

Science Process Skills in the Kenya Certificate of Secondary Education Biology Practical Examinations

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Received September 10th, 2013; revised October 10th, 2013; accepted October 17th, 2013

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The purpose of the study was to determine the science process skills included in the Kenya Certificate of Secondary Education (KCSE) biology practical examinations in Kenya for a period of 10 years (2002-2012). Ex-post facto design was adopted for the study. The content of KCSE Biology Practical Questions (KCSE-BPQ) for the period was analyzed based on 12 categories of science process skills and their descriptions. The data were analyzed descriptively using percentages. The five most common science process skills identified out of the 12 examined in the study are observation (32.24%), communicating (14.63%), inferring (13.13%), experimenting (12.21%) and interpreting data (11.94%). The results also revealed a high percentage of basic science process skills at 73.73% compared to the integrated science process skills at 26.27%. It is recommended that the Kenya National Examination Council should include more integrated science process skills into the KCSE biology practical examinations to enable the students to develop problem solving abilities and creativity which are important tools for biotechnology.

Keywords: Biology; Practical Examinations; Science Process Skills; Kenya

Introduction

The goal of science education is to enhance all students' scientific literacy; that is to help students grasp essential science concepts, to understand the nature of science, to realize the relevance of science and technology in their lives and to willingly continue their science study in school or beyond school (AAAS, 1993). The student-centered active learning process within which the teacher is merely a guide is the focal point of contemporary education systems. The active learning is a learning process in which the learner takes the responsibility of learning and is given the opportunity to make decisions about various dimensions of the learning process and to perform self-regulation. In an active learning process, learning is no longer a standard process, but transforms into a personalized process where process skills are developed (Akinoglu & Tandogan, 2007).

There are three important dimensions of science, viz: 1) content of science, the basic concepts and scientific knowledge 2) the process of doing science and 3) scientific attitudes (Opateye, 2012). One of the domains critical for the development of scientific literacy is science process skills. It is natural for science process skills to be learnt since when learners interact with the world in a scientific way, they find themselves using process skills (AAAS, 1993). Understanding of the world around individuals depends on the development of concepts. The development of concepts depends on the process skills. The concepts and process skills are interrelated. As concepts gradually become sophisticated, process skills need to be refined and ex-

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tended. The implication is that the goal of any science teacher should be to foster the development of science process skills. The application of these science process skills allows the students to investigate important issues in the world around them.

The term science process skills refer to a set of broadly transferable abilities appropriate to many science disciplines and reflective of the behavior of scientists (Padilla, 1990). According to Nwosu and Okeke (1995), science process skills are mental and physical abilities and competencies which serve as tools needed for the effective study of science and technology as well as problem solving and individual societal development. Akinbobola and Afolabi (2010) view science process skills as cognitive and psychomotor skills employed in problem solving, problem identification, data gathering, transformation, interpretation and communication.

According to Ozgelen (2012), science process skills are thinking skills that scientists use to construct knowledge in order to solve problems and formulate results. Implicit in these definitions of science process skills is that these skills are integral and natural to a scientist; they are instruments for the study and generation of scientific knowledge; science learning and development of science process skills are integrated activities.

Categories of Science Process Skills

The commission on science education of the American Association for the Advancement of Science (AAAS) launched a program named Science A Process Approach (SAPA), which emphasized the laboratory method of instruction and learning of scientific processes by children. SAPA grouped process

skills into two types—basic and integrated (AAAS, 1993).

According to Rambuda and Fraser (2004), the basic science process skills apply specifically to foundational cognitive functioning in especially elementary grades. They represent the foundation of scientific reasoning learners are required to master before acquiring and mastering the advanced integrated science process skills (Brotherton & Preece, 1995). Funk et al. (Cited in Rambuda & Fraser, 2004), maintain that basic science process skills are interdependent, implying that investigators may display and apply more than one of the skills in any single activity. For instance to *measure* the area of a habitat, the biology student may start by *observing* the habitat, then *measure* the dimensions and communicate the same using a symbol. Thereafter the student may *calculate* the area. In this scenario, the student was involved in the skill of *observing, measuring and calculating*. The basic science process skills include observing, inferring, measuring, communicating, classifying and predicting (Padilla, 1990). From this, it appears the basic science process skills provide an intellectual groundwork in problem solving.

According to Rambuda and Fraser (2004) integrated science process skills are the immediate skills used in problem solving or doing science experiments. As the term integrated implies, learners are called upon to combine basic science process skills for greater expertise and flexibility to design the tools they apply when they study or investigate phenomena. The integrated skills include controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, and formulating models.

The Rationale for the Process Approach

According to Harlen (1999) and Sevilay (2011), the mastery of science process skills enables students to conceptualize at a much deeper level, the content they do know and equips them for acquiring content knowledge in the future. Content knowledge is acquired more efficiently and understood at a deeper level when obtained through inquiry using science process skills. The science curriculum that emphasizes science process skills will be able to help students to improve the skills in critical thinking, creative thinking and decision making. These skills can be transferred to other disciplines (Meador, 2003; Halim and Meerah, 2012). According to Brotherton and Preece (1996) and Sevilay (2011), the basic science process skills helps in providing the intellectual groundwork in scientific inquiry such as ability to order and describe natural objects and events. The ability to apply basic science process skills is attributed to the ability to perform empirical inductive reasoning or piagetian concrete operational reasoning. Sevilay (2011), holds that the integrated science process skills are the terminal skills for solving problems or doing science experiments. The ability to carry out integrated science process skills are attributed to hypothetico-deductive reasoning. Sevilay (2011), continues to hold that science process skills help the students to develop a sense of responsibility in their own learning, increase permanency of learning as well as teach them research methods. According to Opataye (2012) and Okere (1997), science process skills are helpful on the development of favorable scientific attitudes and a disposition in the learners. These include being curious and imaginative, including enthusiasm about inquisitiveness.

Science Process Skills and Inquiry Approach

Science curricula around the world emphasize the philosophy of inquiry in science teaching. In the context of science, inquiry refers to the abilities students should develop to be able to design and conduct scientific investigations. In the context of instruction, inquiry refers to the teaching and learning strategies that enable concepts to be mastered through investigation and practical work (National Research Council [NRC], 2000). According to Gagne (1963), scientific inquiry is constituted by a set of activities characterized by problem solving approach in which a newly encountered phenomenon becomes a challenge for thinking. Such thinking begins with a careful set of systematic observations, proceeds to design of measurements required, clear distinction between what is observed and what is under ideal circumstances, brilliant leaps but always testable and drawing reasonable conclusions. Brickman et al. (2009) observe that in sciences, inquiry based learning increases literacy and skill development.

According to Maundu, Sambili and Muthwii (2005), in the inquiry approach, learning is by discovery and is characterized by the development of science process skills. Uno and Bybee (cited in Brickman et al., 2009) hold that inquiry is a laboratory inquiry in which the instructor leads the students to discover a specific concept after being prompted by a basic question or problem. Kim (2007), posits that inquiry based teaching that engages students in various hands on activities in the science laboratory is likely to enhance science process skills. Implicit in these arguments is that science process skills are encompassed in the conduct of scientific inquiry and these skills are developed in the laboratory practical situations.

In the Kenyan context, the Kenya Institute of Education (KIE) reorganized and rationalized the current biology curriculum with a strong recommendation for the employment of inquiry approach to teach biology concepts and the development of science process skills and problem solving abilities as some of the broad objectives (KIE, 2002). According to sevilay (2011), students can acquire the science process skills by participating in inquiry in the science laboratory. Ango and Gyuse (Cited in Ango, 2002), argue that practical work engenders not only the science process skills appropriate for scientific inquiry but also inculcates attitudes and conceptual perspectives which are necessary for skilled scientific inquiry. The inquiry approach to teaching can only be enhanced through the application of science process skills.

The biology practical skills are science process skills. They are taught as part of the biology curriculum. These skills can be acquired and developed through activities involved in the biology practical sessions. According to Maundu, Sambili and Muthwii (2005), one of the ways of assessing the objectives of teaching biology is through practical work. In practical work, an opportunity is provided for testing application of scientific procedures, manipulative abilities as well as scientific skills.

The Kenya National Examinations Council (KNEC) makes use of practical examinations to test students' acquisition of various biology practical skills which in essence are science process skills. In these examinations, students are required to carry out biology practical activities following some given instructions. The performance of students in the Kenya National Examinations Council in Biology practical examinations has been below average. For instance in the years 2008, 2009 and 2010 the students scored means of 17.30, 15.86 and 18.42 re-

spectively out of 40 (KNEC, 2011). The scores that students obtain from their practical exams are indirect reflections of the process skills they could display during the practical examination. At the same time, the final score that a candidate scores in biology is contribution of both the theory examination and the practical examination scores. According to Afolabi and Akinbobola (2010), the practical assessment score of a student is a reflection of the teaching approach that a teacher employed during the learning situation especially the process approach.

Problem and Purpose of the Study

The science process skills are practical skills important in the construction of scientific knowledge especially biological knowledge at secondary school level in Kenya. However, for a long time, no analysis has been done on the KCSE biology practical examinations to determine the science process skills present. There is therefore need to investigate the level of testing of the science process skills and also to identify the science process skills inherent in Kenya Certificate of Secondary Education (KCSE) biology practical examinations and classify them to their various categories. The purpose of the study was to determine the science process skills included in the Kenya Certificate of Secondary Education (KCSE) biology practical examinations in Kenya for a period of 10 years.

Objectives of the Study

The study was guided by the following objectives:

- To determine the science process skills included in the KCSE biology practical examinations in Kenya.
- To compare the basic and integrated process skills included in the KCSE biology practical examinations in Kenya.

Research Questions

The study sought to provide answers to the following questions:

- What are the prominent science process skills in the KCSE biology practical examinations in Kenya?
- What are the percentages of basic and integrated process skills included in the KCSE biology practical examinations in Kenya?

Method

The design adopted for the study was an ex-post facto design. The instrument used for the study was the Kenya Certificate of Secondary Education Biology Practical Questions (KCSE-BPQ) across the years 2002-2012. The researchers and three biology teachers collected the biology practical papers for the 10 year period and identified all the basic and integrated process skills for each year independently based on the descriptions of the categories of science process skills in **Table 1**. Thereafter, the researchers and the biology teachers discussed and agreed in cases where differences in the numbers of the process skills existed.

The study adopted the categorization of science process skills according to American Association for the Advancement of Science (AAAS, 1993). According to this categorization, the basic science process skills comprise of Inferring, observing, measuring, communicating, classifying, predicting. The integrated science process skills comprised of controlling variables,

Table 1.
Basic and integrated science process skills.

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;

defining operationally, formulating variables, interpreting data, experimenting and formulating models. The data were collected using simple percentages. Each of the basic and integrated process skills are briefly described in **Table 1**.

Results and Discussion

Research Question 1: What are the most common science process skills in the Kenya Certificate of Secondary Education biology practical examinations in Kenya?

From the analysis shown in **Tables 2** and **3**, out of 330 process skills identified within the period of 10 years (2002-2012) in the Kenya National Examinations Council (KNEC) biology practical examinations, the most common science process skills are Observation with a total frequency of 108 (32.24%), Communicating with a frequency of 49 (14.63%), Inferring with a frequency of 44 (13.13%), Experimenting with a frequency of 41 (12.21%) and Interpreting data with a frequency of 40 (11.94%). This implies that out of the 12 process skills analyzed in this study, experimenting and interpreting data are the most common integrated science process skills. On the other hand, observation, communicating and inferring are the most common basic science process skills. The implication is that 5 out of the 12 science process skills are more common within the years under study in the Kenya Certificate of Secondary Education biology practical examinations.

Research Question 2: what are the percentages of the basic and integrated science process skills included in the Kenya Certificate of Secondary Education biology practical examinations?

The analysis is as shown in **Tables 2** and **3**. The analysis

Table 2.
Basic science process skills in the KCSE biology practical examinations from 2002-2012.

Basic Science Process Skills							
Year	Infer	Obs	Meas	Comm	Class	Predic	Total
2002	7	12	3	3	3	0	28 (8.36)
2003	8	10	5	6	2	2	33 (9.85)
2004	9	15	0	5	1	0	30 (8.95)
2005	7	14	1	5	6	0	33 (9.85)
2006	3	4	0	2	1	0	10 (2.99)
2007	3	8	0	2	3	0	16 (4.78)
2008	1	7	2	5	0	0	15 (4.48)
2009	3	9	0	7	3	0	21 (6.27)
2010	0	12	0	3	0	0	15 (4.48)
2011	0	8	1	8	1	0	13 (3.88)
2012	3	9	10	3	1	1	27 (8.06)
Total	44 (13.13)	108 (32.24)	22 (6.57)	49 (14.63)	21 (6.27)	3 (0.89)	247 (73.73)

Note: ^aThe figures in brackets are percentages KEY: Infer = Inferring, Obs = Observing, Meas = Measuring, Comm = Communicating, Predic = Predicting.

Table 3.
Integrated science process skills in the KCSE biology practical examinations from 2002-2012.

Integrated Science Process Skills							
Year	Cont. Var	Def. Oper	Form. Hyp	Int. Dat	Expt	Form. Mod	Total
2002	0	0	0	2	5	0	7 (2.09)
2003	0	1	1	0	6	0	8 (2.38)
2004	0	0	0	6	4	0	10 (2.98)
2005	0	0	0	9	6	0	15 (4.48)
2006	1	0	0	3	1	0	4 (1.19)
2007	1	0	0	2	3	0	6 (1.79)
2008	0	0	0	3	3	0	6 (1.79)
2009	3	0	0	3	2	0	8 (2.38)
2010	1	0	0	4	4	0	9 (2.68)
2011	0	0	0	5	0	0	5 (2.13)
2012	0	0	0	3	7	0	10 (2.98)
Total	6 (1.79)	1 (0.30)	1 (0.30)	40 (11.94)	41 (12.24)	0 (0.00)	88 (26.27)

Note: ^aThe figures in brackets are percentages KEY: Cont. Var = Controlling variables, Def. Oper = Defining Operationally, Form. Hyp = Formulating Hypotheses, Int. Dat = Interpreting Data, Expt = Experimenting, Form. Mod = Formulating models.

shows that among the basic science process skills identified in this study, observation was rated highest with a frequency of 108 (32.24%), seconded by communication with a frequency of 49 (14.63%), and followed by inferring at a frequency of 44 (13.13%). Other basic process skills were rated very low. These are Measuring at a frequency of 22 (6.57%), Classification at a frequency of 21 (6.27%) and Prediction is the lowest at 3 (0.89%). From **Tables 2** and **3**, among the integrated science process skills identified in this study, experimenting was rated highest with a frequency of 41 (12.21%), followed by interpreting data at a frequency 40 (11.94%), controlling variables at 6 (1.79%). Other process skills were very low in frequency or not tested during the period under review. These are defining operationally, formulating hypotheses and formulating models.

From the results in the above tables, there were more basic science process skills than the integrated science process skills in the years under investigation. Of the basic science process skills the skill of observation was the most emphasized. The

skill of observation is the most basic skill in science and is subsumed in all the integrated science process skills. The integrated science process skill that was most common was the skill of experimenting which was tested in almost equal measure with the skill of interpreting data. The most probable explanation is that for every experimental data gathered, and there is need for interpretation.

The findings of this study are similar to those of Afolabi and Akinbobola (2010) and Nwosu (1994). These studies revealed that more basic science process skills are tested than the integrated science process skills in national examinations. The reason for overemphasis on the basic skills could be due to the fact that these skills are easily learnt and transferable to novel situations unlike the integrated ones that require a series of consistent, multiple practical sessions. At the same time, the integrated science process skills require higher order cognitive abilities which might have not developed well or have not been allowed to grow in the learning environments.

Conclusion

The five most common science process skills identified out of twelve examined in this study are observation (32.24%), communicating (14.63%), inferring (13.13%), experimenting (12.21%) and interpreting data (11.94%). Out of these, the only integrated science process skills are experimenting and interpreting data. The results also indicate a high percentage of basic science process skill at 73.73% compared to the integrated science process skills at 26.27%. The results indicate that there was a significantly higher percentage of basic science process skills than the integrated science process skills in the Kenya Certificate of Secondary Education biology practical examinations within the years 2002 to 2012.

Implications of the Study

The study has implications for practice and further research. The findings of this study have indicated that in the years considered, more basic science process skills were tested than integrated science process skills. In this state of affairs, there is a likelihood that integrated science process skills are not being emphasized in the teaching and learning process. By extension this means that the learners graduate that from grade 12 in the Kenyan system may not be in a position to participate effectively in activities requiring problem solving skills which are developed from the acquisition of integrated science process skills.

The implication of this study is that there is a need to make deliberate efforts to develop the integrated science process skills during the teaching/learning process and thereafter test them in the biology national examinations. There is a need to determine from a point of study the extent of mastery of integrated science process skills among the secondary school students.

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