www.ijpce.org
ISSN: 1306-3049

Analysis of the West African Senior School Certificate Examination Chemistry Questions according to Bloom's Revised Taxonomy

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Abstract

The current reform in science education across the world is a deliberate effort to develop students' higher order cognitive skills (HOCS) through question asking, critical thinking, and problem solving. One of the ways to achieve this goal is to improve on the quality of questions asked in examinations. Therefore, this study analyzes chemistry questions asked in examinations conducted by the West African Examinations Council (WAEC). 328 Chemistry questions for a period of 5 years were analyzed using the framework of Bloom's revised taxonomy that reflects dual perspective on learning and cognition. It was found that 80% of the questions merely measured students' lower order cognitive skills (LOCS), while 49.4% and 19.5% of the questions measured conceptual and procedural knowledge respectively. The results further revealed that none of the questions require students to employ metacognitive knowledge. It is concluded that the questions place much emphasis on LOCS, than on HOCS.

Keywords

Bloom's revised taxonomy, cognitive process skills, knowledge dimension, chemistry questions, higher order cognitive skills

◆Received 24 November 2015 ◆Revised 28 February 2016 ◆Accepted 9 July 2016

Introduction

The purpose of an assessment ranges from its close focus on helping teachers and students build a shared understanding of the progress made by the students (in order to provide teachers, guidance and feedback for future instruction), to the panoramic view of national education goals that test and examination results purport to provide (Mansell, James & Assessment Reform Group, 2009). In other words, formative assessments are often instructional-based measurement methods, which provide feedback to both the teacher and student on the student's learning and developmental progress. They inform instructional strategies, and can be used to assist in the development of a student's metacognitive ability (Gordon, 2001). Summative assessments could be curriculum-based, designed to provide summative information on individual students or a large-scale national assessment of educational progress of representative sample of students designed to provide state or national-level evaluation information in line with the aims of a nation's National Policy on Education (Dixon-Roman, 2011).

Dixon-Roman (2011) submitted that, the purpose of an assessment is dependent on priority, and the context of use could impose constraints on the design. Therefore, it is important to recognize that one type of assessment does not fit for all. However, for whatever purpose an assessment is designed to achieve or measure, it should inform and improve the processes, and the outcomes of teaching and learning. This will, consequently, allow students to acquire the educational support they need to succeed in school and to solve real-life problems.

In Nigeria, students' assessment in chemistry at the secondary school level is based on both formative and summative assessments. The summative assessment is carried out at the end of senior school education that spans 3-years period of learning of chemistry, and its purpose is not only to judge what goals the students have attained, but also serve as a proxy measure to judge the quality of stakeholders of our education system: its teachers, curriculum planners, support services providers, state and federal ministries of education, among others). The final assessments in chemistry are expected to be high stake examinations. This is because, the current reforms in science education accentuate a purposeful effort to develop students' higher order cognitive skills (HOCS) of question asking, among other skills; as opposed to the traditional algorithmic-based nature of assessment typical of school assignments, continuous assessments and examination questions (Zoller 2001).

Assessments should tap into students' higher order cognitive skills (HOCS), which could require students to transfer conceptual knowledge in solving unfamiliar and possibly real-life problems (Zoller, Ben-Chaim, Ron, Pentimalli, & Borsese, 2000; Zoller, Dori, & Lubezky, 2002). However, the lower order cognitive skills (LOCS) type of questions, such that are well-defined with single correct answers/solutions predominant assessment in chemistry (Barak, Ben-Chaim, Zoller, 2007; Zoller & Pushkin, 2007). Lower order cognitive skills (LOCS) questions are knowledge questions that require simple recall of information or a simple application of knowledge of algorithms to familiar situations as a result previous long-term practice mostly of computational questions or exercises (Zoller & Tsaparlis, 1997).

While the distinction between LOCS and HOCS may not be dichotomous, but rather edges of a continuum, Tsaparlis and Zoller (2003) have suggested that chemistry teaching and subsequent design of examination questions should be HOCS-oriented that can foster and develop students' HOCS capabilities and foster a shift from the dominant algorithmic exercise solving to meaningful problem solving. This became necessary as formal examinations that are decisive for students' future in terms of selection of best students for higher education and equipping them for real-life problem solving should place greater emphases on HOCS than on LOCS.

DOI: 10.12973/ijpce/64138
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The West African Senior School Certificate Examination (WASSCE) conducted by the West African Examinations Council (WAEC), is one of the foremost summative assessments students' enroll for; to mark their end of the senior secondary education in Nigeria. Chemistry is one of the elective subjects' students are examined in. The structure of the examination questions are designed by the Examination Boards of the member countries (Nigeria, Liberia, Ghana, Sierra Leone and Gambia), on the basis of the objectives and contents of the national curriculum; teaching and examination syllabi operational in those countries.

For chemistry, there are three papers – Paper 1, Paper 2 and Paper 3. Candidates are usually required to take either Papers 1 and 2 or Papers 2 and 3 only. Paper 2 is a two-hour practical test and is taken by school candidates only. The paper contains three questions which carry 50 marks that form 25% of the total marks for the external examination (West African Examinations Council [WAEC], 2005). The candidates are required to answer all the three questions. Two of the questions are on quantitative and qualitative analyses, while the third question test candidates' familiarity with the practical activities.

Paper 2 is a three-hour theory paper that covers the entire curriculum and carries a total of 150 marks i.e. 75% of the total marks of the external examination. The paper has two parts; Part A and Part B. Part A contains fifty multiple choice tests where candidates are required to answer all the questions within 60 minutes for 50 marks. Part B contains three sections: Sections I, II and III. Section I contain four essay questions for candidates in all the member countries. Candidates are required to answer any three of the questions. Each of the questions carries 25 marks (WAEC, 2005).

The WASSCE is a qualitative and reliable examination in West Africa that has a strong influence on learning, teaching of; and assessment in chemistry. The results from these examinations could influence students' progression to the next stage of education or higher education (for those who seek to proceed to tertiary institutions). The results are used by universities to make external judgment about students' performance, and to offer admissions to students into courses or programmes for which they are considered adequate enough to cope with.

Conceptual Framework

This is study is hinged on the conceptual framework of cognitive domain provided by Bloom (1956) and redesigned by Anderson and Krathwohl (2001). In its general form Bloom's (1956) original taxonomy outlines six levels of cognitive processes: knowledge, comprehension, application, analysis, synthesis and evaluation. According to Anderson and Krathwohl (2001), the revision was needed to update the framework in terms of the advances in cognitive psychology. Bloom's revised taxonomy reflects the dual perspective on learning and cognition. According to the researchers, the need to have two dimensions to guide the processes of stating learning objectives, and instruction will lead to sharper, and more clearly defined assessments, which consequently, provide a stronger connection of assessment to both the learning objectives and instruction.

According to Tikkanen and Aksela (2012), the two dimensions of knowledge and cognitive process as shown in (Table 1) have the noun and verb components that could be used in the classification of examination questions. The noun component provides the basis for the knowledge dimension, while the verb component forms the basis for the cognitive process dimension (Krathwohl, 2002).

Table 1. The Revised Taxonomy Table

The Knowledge Dimension	The Cognitive Process Dimension					
	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual knowledge						
Conceptual knowledge						
Procedural knowledge						
Metacognitive knowledge						

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

The original taxonomy of Bloom assumes a hierarchical order where the cognitive process increases from left to right (as in Table 1). In the same vein, the category of the knowledge dimension also follows a continuum from factual knowledge through to metacognitive. Like the original, the revised taxonomy assumed a hierarchical structure in the sense that the six categories of the cognitive process dimension differs from one another in their complexity, with remember being less complex than understand; understand less complex than apply; in that order. However, because the revised taxonomy gives greater weight to teacher usage, the requirement of a strict hierarchy has been relaxed to allow the categories to overlap one another, in such a way that a chemistry question classified under the category of understand (for instance, a question that require students to explain chemical concept), may be more complex as a questions in the apply category, that require students to execute/perform a routine algorithm to reach the possible answer.

The cognitive process dimension of the revised taxonomy have six categories of: remember, understand, apply, analyze, evaluate and create (Krathwohl, 2002). The knowledge dimension of the revised taxonomy contains four categories, which include: factual knowledge, conceptual knowledge, procedural and the metacognitive knowledge. According to Anderson and Krathwohl (2001), factual knowledge involves an understanding of basic elements students must be acquainted with in a subject or to be able solve a problem in it. Conceptual knowledge deals with the interrelationships among the basic elements within a larger structure that enable them to function together. Procedural knowledge entails the skills to do something, methods of inquiry, criteria for using skills, algorithms, techniques, and methods. Generally, metacognitive knowledge is the knowledge of cognition, as well as, awareness of one's own cognition. Some examples of the structures of the knowledge dimension and the cognitive process skills as applied in chemistry context are shown in Tables 2 and 3.

Table 2. Structure of the Knowledge Dimension of the Revised Taxonomy Applied in Chemistry Context

Category	Definition	Examples
Factual Knowledge	Knowledge of terminology, specific details and elements	Symbolic language of chemistry Names of famous scientists Dates of historical chemical inventions
Conceptual knowledge	Knowledge of classifications, categories, principles, generalizations, theories, models, and structures	Classification of elements in the Periodic table Le' Chatelier's principle Atomic theory and structure
Procedural knowledge	Knowledge of subject-specific skills, algorithms, techniques, methods and criteria for determining when to use appropriate procedures	Mathematical calculations in quantitative chemical problems Chemical investigation methods Laboratory skills
Metacognitive knowledge	Knowledge of cognition in general, as well as, awareness and knowledge of one's own cognition.	Flame tests, precipitation tests and solubility Students' strengths and weaknesses

Source. Adapted from "Analysis of Finnish Chemistry Matriculation Examinations Questions According to Cognitive Complexity" by Tikkanen G. and Aksela M., 2012, NORDINA, 8 (3), p. 259.

Table 3. Structure of the Cognitive Process Dimension of the Revised Taxonomy Applied in Chemistry Context

	Category	Definition	Examples
LOCS	Remember	Retrieve relevant knowledge from long-term memory (recognizing, recalling).	▪ recognize the symbols of chemical elements; ▪ recalling the dates of historical chemical ▪ innovations
	Understand	Construct meaning from instructional messages, including oral, written, and graphic communication (interpreting, exemplifying, classifying, summarizing, inferring, comparing, and explaining).	▪ paraphrase chemical concepts; ▪ give an example of an saturated organic compound; ▪ classify carbohydrates into mono-, di- and polysaccharides; ▪ summarize an article; ▪ infer a molecular structure of an organic compound; ▪ compare elements of the periodic table; and ▪ explain the direction of an equilibrium reaction.
	Apply	Carry out or use a procedure in a given situation (executing, implementing).	▪ Follow a procedure to perform fractional distillation; ▪ use the ideal gas law in applicable situations
HOCS	Analyze	Break material into its constituent parts and determine how the parts relate to one another and to the overall structure or purpose (differentiating, organizing, attributing).	▪ identify the essential elements of a problem; ▪ analyze a chemistry research report; ▪ scrutinize the attitude of the author of a chemistry article
	Evaluate	Make judgments based on criteria and standards (checking, critiquing).	▪ check the reasonableness of the solution; ▪ critique of different chemical methods
	Create	Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure (generating, planning, producing).	▪ generate a hypothesis; ▪ plan a laboratory activity; ▪ write a chemistry essay

Source. Adapted from "Analysis of Finnish Chemistry Matriculation Examinations Questions According to Cognitive Complexity" by Tikkanen G. and Aksela M., 2012, NORDINA, 8 (3), p. 260.

To locate the centre point of the six categories of the cognitive process dimensions on a scale of judged complexity, the categories are likely to form a scale from simple to complex. It then follows that, the cognitive process dimensions appear to be hierarchical in nature, but flexible to allow for overlaps (Anderson *et al.*, 2001).

Literature Review

Research studies have conducted with respect to the cognitive process skills and knowledge dimensions in the sciences, and particularly, chemistry education (Karamustafaoglu, Sevim, Karamustafaoglu & Cepni, 2003; Tsaparlis & Zoller, 2003; Azar, 2005; Zheng, Lawhorn & Freeman, 2008; Edwards, 2010; Tikkanen and Aksela, 2012).

Karamustafaoglu et al. (2003) analyzed and compared Turkish high school chemistry examination questions from three different schools of Ordinary, Anatolian and Vocational from the cities of Trabzon and Amasya, Turkey. 403 questions were obtained from 17 chemistry teachers and analyzed. It was found that 96% of the questions were of the LOCS type, and statistical tests showed that the question types were related to the school types. When these questions were compared with the University entrance examination questions, further results showed that more than half of the university entrance examination questions were of the HOCS type. These results revealed the wide discrepancies between assessment at the high schools and at the university entrance exams.

Tsaparlis and Zoller (2003) conducted three research studies to measure students' performance in chemistry examinations that require HOCS and LOCS at the high school and university levels in Greece and Israel. The research indicates that the chemistry examination used for entry into higher education in Greece would have selected the best LOCS-performing students, because LOCS-type of questions were predominant in the examination questions. A different pattern of students' performance on examination questions that require HOCS was compared with questions that require LOCS. The results revealed that a high performance on the LOCS-type of questions does not necessarily guarantee a high performance on questions that require HOCS. The results further revealed that many students did not perform any better on the purportedly easier LOCS questions when compared with their performance on HOCS questions. The researchers attributed this finding to insufficient pre-examination preparation based on the analysis of the research data. In the Israeli study conducted within an introductory freshman general and inorganic chemistry course, it was found that, top performing students who were given a free choice between HOCS- and LOCS-type questions, preferred to select and answer the LOCS-type questions. This finding indicates that a short-term HOCS-oriented instruction is not sufficient to determine students' examination attitudes or behaviour with respect to LOCS and HOCS learning.

Azar (2005) analyzed and compared high school physics and the university examination questions according to Bloom's taxonomy. The examination questions came from two sources: 76 physics questions from the university entrance examinations conducted between the years of 2002 and 2003; and 556 physics questions were obtained from physics teachers in the Kdz. Ereğli of Turkey. Findings from the study showed that physics questions asked at the university entrance examinations taps into students higher order cognitive skills (of analyze, evaluate and create), while the high school questions only measure the students lower order cognitive skills (of remember, understand and apply).

In the United States, Zheng, Lawhorn and Freeman (2008) classified biology examination questions using Bloom's taxonomy. The biology questions were drawn from AP biology; undergraduate majors' introductory biology courses from three universities; the biology parts of the Medical College Admission Test (MCAT) and the Graduate Record Examinations (GRE); and the first-year medical courses from an institution that operates a traditional curriculum. The results from the research revealed that the majority of the questions were at comprehension level; followed by the application level of the taxonomy. Though, there were questions at analysis level in all the questions, but the percentages of those questions were quite small. While there were comparatively few questions at synthesis level, no question could be classified into the evaluation level in all the examination questions.

Edwards (2010) conducted a study to analyze the alignment of Grade 12 physical sciences (physics and chemistry) examination papers for 2008 and 2009 with the core curriculum in South Africa. The study adopted the framework of the revised Bloom's taxonomy for analyses. The results showed discrepancies in the cognitive levels and content areas of both physics and chemistry. While the chemistry and physics questions were under-represented in the cognitive level, remember; the cognitive levels understand and apply were over-represented in the chemistry examination questions.

Tikkanen and Aksela (2012) conducted a study to determine cognitive skills and knowledge measured by the Finnish chemistry matriculation examination questions using Bloom's revised taxonomy of cognitive objectives. The research indicated that the examinations were cognitively demanding, with majority (77%) of the questions requiring higher order cognitive skills, HOCS. Though, the questions were not evenly distributed among analyze, evaluate and create categories of the cognitive process dimension.

An analysis of the literature reviewed provides inconsistent reports on the classification of examination questions as either HOCS or LOCS. While certain questions for entry into higher education were predominantly of the lower-order cognitive domain (Tsaparlis & Zoller, 2003), comparatively fewer literature reported questions which were on HOCS (Tikkanen and Aksela, 2012; Edwards, 2010). If the current reforms in science education have advocated for the development of students' higher-order cognitive skills (HOCS) through question-asking, critical thinking, decision making and problem solving, then, there is the need for a deliberate shift from the prevalent traditional algorithmic exercises to HOCS-promoting assessment methodologies that can lead to improved students' problem solving capabilities.

The LOCS-type of questions tend to be predominant in most traditional assessments across the world, because they are considered familiar and recognized by the students to be straightforward and solvable; and for the teachers, it is easy to grade (Tsaparlis & Zoller, 2003). However, in the midst of the current economic perspective that have necessitated the ongoing reforms in science education, students who will consequently become graduates, need to be well-equipped with intellectual and personal skills to succeed in a rapidly changing professional and cultural environment. This is because employers have encouraged schools and universities to produce graduates, who possess ability to solve novel problems; communicate effectively; handle complex data; and work as part of a team, among other interpersonal skills (Mason, 1998).

If these reforms are an implied aim of science teaching, then, summative chemistry examination questions ought to be questions that are carefully designed to tap into students' HOCS. This study, therefore, analyze chemistry examination questions conducted by WAEC using the two-dimensional framework of the Bloom's revised taxonomy. This study was guided by a research question on: What type of cognitive process skills and knowledge dimensions are measured in the West African senior school certificate examination chemistry questions?

Methodology

The source of data for this study consisted of 328 chemistry questions drawn from the senior school certificate examinations conducted by the West African Examinations Council for a period of 5 years from 2010 – 2014. In each year, there are usually four questions with many sub-questions. For ease of analysis, each sub-question was taken as a single question to be analyzed.

This study employs a quantitative approach and content analysis to classify the chemistry questions that covers the entire syllabus. The chemistry examination questions were classified into the knowledge and cognitive process dimensions of the taxonomy table (Table 1). Bloom's revised taxonomy was used in this research because it is suitable for analysis of test items and has been developed on the basis of the current educational research (Anderson & Krathwohl, 2001). These two-dimensional taxonomy places emphasis on the need to assess higher order cognitive processes and metacognitive knowledge for all who are engaged in the field of assessment. Therefore, it is appropriate to classify the chemistry examination questions into knowledge and the cognitive process dimensions. The examination questions were also classified into LOCS and HOCS.

To establish the reliability of the research, 50% of the examination questions were randomly selected and analyzed by one of the researchers and a Professor of science education who have a clear understanding of the revised Bloom's taxonomy and its application for classifying examination questions. The value of Kappa measure of agreement was calculated based on the classification of the raters, for each of the cognitive process skills and the knowledge dimension. The Kappa-values for the cognitive process and knowledge dimensions were .82 and .93 respectively. The high values ($\kappa > .65$) for the two dimensions of classification indicate a good measure of agreement between the two raters, which thus, guarantee a high reliability of the research.

Results

Table 4 presents the distribution of the 328 chemistry questions according to the years of the examinations and the cognitive process skills such examination questions were designed to measure. Only 20% of the chemistry questions were at the higher levels of the cognitive domain (analyze, evaluate and create). On the other hand, 80% of the questions were at the lower levels of the cognitive domain (39.3%, 27.1% and 13.4% of the questions require students to remember, understand and apply respectively).

Table 4. *Distribution of Chemistry Examination Questions according to Year and the Cognitive Process Skills*

Year	Remember		Understand		Apply		Analyze		Evaluate		Create		Total	
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
2010	21	33.9	14	22.6	10	16.1	8	12.9	0	-	9	14.5	62	18.9
2011	30	36.6	17	20.7	15	18.3	11	13.4	0	-	9	11.0	82	25.0
2012	17	27.0	27	42.9	6	9.5	10	15.9	0	-	3	4.8	63	19.2
2013	34	56.7	9	5.0	8	13.3	0	-	1	1.7	8	13.3	60	18.3
2014	27	44.3	22	36.1	4	8.2	0	-	0	-	7	11.5	61	18.6
Total	**129**	**39.3**	**89**	**27.1**	**44**	**13.4**	**29**	**8.8**	**1**	**.3**	**36**	**11.0**	**328**	**100**

Figure shows a graphical representation of the frequency of chemistry questions that measures the six main categories of the cognitive process skills. An inspection of the shape of the histogram shows that the frequency of questions is not normally distributed among the six categories of the cognitive process skills. The questions are skewed to the left, that is, majority of the questions only require students to recall relevant chemical knowledge from long-term memory and to construct meaning for chemical concepts.

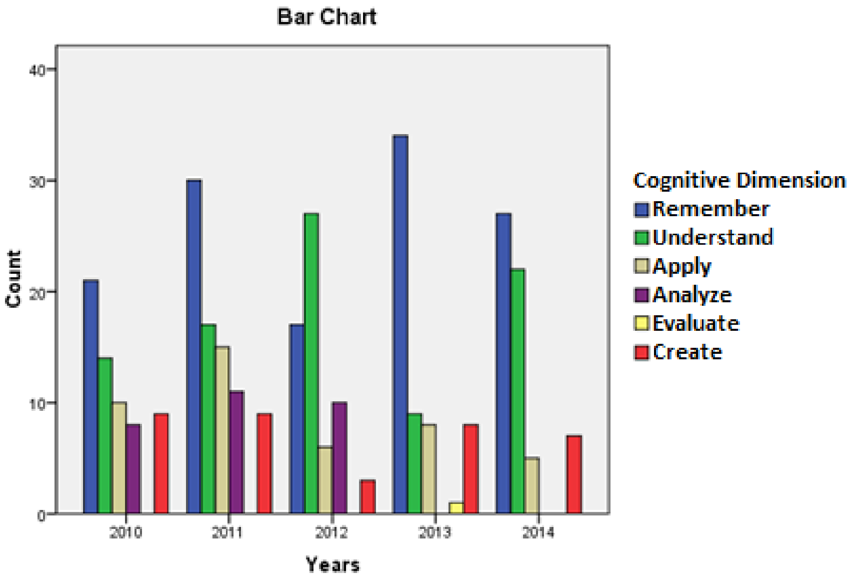

Figure 1. Frequency of questions according to the categories of the cognitive process skills and the years

Table 5 shows the distribution of the questions based on the years of examination and the knowledge dimension measured by the questions. About 49.4% and 19.5% of the examination questions measured conceptual and procedural knowledge respectively. None of the questions measure students' metacognitive knowledge about chemistry.

Table 5. Distribution of Chemistry Examination Questions according to Year and the Knowledge Dimension

	Factual knowledge		Conceptual Knowledge		Procedural Knowledge		Total	
Year	*N*	%	*N*	%	*N*	%	*N*	%
2010	27	43.5	22	35.5	13	21.0	62	18.9
2011	29	35.4	38	46.3	15	18.3	82	25.0
2012	14	22.2	36	57.1	13	20.6	63	19.2
2013	14	23.3	29	48.3	17	28.3	60	18.3
2014	18	29.5	37	60.7	6	9.8	61	18.6
Total	**102**	**31.1**	**162**	**49.4**	**64**	**19.5**	**328**	**100**

Figure 2 provides a quick summary of the frequency of chemistry questions that only measures three out of the four categories of the knowledge dimension. The shape of the histogram shows that the frequency of questions is a normally distributed among the three categories of factual, conceptual and procedural knowledge. The chart/graph suggests that the questions were more conceptual and factual, except for year 2013 where the frequency of question that measured procedural knowledge was higher than factual knowledge.

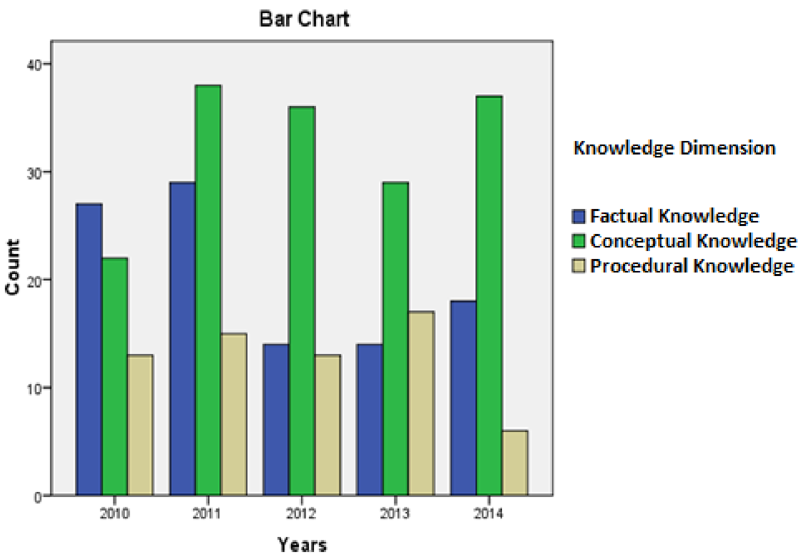

Figure 2. Frequency of questions according the categories of the knowledge dimension and the years

Table 6 presents a one-way between groups Analysis of Variance conducted to compare the categories of the knowledge dimensions across five examination years. There was a statistically significant difference in the knowledge dimensions measure in the five examination years, $F(2, 235) = 3.65$, $\varrho < .05$. Despite reaching statistical significance, the actual difference in mean scores between groups was quite small (2.68, 3.13 and 2.81). This was evident in the small effect size obtained (*eta squared* = .02). With a large sample of chemistry questions analyzed (in this case, $N = 328$), small differences in the mean scores can become statistically significant, even if the difference between the groups is of little, practical significance. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for factual knowledge ($M = 2.68$, $SD = 1.45$) was significantly different from the mean score of conceptual knowledge ($M = 3.13$, $SD = 1.37$). Procedural knowledge mean score ($M = 2.81$. $SD = 1.30$) did not differ significantly from that of factual and conceptual knowledge.

Table 6. A One-way ANOVA for the Knowledge Dimensions in the Chemistry Examination Questions

Analyzed Chemistry Questions	Type III Sum of Squares	*Df*	Mean Square	*F*	Sig.	Eta Squared
Knowledge dimensions	13.89	2	6.95	3.65	.03	.02
Error	618.35	325	1.90			
Corrected Total	**632.24**	**327**				

Discussion, Conclusion and Recommendations

This study sought to analyze the May/June chemistry examination questions conducted by the West African Examination Council (WAEC) for a period of 5 years from 2010 – 2014.

To provide answers to the research question on: What type of cognitive process skills and knowledge dimensions are measured by the chemistry examination questions? The result of the type of cognitive process skills measured by these chemistry questions as shown in Table 4 reveals that, only 20% of the chemistry questions were of the higher order cognitive domain. These results contradict previous findings (Tsaparlis & Zoller, 2003; Azar, 2005; Tikkanen & Aksela, 2012) with respect to the university entrance and matriculation examination questions analyzed in those studies, where the majority of the chemistry examination questions required HOCS. These differences could be attributed to the fact that not so much emphasis is placed on the development of students HOCS throughout their secondary education in Nigeria, and in the study of Tsaparlis and Zoller (2003) where emphases were on HOCS, students who were given free choice on what questions to answer, opted for LOCS questions. On the other hand, the findings are consistent and comparable with the study of Zheng, et al. (2008), Karamustafaoĝlu, et al. (2003) and Edwards (2010), where the cognitive levels of understand and apply were over-represented in both the biology and chemistry examinations. This could be because such questions are undemanding, solvable and gradable (Tsaparlis & Zoller, 2003).

The result of the subcategories of the knowledge dimension measured by the chemistry questions presented in Table 5 revealed that, about 49.4% of the examinations questions measured conceptual knowledge, while 19.5% measured procedural knowledge of algorithms and experimental procedures. These results are fairly in line with Tikkanen & Aksela (2012) findings, which indicated a similar proportion of the questions that measured conceptual knowledge, but differs significantly with the proportion of questions that measured procedural knowledge. To provide further evidence in support of the descriptive statistics in Table 5, the result of the ANOVA in Table 6 compared the categories of knowledge dimensions measured by the chemistry questions, and revealed a statistically significant difference in the number of questions that measure the categories of the knowledge dimensions in 5 years examination chemistry questions [$F(2, 235) = 3.65$, $\varrho < .05$]. To identify the category that was the main contributor to the significant difference, a Tukey HSD Post-hoc comparison revealed that the significance is the number of questions in the procedural category which was the least emphasized. These differences could be attributed to the numbers of practical/laboratory-related questions included in the chemistry questions analyzed. There was not a single question that requires students to employ their cognitions, where students are provided with tasks that requires checking, planning and generating. Even though, assessing student's cognition could be a difficult task, but a fair representation of metacognitive tasks in summative assessments like the WASSCE could be considered appropriate for HOCS-oriented assessments.

From the findings of this study, it can be concluded that majority of the chemistry examination questions were of the LOCS, which do not seek to tap into students' HOCS. The dominance of LOCS-oriented questions in these high-stakes and nationwide (for candidates in Nigeria) chemistry examination questions could possibly impact on instruction, particularly, on where schools put their emphases, how and what the teachers teach, as well as students and teachers who rely on such questions for practices and assessments. Summative assessments like the WASSCE should not merely measure students' ability to apply routine algorithms to familiar situations of problem solving, but should rather, require students to relate conceptual knowledge in real-life situation problems. Otherwise, the attainments of the goals of the current science education reforms may not be quite possible with the current practices in testing and assessments, as evident in the chemistry questions of the WASSCE.

Based on the findings of this study, it is recommended that questions' difficulty and skills are scaled-up; to focus on conceptual understanding and on promoting HOCS in assessment and students' learning, without overly concerned with teaching to the test. Examination bodies like the WAEC should ensure that examination questions are carefully designed to be such that requires conceptual understanding to solve; so as to ensure that the questions tap into students' HOCS. The classroom teachers, who rely largely on the bank of questions of the WASSCE for their formative and summative assessment questions, should do so with much caution. This is to avoid the false impression that such banks of questions were developed to promote HOCS capability among students. Chemistry teachers should teach and prepare their examination questions using the framework of Bloom's revised taxonomy which takes into account the cognitive process and knowledge dimensions, for adequate representation of HOCS-oriented teaching and assessments.

Acknowledgments

The authors would like to acknowledge Prof. I. O. Abimbola of the Department of Science Education, University of Ilorin, Ilorin, Nigeria for assisting to rate 50% of the chemistry questions in spite of busy schedules. We also wish to extend our appreciation to the Co-Editors: Prof. Dr. M. Fatih Tasar and Prof. Dr. Ingo Eilks for their assistance and the anonymous reviewers for their constructive comments that has added value to; and greatly improve the manuscript.

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