

Analysis of West African Examination Council Chemistry Questions Using Revised Bloom's Taxonomy

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Abstract

This study examined chemistry examination questions conducted by West African Examination Council (WAEC) using revised Bloom's taxonomy as analytical tool with the aim of improving the quality of the examination questions. The employed theory-driven Content analysis research method. Two hundred and ninety-one (291) chemistry examination questions from WAEC from 2013-2017 consisted the population as well as sample size. Mean, frequency counts and percentages were used as data analysis technique. The results revealed that 80% of the questions covered remembering, understanding and applying cognitive process levels and 20% covered analysis, creating and evaluating cognitive process levels. The result further revealed that 46%, of the questions required factual knowledge, 36% required conceptual knowledge while 18% of the questions required procedural knowledge respectively. The study recommends that workshops should be held for the chemistry teachers, educators and examiners to make them familiar with the revised Bloom's taxonomy and how it can be used to set examination questions.

Keywords: Chemistry; Theory-driven Content Analysis; Revised Bloom's taxonomy; WAEC.

Introduction

It is the wish of every school organisations both secondary schools and tertiary institutions to see that students performed highly in all disciplines especially science and science related areas. Students' achievement in Examination has been the contemporary issue in the science education (Mamba & Putosa, 2017). In Nigeria, students' achievement in chemistry has not been satisfactory for many years (West African Examination Council, WAEC, Chief Examiner's Report from 2014-2017; Sakiyo & Badau, 2015). Moreover, even chemistry students that achieved satisfactorily in Senior Secondary School Examinations (SSCE) cannot achieve better in tertiary institutions after admission have been given to them as indicated by the failure of the students in most chemistry courses (Umate, Eya & Okebannama, 2019).

Review of related literature revealed that there are many reasons for the students' underachievement in SSCE and tertiary institutions. Some of these reasons are inappropriate teaching method (Omwirhiren, 2015; Attah, 2014), lack of well equipped laboratory (Odum, Akomaye & Chinyere, 2013), lack of interest and attitude from the students (Ozel, Caglak & Erdogan, 2013), abstract nature of chemistry concept (Njoku & Ezeodurukwe, 2014) and test items measuring low order thinking by examination bodies, e.g West African Examination Council (Uphahi, Isreal & Olorundare, 2017).

West African Examination Council is of the examination body that is in charge of conducting senior secondary school examination in Nigeria and other West Africa countries. Each state of the federation has WAEC state headquarter which liaise with the national headquarter at the Lagos. Chemistry is one of the science subjects in which students set for examination on it. WAEC chemistry questions are made up of three Papers: I, II, and III (WAEC, 2017). Paper I consist of fifty multiple choice objectives in which students are to answer all within 1

hour and it carries 50 marks. Paper II is a two hours essay paper with two sections: A and B; Section A is a short essay made up of ten questions. Candidates are required to answer all which carries 25 marks. Section B is made up of two questions from common portion of syllabus and two other questions from the section of the syllabus peculiar to a particular country. In all candidates will be expected to answer three questions in this section and each question carries 25 marks. Paper III which carries 50 marks is 2-hour practical test made up of three compulsory questions, one question each from quantitative and qualitative analysis and general knowledge of practical chemistry (WAEC, 2017). In this study, paper II was used for the analysis using revised Bloom's taxonomy with the aim of determining the extent to which these questions cover levels of cognitive process and knowledge dimension.

Questioning is accepted as a methodology which triggers thinking (Demir & Erayaman, 2012). Examining items of examination plays a vital role in the field of science education (Fiegel, 2013). Questioning is widely acknowledged as an effective strategy in education (Yahaya, Osman, Taleb & Alattab, 2013). Kasilingam, Ramalingam and Chinnavan (2014) suggested that in order to improve quality of education, science teachers and examination bodies should set standard examination questions that could facilitate higher order thinking. One of the objectives of teaching and learning is the assessment of the students' cognitive levels and written exam is the medium for teachers and educationist to confirm students' knowledge and understanding (Brame & Biel, 2015). Despite the relevance of examination questions in probing students' conceptual understanding, the literature revealed (Motlhabane, 2017) that there are scarce of studies particularly in the field of chemistry education that discussed the analysis of examination questions for the purpose of improving for future use. Thus this study used Revised Bloom's taxonomy as a guide to analyse WAEC chemistry past examination questions from 2013-2017.

Bloom's Taxonomy outlines six levels of cognitive process: Remembering, understanding, applying, analyzing, evaluating and creating. Anderson and Krathwohl (2001) reported revised version of Bloom's taxonomy that reflect dual perspectives in learning and cognition. In 2012 Tikkanen and Aksela reported that the two dimensions of knowledge and cognitive process has noun and verb components which could be used in classifying examination questions. Krathwohl (2002) opined that the noun form of cognitive domain provides basis for knowledge dimensions while the verb component forms the basis for cognitive process dimension. The Table 1 in page 4 shows the summary of revised Bloom's Taxonomy.

Table 1: The Revised Bloom's Taxonomy of Cognitive Domain
Cognitive Process dimension

| Knowledge dimension | Remember | Understand | Apply | Analyze | Evaluate | Create |
|--------------------------|----------|------------|-------|---------|----------|--------|
| Factual knowledge | | | | | | |
| Conceptual Knowledge | | | | | | |
| Procedural knowledge | | | | | | |
| Meta-cognitive knowledge | | | | | | |

Adapted from "A Revision of Bloom's Taxonomy: An Overview" by D. R. Krathwohl, 2002, Theory into Practice, 41 (4), p.: 216.

The cognitive process dimension (Table 1) ranges from remembering which is the least to creating which is the highest. Remembering requires the students to identify certain chemistry concepts for example recognising symbols and formulas of elements and compounds. Understanding involves constructing meaning from instructional messages and the students are expected to explain or infer certain phenomenon. For example, explaining direction of chemical equilibrium reaction based on experimental conditions given. Applying

involves carrying procedure in a given situation for example using Aufbau principle to write electronic configuration of element.

Analysing involves breaking down materials into its components and how each component is related to other parts and overall structure. For example, enumerating essential elements in protein and identify basic components of sucrose. Evaluating requires passing valued judgment based on predetermined conditions or by providing reasons to support it. For instance, give reason(s) why transition metal salt are coloured except Zinc (II) and Cu (II) salts. Creating involves putting some parts together to form a functional whole. For example, deriving molecular formula from percentage by mass of given elements.

The knowledge dimension in revised Bloom's taxonomy consists of four categories: factual knowledge, Conceptual knowledge, procedural knowledge and Meta-cognitive knowledge (Anderson & Krathwohl, 2001). Factual knowledge is the understanding of basic elements that students must be familiarised with in a subject. For example, in chemistry students must be familiar with symbol of element, formulae of compounds, and oxidation numbers of ions and so on. Conceptual knowledge involves dealing with the interrelationships between the basic elements within a larger structure that enable them to function together. For instance, chemical properties of element in the same group like halogen. Procedural knowledge includes the skills of doing particular task, methods of investigation, arithmetic, and criteria for using skills, techniques, and methods. For example, in chemistry mathematic calculations in gas laws, quantitative chemical process etc. Meta-cognitive knowledge is the knowledge of cognition in general which involves strategic knowledge, knowledge about tasks such appropriate contextual and conditional knowledge (Haring, Warmelink, Valente & Ruth, 2018)

Bloom's Taxonomy has been applied in education situations such as curriculum development, Lesson planning and instructional strategies (Cullinane, 2015), in writing test and examination questions for both internal and external (Fiegel, 2013; Cullinane, 2015), analysis of past question papers for the purpose of assessment and improvement (Motlhabane, 2017; Uphahi, Issa & Oyelekan, 2015). This study was set out to look at chemistry students' non satisfactory achievement in the light of examination questions that they underwent before gaining admission into university. Thus this study used revised Bloom's taxonomy of educational objectives as an analytical tool to investigate chemistry examination questions with the aim of determining the extent to which the examination questions covers both cognitive process levels and knowledge dimensions. When cognitive process levels and knowledge dimensions are covered enough in an examination questions stimulate students' thinking and problem solving skills. This in turn, improves students' academic achievement.

Numerous studies conducted on examination questions analysis using revised Bloom's taxonomy as framework in science education and other related disciplines, for example, in biology (Karamustaoglu, Karamustaoglu, Bacanak & Degirmenci, 2011); in chemistry (Tikkanen and Aksela, 2012; Uphahi, Isreal & Olorundare, 2017; Uphahi, Issa & Oyelekan, 2015) in physics and Chemistry (Edwards, 2010; Mothabane, 2017) in Engineering (Kasilingam, ramalingam & Chinnavan, 2014; Ogunwolu, Ajibola & Sosimi, 2018; Sowmya & Adithan, 2015). In addition to dearth of literature in area of chemistry examination questions analysis, the few studies conducted in the area reported contradictory findings.

For example, the study carried out by Uphahi, Issa & Oyelekan in 2015 on the Analysis of senior school certificate examination chemistry questions for higher-order cognitive skills. The findings of the study revealed that most chemistry questions required the students to apply remembering and understanding levels of cognitive process and factual knowledge in

knowledge dimensions levels. The study conclude that the chemistry examination questions were found within lower order thinking and hence do not stimulate chemistry students' critical thinking and problem solving skills.

In a study conducted by Tikkanen and Aksela 2012 on Analysis of Finnish chemistry Matriculation Examination questions according to Cognitive Complexity. The study found that most chemistry questions required students to apply analysis, synthesis and creating skills of cognitive process. Conceptual and procedural knowledge skills of knowledge dimension are also required for the students to answer the questions. The study concludes that Entrance chemistry examination questions assessed higher-level cognitive skills and knowledge levels. The conflicting result from the previous studies is one of the reasons that calls for this study. It would serves as an updates and extension of previous studies conducted using revised Bloom's taxonomy as an analytical framework. The study would also serve as future reference for further research on the analysis of chemistry examination questions. This in turn, may improve the questions for future use thereby preparing chemistry students for better understanding of chemistry in Nigerian and world at large.

Research Questions

RQ1. To what extent do WAEC past chemistry questions from 2013-2017 cover levels of cognitive process

RQ2. To what extent do the WAEC chemistry past questions from 2013-2017 cover Bloom's Knowledge dimension

Methodology

The study used theory-driven content analysis research method. According to Cohen, Manion, and Morrison (2007) Content analysis is the process of summarising and reporting written data – the main contents of data and their messages. In this study, the content of chemistry examination questions was interpreted through systematic process of coding and identifying themes or patterns. The sample size of the study consisted 291 chemistry essay questions drawn from the senior school certificate examinations conducted by the West African Examination Council for a period of 5 years from 2013-2017. In each year, there are four questions with many parts for students to answer. To ease the analysis, each part of the main easy question was taken as a single question to be analysed. The study adopted the framework of the revised Bloom's Taxonomy of educational objectives and prepared coding scheme to classify the chemistry examination questions into the cognitive process and knowledge dimensions. This because the revised Bloom's taxonomy of educational objectives is based on current educational research and its suitability for analysing test items (Anderson & Krathwohl, 2001). To ensure reliability of data, the coding practice/training was used to enhance the consistent interpretation of data and reduce individual interpretive bias (Creswell, 2012). Thus, before coding the examination questions, three chemistry education researchers coded the questions and 0.7 inter-rater reliability was obtained. The descriptive statistics; frequency counts, means and percentages were used as data analysis technique.

Results

RQ1. To what extent do WAEC past chemistry questions from 2013-2017 cover levels cognitive process

In order to answer this research question, frequency counts and percentages were used

Table 2: Frequencies and Distributions of WAEC Chemistry Questions based on The Examination Year (2013-2017) and Cognitive Process.

| Year | Remember Freq. % | Understand Freq. % | Apply Freq. % | Analyse Freq. % | evaluate Freq. % | Creating Freq. % |
|------|---------------------|-----------------------|------------------|--------------------|---------------------|---------------------|
| 2013 | 2038.5 | 23 44.2 | 4 7.7 | 4 7.7 | 1 2.0 | -- |
| 2014 | 20 30.3 | 25 37.9 | 8 12.1 | 4 6.1 | 3 4.5 | -- |
| 2015 | 25 39.1 | 16 25.0 | 10 15.7 | 8 12.5 | 2 3.1 | 3 4.7 |
| 2016 | 15 25.4 | 2034.5 | 9 15.3 | 8 13.6 | 3 5.1 | 4 6.9 |
| 2017 | 20 40.0 | 13 26.0 | 6 12.0 | 7 14.0 | 2 4.0 | 2 4 |

Table 2 displays the frequency distributions and frequencies of 291 chemistry past questions conducted by West African Examination Council (WAEC) within the range of 2013- 2017 and cognitive process skills assigned to each item. The examination questions about 80% covered remembering, understanding and applying cognitive process. Only few questions approximately 20% or less that was spread around analysing, creating and evaluating. The excerpt of the of 2015 examination questions is presented in figure 1 and a sample of how examination questions was analysed based on cognitive process levels and Knowledge dimensions is shown in Table

| | | |
|--------|---|-------------|
| 1. (a) | Define esterification. | [2 marks] |
| (b) | State two properties of plastic. | [2 marks] |
| (c) | Name the components of duralumin. | [2 marks] |
| (d) | What is meant by each of the following terms? | |
| (i) | Raw material. | |
| (ii) | Primary product. | [4 marks] |
| (e) | State Charles' law. | [2 marks] |
| (f) | List four pieces of protective equipment in the laboratory. | [4 marks] |
| (g) | Give two uses of ammonia. | [2 marks] |
| (h) | Name the: | |
| (i) | process by which lighter hydrocarbons are obtained from heavier ones; | |
| (ii) | products formed from the reaction between ethanol and sodium metal. | [3 marks] |
| (i) | Determine the oxidation number of sulphur in H ₂ SO ₄ . | [2 marks] |
| (j) | Write the IUPAC name for each of the following compounds: | |
| (i) | NaClO ₃ ; | |
| (ii) | CuSO ₄ ·5H ₂ O. | [2 marks] |

Figure 1: Sample Excerpts from 2015 WAEC Examination Questions

Table 3: Sample of Chemistry Examination Questions Analysis Using Revised Bloom Taxonomy as Analytical Tool

| Examination Year | Question | Verb used in the question | Cognitive process levels | Knowledge dimension |
|------------------|----------|------------------------------|-----------------------------|------------------------|
| 2015 | 1a | Define | Remembering | Factual |
| | 1b | State | Understanding | Factual |
| | 1c | Name | Understanding | Conceptual |
| | 1d | What is meant | Understanding | Factual |
| | 1e | State | Understanding | Conceptual |
| | 1f | Lists | Remembering | Factual |
| | 1g | Give | Understanding | Conceptual |
| | 1h | Name | Understanding | Conceptual |

| | | | |
|----|-----------|----------|------------|
| 1i | Determine | Applying | Procedural |
| 1j | Write | Applying | Procedural |

RQ2. To what extent do the WAEC chemistry past questions from 2013-2017 cover Bloom's Knowledge dimension

Frequency counts and percentages were used to answer this research question

Table 4: Frequencies Distributions and Percentages of WAEC Chemistry Questions based on the Examination Year(2013-2017) and Knowledge Dimensions

| Year | Factual Knowledge | | | Conceptual Knowledge | | | Procedural Knowledge | | | Total |
|-------|-------------------|------|--------|----------------------|------|--------|----------------------|------|--------|-------|
| | Freq. | % | Mean % | Freq. | % | mean % | Freq. | % | Mean % | |
| 2013 | 22 | 42.3 | 46 | 20 | 38.5 | 36 | 10 | 19.2 | 18 | 52 |
| 2014 | 30 | 45.5 | | 27 | 40.9 | | 9 | 13.6 | | 66 |
| 2015 | 31 | 48.4 | | 20 | 31.3 | | 13 | 20.3 | | 64 |
| 2016 | 25 | 42.4 | | 24 | 40.7 | | 10 | 16.9 | | 59 |
| 2017 | 25 | 50.0 | | 15 | 30.0 | | 10 | 20.0 | | 50 |
| Total | 133 | | | 106 | | | 52 | | | 291 |

Table 4 displays the frequency distributions and frequencies of 291 chemistry past questions conducted by West African Examination Council (WAEC) based on examination year (2013-2017) on Knowledge dimensions. On average 46% and 36% of the questions were mostly distributed around factual knowledge and conceptual knowledge. Only 18% of the questions centered on procedural knowledge and none of the questions that was on conceptual knowledge.

Discussion of Results

The study examined WAEC past chemistry questions for period of five years, 2013-2017. Table 2 presented results of chemistry questions based on cognitive process skills which revealed that about 80% of the questions measured remembering, understanding and applying. Only 20% or less measured analysing, creating and evaluating. The finding of this study support findings of some previous studies in the literature (Uphahi, Issa & Oyelekan, 2015; Uphahi, Isreal & Olorundare, 2017; Edwards, 2010) who found that chemistry examination questions for entry into higher education were predominantly spread around remembering, understanding and applying, and comparatively few questions on analyzing, synthesizing and creating. This could be because of the guidelines given to examiners' before setting the examination questions. Also it might be the current reform in science education has not been articulated in the assessment goals of West African Examination Council (WAEC). Thus, most chemistry examination questions used in SSCE (WAEC) have consistently required remembering, understanding and applying skills of cognitive domain to answer them. The result of this study contradicts the findings of the study carried out by Tikkanen and Aksela, in 2012 which conducted on Finnish chemistry matriculation examination questions and found that large proportion of the chemistry questions were adequate for the assessment of analyzing, synthesis and creating skills of cognitive domain. These differences could be attributed to fact that in Nigerian secondary school education, no emphasis was made as regard to advocacy on current reform in science education. Also Tikkanen and Aksela, 2012 studies considered entrance examination while present study examined secondary school leaving examination that is Senior Secondary School Examination.

Table 4 in page 10 displays the frequency distributions and percentages of WAEC chemistry questions based on knowledge dimension for a periods of five years from 2013-2017. The

results revealed that 46% and 36% of the chemistry questions measured factual and conceptual knowledge respectively. Only 18% of the questions measured procedural knowledge to solve algorithm questions and some alternative to practical questions. The result of this study supports the findings of some past studies in the literature (Uphahi, Issa & Oyelekan, 2015; Uphahi, Isreal & Olorundare, 2017) who reported that most chemistry examination questions in West African Examination Council and National Examination Council in Nigeria from 2010-2014 measured conceptual and factual knowledge. Only few questions required the skills of procedural knowledge. The reason for similarities in the findings could be because the examination bodies are yet to consider current reform in science education in their examination goals. Also though these studies were already published, may be examination bodies, chemistry examiners and chemistry teachers might have not laid hand on them. The finding of this study is in disagreement with the finding of study carried by Tikkanen and Aksela, 2012 who reported that larger proportion of the questions measured procedural knowledge and Meta-cognitive knowledge.

Conclusion

In this Study, chemistry examination questions conducted by West African Examination Council from 2013-2017 was analysed using revised Bloom's taxonomy as analytical tool. The aim of the study was to determine the extent to which chemistry questions cover cognitive process levels and knowledge dimensions. The findings of this study will benefit chemistry teachers, educators and examiners to identify gaps and flaws in the examination questions used. The findings of this study revealed that most chemistry examination questions conducted by WAEC from 2013-2017 were centered on remembering, understanding, and applying skills which do not stimulate students' critical thinking. The dominance of remembering, understanding and applying skills questions in the WAEC could affect chemistry students ability to think and solve problems in chemistry and how to relate it to daily activities. Also, this will affect chemistry teachers and students who depend on these questions for practices and examination. If the goals of current reform in science education are to be achieved, then examination bodies need to ask questions that will stimulate students' thinking and problem-solving abilities by requiring them to relate chemistry concepts to real life situation.

Recommendations

1. This study recommends that workshop should be held with the chemistry teachers, chemistry educators and examiners to familiarise with the revised Bloom's taxonomy of educational objectives and how could be used to set examination questions.
2. The Examination bodies (WAEC, NECO JAMB) should ensure that exam questions are carefully designed to the extent that students' conceptual understanding must be required in order to arrive at the answers so that analysis, synthesis and creating skills of cognitive domain could be utilised.
3. Chemistry teachers should make effort in improving questioning skills so that the revised Bloom's taxonomy of educational objectives are followed.
4. Chemistry teachers should consider revised Bloom's taxonomy of cognitive objectives when setting up examination questions and preparing lessons that stimulate students' thinking and problem-solving skills.

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