will be less and sometimes it will be greater. Develop specific steps and procedures to identify the conditions where air pressure is less and where it is greater.

The above activity merely poses the problem. The teacher might provide the student with the necessary materials. The student will then devise his/her own procedures, organize his/her data and finally arrive at the generalization that *air pressure is less where the velocity of the stream is high and greater where the velocity is low.*

This study is an attempt to determine the extent of elements of the science process skills found in the Ethiopian high school Chemistry textbooks, and their ways of organization. In order to tackle this problem, the following three basic questions were formulated:

- To what extent are there individual elements of the chemical process skills?
- How are these chemical process skills organized?
- Does each experiment involve more than one process skill?

The Ethiopian high school Chemistry Curriculum consisted of five textbooks. Both the experimental activities (processes) and the concepts, principles and generalization (products) are organized in the same texts. Although a new chemistry curriculum is developed for our high schools, the previous textbooks for the upper secondary school are still in use. Moreover, a new chemistry textbook is available in the market only for grade 9. The study therefore analyzed the old chemistry textbooks with the intention that textbook writers and revisers (science subject specialists in general and chemistry scholars in particular) will benefit a lot from the findings.

Methods

In this study, the experiments or practical activities in each textbook were first listed and analyzed in terms of their structuredness or unstructurednes. These activities were then classified into close-ended and open-ended activities. Finally, individual elements of the science process skills required of the student by each experiment were identified and then categorized into one of the ten categories of the science process skills described earlier in this paper.

Results and Discussion

Using the above mentioned criteria for analysis, i.e., (a) close- and open-endedness, (b) structured- and unstructuredness, and (c) presence and/or absence of elements of the science process skills, the following results are obtained. In all the 5 textbooks, a total of 106 laboratory activities are found. Of these activities 17.9% (19), 5.7% (6), 26.4% (28), 26.4% (28), and 23.6% (25) are found in grades 9, 10, 11 (Vol. I), 11 (Vol. II), and 12, respectively. These figures indicate that 52.8% (56) of the activities are found in grade 11 textbooks and that the grade 10 chemistry textbook is the least of all activity-oriented textbooks in the Ethiopian High School Chemistry Program.

What is more surprising is that all the laboratory activities are found to be structured activities. This is to say, the organization of the activities are in such a way that the student is given detailed instructions that lead him/her through a procedure designed to produce certain specific results. In other words, no activity in the textbooks poses a problem which allows the student complete freedom to devise his/her own procedure, organize his/her own data, and arrive at his own generalizations.

The next point is how many of these activities are close-ended (answers known in advance) and how many of them are open-ended (answers to be learned through the activity)? Table 1 depicts the number and percentage of each type of activities in each grade level.

Table 1: Distribution of Close and Open-ended Activities

Type of Activity	Number and Percent of Activities in Grade											
	9		10		11(I)		11 (II)		12		Total	
	No	%	No	%	No	%	No	%	No	%	No	%
Close-ended	2	10.5	6	100	17	60.7	22	78.6	11	44	58	54.7
Open-ended	17	89.5	0	0	11	39.3	6	21.4	14	56	48	45.3
Total	19	100	6	100	28	100	28	100	25	100	106	100

As can be seen from Table 1, the Ethiopian high school chemistry textbooks are found to contain 54.7% (58) and 45.3% (48) close-ended and open-ended activities, respectively. In other words, taken all together, there is a reasonable degree of balance between close- and open-ended activities. But this proportion is not found to be regular in each grade level. In grade 9, 89.5% (17) of the activities are open-ended; in grade 10, 100% (6) of them are close-ended; in grade 11(Vol. I), 60.7% (17) are close-ended; in grade 12 (Vol. II), 78.6% (22) of them are close-ended; whereas in grade 12, 56%(14) of them are open-ended. Furthermore, the grade 10 chemistry textbook is found to contain only 6 experiments all of which are close-ended activities. These activities, in turn, contain 419 chemical process skills, which are organized as both close-ended and open-ended activities. Table 2 shows the number and percentage of each skill in each grade level.

As can be seen from Table 2, activities requiring the student to observe are the most abundant (49.2%, 206). This trend, in which the skill to observe is abundant, is also true in each grade level. However, there is no regular increase or decrease in the number of science process skills as we go up the educational ladder, i.e., from grade 9 through 12.

It is also evident from Table 2 that the most serious omission from our secondary school chemistry textbooks is the skill to control variables (0%) during any one of the experiments. This is followed by the skill to communicate (1%, 4), and then the skill to experiment (1.2%, 5). Further analysis of the textbooks revealed that most of the experiments involve more than one science process skills. But none of the experiments involve all of the skills at a time.

Table 2: Distribution of the Chemical Process Skills

Process Skills	Process Skills Required in Grade											
	9		10		11(I)		11 (II)		12		Total	
	No	%	No	%	No	%	No	%	No	%	No	%
Observing	27	6.4	11	2.6	41	9.8	64	15.3	63	15.1	206	49.2
Classifying	2	0.5	-	-	4	1.0	2	0.5	17	4.0	25	6.0
Using Numbers & Symbols	-	-	-	-	6	1.4	1	0.3	5	1.2	12	2.9
Measuring	1	0.3	8	1.9	24	5.7	14	3.3	32	7.6	79	18.8
Communicating	-	-	-	-	-	-	3	0.7	1	0.3	4	10
Predicting	1	0.3	-	-	6	1.4	1	0.2	18	4.3	26	6.2
Inferring (Data Interpretation)	3	0.7	-	-	25	6.0	1	0.2	11	2.6	40	9.5
Formulating hypothesis	3	0.7	-	-	8	1.9	-	-	11	2.6	22	5.2
Controlling Variables	-	-	-	-	-	-	-	-	-	-	-	-
Experimenting	1	0.2	-	-	-	-	-	-	4	1.0	5	1.2
Total	38	9.1	19	4.5	114	27.2	86	20.5	162	38.7	419	100

Concluding Remarks

Based on the findings, the following concluding remarks are made:

- Most of the individual elements of the science process skills applicable in high school chemistry experiments are included in the chemistry textbooks, but not necessarily all elements in any one experiment.

- The most serious omission is the need for controlling variables in any one of the experiments. The skill to communicate and the skill to experiment are also found to be almost negligible.

- The organization of the activities does not include the need for unstructured activities.

It should be stressed that the process skills are components of a complex activity called inquiry or investigation. In line with Harlen's (2000) argument, however, it is necessary to look at the component parts so as to help students develop skills in all aspects of the development of understanding.

It is thus recommended that the following points be given special attention when new chemistry textbooks are written and/or chemistry textbooks are revised:

- It would seem profitable if all the elements of the chemical process skills are found to a reasonable degree at least in the higher grade levels of the high school.
- As much as possible the organization of the skills in textbooks and/or in laboratory manuals should take into account the need for unstructured activities. It is such activities that help students exercise their critical and creative thinking skills, skills that are necessary for solving problems in daily and academic situations.
- Curriculum developers should, from the outset, consider not only which items of content should be included in syllabuses but also which skills and processes should be included.

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