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Science Process Skills Assessed in the Examinations Council of Zambia (ECZ) Senior Secondary School Chemistry-5070/3 Practical Examinations

Billy Siachibila[1]* Asiana Banda[2]
1. School of Natural Sciences, Mukuba University, P.O Box 20382, Kitwe, Zambia
2. School of Mathematics and Natural Sciences, Copperbelt University, P.O Box 21692, Kitwe, Zambia

Abstract
The purpose of this study was to determine the science process skills inherent in the Examination Council of Zambia (ECZ) pure chemistry practical examinations (5070/3) for a period of 10 years (2007-2016). The study adopted the Ex-post facto research design. The questions from the ECZ chemistry-5070/3 practical examination (5070/3) from 2007-2016 were analyzed for science process skills based on the 12 categories of science process skills adopted from the AAAS (1993), with an addition of one more integrated skill which is *graphing*. Data were analyzed descriptively by computing frequencies and percentages. The results from the study shows that the science process skills included in the practical examinations are; interpreting data, experimenting, inferring, observation, measurement and communicating only. Among the 13 science process skills focused, the most prominent were observing (28.94%), measuring (15.44%), communicating (28.64%), and interpreting data (11.10%). Comparing the two categories of science process skills, basic and integrated science process skills, the results show a high percentage of the basic science process skills at 80.51% as compared to integrated science process skills at 19.50%. This implies that ECZ included more basic science process skills as compared to integrated science process skills in its national examination for the period from 2007 to 2016. These results have implications to chemistry teaching and learning at high school level.
Keywords: chemistry, chemistry education, science education, practical examinations, science process skills.

1. Introduction

The Zambian chemistry curriculum was recently revised placing much emphasis on the acquisition of science process skills (Ministry of Education [MoE], 2013). This means that the teachers of chemistry need to reflect all the dimensions of science in their lessons so as to promote the acquisition of science process skills. The three dimensions of science are; scientific attitudes, process skills and scientific content knowledge (Opateye, 2012). According to Akinbobola and Ikitde (2008), the process approach method of teaching science or chemistry is meant to foster inquiry and manipulative skills in students and discourage rote learning. The process approach method ensures learners are actively involved in the learning process. This implies that teachers of chemistry should embrace such methods if they are to ensure that learners acquire the science process skills. In particular, chemistry teachers need to accommodate practical activities in their lessons.

According to Giddings & Fraser (1988, as cited in Akinbobola & Afolabi, 2010), achieving the objectives of science practical work is dependent on the mode of assessment of laboratory work used by the teachers as well as the examination bodies. They argue that the methods used for assessment directly influence teachers' methods of teaching, students' learning styles and attitudes towards practical activities. The practical skills in chemistry are science process skills which are taught as part of the chemistry curriculum. These skills can be acquired and developed by the pupils through getting involved in the activities that take place in the chemistry practical sessions. Maundu, Sambili and Muthwii (2005) stated that one of the ways of assessing the objectives of teaching biology is through practical work. In the same way objectives of teaching chemistry can be assessed through practical work as well. In practical work, an opportunity is provided for testing application of scientific procedures, manipulative abilities as well as science process skills (Ongowo & Indoshi 2013).

The Examinations Council of Zambia (ECZ) is a body mandated to run the affairs of national examinations in the country. ECZ is responsible for national examinations at Grades 7, 9 and 12 levels. ECZ is also in charge of Diploma examinations in Teacher Education Colleges at tertiary level. ECZ is responsible for preparing and marking the examinations at all these levels. ECZ makes use of practical examinations to test students' acquisition of biology, chemistry and physics practical skills which in the real sense are science process skills. In these practical examinations, the learners are required to carry out biology, chemistry and physics practical activities following some given instructions. These practical activities are in form of experiments. In the case of chemistry, these examinations usually have two questions of which one is on qualitative analysis (identification of cations/anions) and the other one is on quantitative analysis (titration). Akinbobola and Afolabi (2010) hold the view that the scores that the pupils obtain from their practical examinations are indirect reflections of the process skills they could display during the practical examination. At the same time, the final score that a candidate obtains in biology, chemistry or physics is contribution of both the theory examination and the practical examination scores. Akinbobola and Afolabi (2010) further notes that the practical assessment scores of a pupil is a reflection of the teaching approach that a teacher employed during the learning situation especially the process approach. The examination bodies should therefore stipulate that practical work should form the basis of teaching so as to encourage teachers of chemistry to impart these process skills in the pupils.

Science process skills have been described differently by different scholars. Padilla (1990) described science process skills as, “a set of broadly transferrable abilities appropriate to many science disciplines and reflective of the behavior of scientists”. Nwosu and Okeke (1995) view science process skills as, “mental and physical abilities and competencies which serve as tools needed for effective study of science and technology as well as problem solving, individual and societal development”. The implication of these two definitions is that every pupil passing through the formal education system should have knowledge about these process skills. More so, Akinbobola & Afolabi (2010) view science process skills as cognitive and psychomotor skills employed in problem solving, problem identification, data gathering, transformation, interpretation and communication. Therefore, these science process skills are important as they aid science learning and generation of scientific knowledge.

The American Association for the Advancement of Science (AAAS) classified the science process skills into fifteen and these are: observing, measuring, classifying, communicating, predicting, inferring, using number, using space/time relationship, questioning, controlling variables, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data. These science process skills are grouped into two categories which are basic and integrated science process skills (AAAS, 1993).

Other scholars developed their own lists. For example Bybee et al. (1989) and Ango (1992) developed a list with basic science process skills comprising observing, measuring, classifying, communicating, inferring, using number, using space/time relationship and questioning while the integrated science process skills list include controlling and manipulating variables, hypothesizing, defining operationally, formulating models, designing experiment and interpreting data.

According to Padilla (1990), the science basic process skills are observing, classifying, predicting, inferring, measuring, and communicating. For integrated skills, most lists include identifying and controlling variables, defining operationally, reading/constructing graphs, formulating hypotheses, interpreting data, experimenting, and formulating models.

Rambuda and Fraser (2004) commented that basic science process skills apply specifically to foundational cognitive functioning in especially elementary grades. As noted by Brotherton and Preece (1996), basic science process skills represent the foundation and basis of scientific reasoning that the learners are required to master before acquiring and mastering integrated science process skills that are much more advanced. Integrated science process skills depend much on each other, meaning that pupils or any investigator may apply more than one of the basic process skills in a single activity, (Rambuda & Fraser, 2004). Rambuda and Fraser (2004) further state that, integrated science process skills are the immediate skills used in problem solving or doing science experiments. With the integrated science process skills, learners have to combine a number of basic science process skills for greater expertise and flexibility to design the tools they apply when they study or investigate phenomena.

2. Problem statement

The science process skills are practical skills important in the construction of scientific knowledge (Ongowo & Indoshi, 2013). In view of this, it simply means that chemistry practical skills are science process skills. In Zambia, chemistry practical skills (science process skills) are taught as part of the chemistry curriculum. Grade 12 pupils at senior secondary level write practical examinations in chemistry. Initially, only those taking Chemistry- 5070 (considered as pure chemistry) were required to take chemistry practical examination, but now even those taking Science-5124 are expected to take chemistry practical examinations as well prepared by the Examinations Council of Zambia (ECZ). The examination format is such that there are two questions in the paper, one on qualitative and another on quantitative analyses which raises a question of whether the two questions cover the full range of science process skills. More so, no research has been done to analyze science process skills inherent in the ECZ 5070/3 chemistry practical examinations and classify them according to their categories of either basic or integrated science process skills. There is therefore need to investigate the levels of testing of science process skills and hence identify the science process skills present in the ECZ 5070/3 chemistry practical examinations and classify them according to their categories.

3. Purpose and Research questions of the Study

The purpose of the study was to determine the science process skills included in the Examinations Council of Zambia 5070/3 Chemistry practical examinations for a period of 10 years, from 2007 up to 2016. The study was guided by the following research questions:

1. What are the prominent science process skills in the Examinations Council of Zambia 5070/3

chemistry practical examinations from 2007-2016?
2. What are the percentages of basic and integrated science process skills included in the Examination Council of Zambia 5070/3 chemistry practical examinations from 2007-2016?

4. Methodology

This study used the ex-post facto research design. The research design used a quantitative survey type of research methodology. The design was chosen because it uses data that is already collected, but not amassed for research purposes. Some of the advantages of ex post facto study are that; data are already collected; obtaining permission to conduct the study is less involving and also less time is involved in conducting the study than what it would require to create new data. The instrument used for the study was the Examinations Council of Zambia 5070/3 chemistry practical question papers (ECZ-5070/3 CPQP) across the years 2007-2016. The instrument (ECZ-5070/3 CPQP) had already been validated and the reliability had been conducted and obtained by the Examinations Council of Zambia (ECZ).The researcher collected the 5070/3 chemistry practical examination papers across the years 2007-2016 and working with one chemistry expert identified all basic and integrated science process skills for each year based on the categorization of basic and integrated science process skills made by the AAAS (1993). According to this categorization, the category of basic science process skills include inferring, observing, communicating, classifying, measuring and predicting while that of integrated science process skills includes controlling variables, defining operationally, graphing, formulating hypothesis, formulating models, interpreting data and experimenting. Each of the basic and integrated science process skills is briefly explained in Table 1 below. The collected data were analyzed by computing frequencies and percentages.

Table 1**:** Basic and integrated science process skill.

Basic process skills	**Description**
Observing	Use of five senses to derive characteristics of living organisms
Inferring	Explanation of observations and data
Measuring	Using standard and non-standard measures to describe dimensions
Communicating	Using words or symbols to describe an action, object or event
Classifying	Sorting, grouping and arranging based similarities and differences
Predicting	Stating the outcome of a future event based on a pattern of evidence
Integrated Process skills	**Description**
Controlling variables	Identifying variables, keeping variables constant and manipulating
Defining operationally	Stating how to measure a variable in an experiment
Formulating hypotheses	Stating the expected outcome of an experiment
Interpreting data	Organizing , concluding from data and making sense of data
Experimenting	Testing by following procedures to produce verifiable results
Formulating models	Creating a mental or physical model of a process or event;
Graphing	Using information about the data as numerical quantities and converting into a diagram or picture that shows the relationships among the quantities

Source: Ongowo & Indoshi (2013), with an addition of the skill of graphing.

5. Results of the study

5.1 Science process skills in the ECZ chemistry (5070/3) examinations

Research Question 1: What are the prominent science process skills in the Examinations Council of Zambia 5070/3 chemistry practical examinations from 2007-2016?

The results are as shown in Tables 2 and 3 below. Table 2 shows the results of basic science process skills while Table 3 shows the results of the integrated science process skills. More so, they show percentages out of the total science process skills identified in the ECZ 5070/3 chemistry practical questions.

Table 2: Basic science process skills in the ECZ 5070/3 chemistry practical examination papers from 2007-2016.

YEAR	Basic Science Process Skills						
	Infer	Obs	Meas	Comm	Class	Predic	TOTAL Freq (%)
2007	7	22	12	18	0	0	59 (8.85)
2008	7	17	9	16	0	0	49 (7.35)
2009	4	13	6	20	0	0	43 (6.45)
2010	7	22	12	25	0	0	66 (9.89)
2011	6	20	10	20	0	0	56 (8.39)
2012	4	29	15	22	0	0	70 (10.49)
2013	4	14	7	19	0	0	44 (6.59)
2014	3	22	11	19	0	0	55 (8.25)
2015	3	20	13	16	0	0	52 (7.79)
2016	5	14	8	16	0	0	43 (6.45)
TOTAL Freq (%)	50 (7.49)	193 (28.94)	103 (15.44)	191 (28.64)	0 (0.00)	0 (0.00)	537 (80.51)

KEY: Infer = Inferring, Obs = Observing, Meas = Measuring, Comm = Communicating, Class = Classifying, Predic = Predicting.

Table 3: Frequencies of integrated science process skills in the ECZ 5070/3 chemistry practical examination papers from 2007-2016

YEAR	Integrated Process Skills							
	Cont. Var	Def. Oper	Form Hyp	Int. Dat	Exp't	Form Mod	Gra	TOTAL Freq (%)
2007	0	0	0	7	6	0	0	13 (1.95)
2008	0	0	0	7	5	0	0	12 (1.80)
2009	0	0	0	8	3	0	0	11 (1.65)
2010	0	0	0	7	6	0	0	13 (1.95)
2011	0	0	0	9	6	0	0	15 (2.25)
2012	0	0	0	7	9	0	0	16 (2.40)
2013	0	0	0	7	3	0	0	10 (1.50)
2014	0	0	0	7	6	0	0	13 (1.95)
2015	0	0	0	7	6	0	o	13 (1.95)
2016	0	0	0	8	6	0	0	14 (2.10)
TOTAL Freq (%)	0 (0.00)	0 (0.00)	0 (0.00)	74(11.10)	56(8.40)	0 (0.00)	0(0.00)	130 (19.50)

KEY: Cont. Var = Controlling Variables, Def Oper = Defining operationally, Form Hyp = Formulating Hypothesis, Int. Dat = Interpreting Data, Expt = Experimenting, Form Mod = Formulating Models, Gra = Graphing

Table 2 shows that there were a total of 537 basic science process skills included in the chemistry practical examination papers from 2007 to 2016. Furthermore, Table 3 shows that 130 integrated science process skills were examined in the same period. Thus, a total of 667 science process skills were included in the chemistry-5070/3 practical examinations for a period of 10 years from 2007 to 2016. Out of the 667 science process skills identified within the period of 10 years (2007-2016) in the Examinations Council of Zambia 5070/3 chemistry practical examinations, the most common or prominent science process skills are Observation with a total frequency of 193 (28.94%), Measuring with a frequency of 103 (15.44%), Communicating with a frequency of 191 (28.64%) and Interpreting Data with a frequency of 74 (11.10%). The percentages are of the total process skills identified. The results further show that out of the 13 science process skills considered in this study, Interpreting Data is the only common integrated science process skill in the years under study while observation, measuring and communicating are the most common basic science process skills. This means that 4 out of the 13 science process skills are more prominent across the years under study in the ECZ 5070/3 chemistry practical examinations in Zambia.

Further analysis was done to determine percentages of basic process skills out of the total basic science process skills identified in the years under consideration as well as integrated science process skills in the same manner. Tables 4 and 5 show these results.

Table 4: Percentages of basic science process skills out of total basic process skills in the ECZ 5070/3 chemistry Practical examinations in Zambia from 2007-2016

YEAR	**Basic Science Process Skills**						
	Infer	Obs	Meas	Comm	Class	Predic	**TOTAL Freq (%)**
2007	7	22	12	18	0	0	59 (10.99)
2008	7	17	9	16	0	0	49 (9.12)
2009	4	13	6	20	0	0	43 (8.01)
2010	7	22	12	25	0	0	66 (12.29)
2011	6	20	10	20	0	0	56 (10.43)
2012	4	29	15	22	0	0	70 (13.04)
2013	4	14	7	19	0	0	44 (8.19)
2014	3	22	11	19	0	0	55 (10.24)
2015	3	20	13	16	0	0	52 (9.68)
2016	5	14	8	16	0	0	43 (8.01)
TOTAL Freq (%)	50 (9.31)	193(35.94)	103 (19.18)	191 (35.57)	0 (0.00)	0 (0.00)	537 (100)

KEY: Infer = Inferring, Obs = Observing, Meas = Measuring, Comm = Communicating, Class = Classifying, Predic = Predicting.

Table 5: Percentages of basic science process skills out of total integrated process skills in the ECZ 5070/3 chemistry Practical examinations in Zambia from 2007-2016

YEAR	**Integrated Process Skills**							
	Cont. Var	Def. Oper	Form Hyp	Int. Dat	Exp't	Form Mod	Gra	**TOTAL Fre (%)**
2007	0	0	0	7	6	0	0	13 (10.00)
2008	0	0	0	7	5	0	0	12 (9.23)
2009	0	0	0	8	3	0	0	11 (8.46)
2010	0	0	0	7	6	0	0	13 (10.00)
2011	0	0	0	9	6	0	0	15 (11.54)
2012	0	0	0	7	9	0	0	16 (12.31)
2013	0	0	0	7	3	0	0	10 (7.69)
2014	0	0	0	7	6	0	0	13 (10.00)
2015	0	0	0	7	6	0	0	13 (10.00)
2016	0	0	0	8	6	0	0	14 (10.77)
TOTAL Fre (%)	0 (0.00)	0 (0.00)	0 (0.00)	74(56.92)	56(43.08)	0 (0.00)	0(0.00)	130 (100)

KEY: Cont. Var = Controlling Variables, Def Oper = Defining operationally, Form Hyp = Formulating Hypothesis, Int. Dat = Interpreting Data, Expt = Experimenting, Form Mod = Formulating Models, Gra = Graphing

The results from Tables 4 and 5 confirm the analysis from Tables 2 and 3 revealing that only 4 science process skills are common out of the 13 analyzed in this study in the years from 2007-2016. However, the pattern has changed, interpreting data and experimenting in this case have higher percentages as compared to any of the basic science process skills, the analysis in Tables 2 and 3 show observation and communication having higher percentages as compared to any other process skill be it basic or integrated.

5.2 *Percentages of basic and integrated science process skills*

Research Question 2: What are the percentages of basic and integrated science process skills included in the Examination Council of Zambia 5070/3 chemistry practical examinations Zambia from 2007-2016?
The results answering this question are summarized in Table 6 below.

Table 6: Summary of basic and integrated science process skills in the ECZ 5070/3 chemistry practical Examinations from 2007-2016

S/N	Basic Process Skills	Freq (%)	S/N	Integrated science process skills	Freq (%)
1.	Inference	50 (7.49%)	1.	Controlling Variables	0 (0.00%)
2.	Observing	193 (28.94%)	2.	Defining operationally	0 (0.00%)
3.	Measuring	103 (15.44%)	3.	Formulating Hypothesis	0 (0.00%)
4.	Communicating	191 (28.64%)	4.	Interpreting Data	74 (11.10%)
5.	Classifying	0 (0.00%)	5.	Experimenting	56 (8.40%)
6.	Predicting	0 (0.00%)	6.	Formulating Models	0 (0.00%)
			7.	Graphing	0 (0.00%)
	Total	**537 (80.51%)**			**130 (19.50)**

KEY: Freq = Frequency

From the results in Table 6, among the basic science process skills analyzed in this study, observation had a high rate with a frequency of 193 (28.94%), seconded by communication with a frequency of 191 (28.64%) and followed by measuring with a frequency of 103 (15.44%). Other basic science process skills were rated very low. These are as follows; inferring at a frequency of 50 (7.49%); classification and prediction had a frequency of 0 (0.00%) each.

The results in Table 6 also show that among the integrated science process skills identified in this study, interpreting data was rated highest with a frequency of 74 (11.10%) followed by experimenting at a frequency of 56 (8.40%). Other integrated science process skills were not tested during the period under review. These included the following; controlling variables, defining operationally, formulating hypothesis, graphing and formulating models.

Results in Tables 6, reveal that there were more basic science process skills being examined than integrated science process skills in the years under study. This is indicated by high percentage of basic science process skills at 80.51% as compared to the integrated science process skills at a percentage of 19.50%. Of the basic science process skills, the skills of observation and communication were the most examined and emphasized. As noted by Ongowo & Indoshi (2013), the skill of observation is the most basic process skill and is subsumed in all the integrated science process skills. Equally the skill of communication was the most emphasized because at all stages the learners need to communicate their findings from the experiments done such as observations and calculations.

The results in this study are similar to those of Nwosu (1994), Akinbobola and Afolabi (2010), and Ongowo and Indoshi (2013). These studies revealed that in national examinations, examination bodies examine more basic science process skills than integrated science process skills. Ongowo & Indoshi (2013) suggested that the reason for overemphasis of basic science process skills could be due to the fact that they are the most easily learnt and transferrable to novel situations as compared to integrated science process skills that require more practice consistently.

6. Conclusion

The four (4) common science process skills identified in the Examinations Council of Zambia (ECZ) 5070/3 chemistry practical examinations in the period 2007-2016 out of the thirteen (13) examined in this study are, observing (28.94%), measuring (15.44%), communicating (28.64%), and interpreting data (11.10%). Out of these, the only integrated science process skill is interpreting data. Comparing the two categories of science process skills, basic and integrated skills, the results show a high percentage of the basic science process skills at 80.51% as compared to integrated science process skills at 19.50% indicating that the number of basic science process skills was significantly higher than the number of integrated science process skills in the Examinations Council of Zambia (ECZ) 5070/3 chemistry practical examinations within the years 2007-2016.

7. Implications of the Study

The findings of this study reveal that in the years considered, more basic science process skills were examined than integrated science process skills showing likelihood that integrated science process skills are less emphasized in the teaching and learning process. Ongowo & Indoshi (2013) commented that such findings mean that learners that complete graduate from high school may not be in the position to participate effectively in activities where problem solving skills are required which are developed from acquisition of integrated science process skills. Integrated science process skills are very important as they are more required for self reliance, development and problem solving as compared to basic science process skills. As such, ECZ should ensure that chemistry 5070 practical examinations should include activities that demand students to use more of both basic and integrated science process skills.

8. Recommendations for future study

The research should be extended to other practical examinations such as Science 5124, Biology 5090, and physics 5054. This would give a full picture of the coverage of science process skill in the national examinations. All practical examinations make use of the same science process skills.

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