A Comparative Analysis of Cognitive Complexity of Nigerian Senior School Certificate Chemistry Examination Questions Constructed by Two Examination Bodies

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Abstract
Using revised Bloom's Cognitive Taxonomy Scale as a major categorization tool this paper presents a comparative analysis of cognitive complexity of West African Senior School Certificate Chemistry Examination questions constructed by the West African Examinations Council (WAEC) and the National Examinations Council (NECO) between the periods of 2008-2012. This research was guided by the four questions. (1)At what level of the revised Bloom's cognitive Taxonomy of learning objectives does the chemistry examination questions constructed by the two examination bodies (between the periods of 2008 - 2012) require the learners to operate? (2) What discrepancies, if my, exist in the characteristics features of LOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008-2012? (3) What discrepancies, if any, exist in the characteristics features of HOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008- 2012? (4) Are all categories of LOCS- and HOCS – type of chemistry examination questions featured in the test items constructed by the two examination bodies? The research data consisted of 475 questions from 10(5 per each examination body) Senior School Certificate Chemistry Examinations conducted by the WAEC and NECO between 2008 and 2012. Qualitative approach and content analysis method were employed in the research. The knowledge components (factual, conceptual, procedural, meta-cognitive), the categories of the cognitive skills (HOCS and LOCS) and the Expanded Framework for Analyzing General Chemistry Exams (EFAGCE) form the basis of the coding scheme used to analyzed data collected (examination questions). The examination questions were coded by two independent raters. The inter-rater reliability was high. The findings of this study indicate that the majority of the questions constructed by the two examination bodies required LOCS. In addition, there were slight discrepancies in the characteristics features of HOCS-type chemistry examination questions constructed by the two examinations bodies between the period of 2008-2012 in the sense that out of the four categories of HOCS-type chemistry examination questions that appeared in both examinations only one categories differs. The study also revealed that both the HOCS-type questions and LOCS-type questions were not evenly distributed for the periods of examination considered in this study. Based on the findings, it was recommended that the instructional objectives formulated on chemistry topics must incorporate HOCS so that examination questions can be based on these objectives and that all different categories of examination questions should be more evenly presented as test items in West African Senior School Certificate Chemistry Examinations.
Keywords: Chemistry examination questions, cognitive skills, examination bodies, Bloom's cognitive taxonomy scale

1. Introduction

Bloom's cognitive taxonomy scale (Bloom *et al*., 1956) is frequently used for writing of learning objectives, because it provides a ready-made structure and list of active verbs. It can be argued that the use of the correct verbs is the key to the successful writing of learning objectives and construction of test items. Teachers choose the appropriate cognitive level for classroom objectives and a quality assessment is designed by the assessor (e.g., teacher, examination body) to measure how well these learning objectives have been met. Assessment is often divided into two categories, namely formative assessment and summative assessment (Gronlund, 1985). Formative assessment has been described as the assessment that refers to all those activities undertaken by the teachers, and the students in assessing themselves, which provide information to be used as feedback to modify the teaching and learning activities in which they engaged (Black and Williams, 1998). Formative assessment is usually carried out at the beginning of a programme or during a programme. In contrast, summative assessment is the assessment that tries to summarise students' learning at some point in time; usually at the end of module or programme. So, the use of summative assessment enables a grade to be generated that reflects the students' performance.

Senior School Certificate Examination (SSCE) is a well recognized summative assessment tool in Nigerian senior secondary schools. SSCE covers all the school subjects including chemistry. The two examination bodies, the West African Examinations Council (WAEC) and the National Examinations Council (NECO) are saddled with the responsibility of conducting SSCE. Recently, National Business and Technical

Examinations Board (NABTEB) embarked on the conduct of National Business/Technical Certificate Examination (an equivalent of SSCE). The test questions and the structure of the tests are designed by the members of the various examinations Councils/Boards on the basis of specific learning objectives and contents defined in the officially prescribed national curriculum for the senior secondary schools. Although, the test questions and the structure of the tests are tailored towards national curriculum, there are two main concerns regarding the SSCE: (1) assessment for senior secondary school students is directed more to passing the assessment rather than developing learning due to the competition among the examination bodies (2) assessors (examination bodies) are assessing what is easy for them to assess rather than what they ought to assess.

From this point of view, there is need to conduct a study on comparative analysis of cognitive complexity of Nigerian senior school certificate chemistry examination questions constructed by these examination bodies. Thus, this study was undertaken to provide answers to the following research questions:

1. At what level of the revised Bloom's cognitive Taxonomy of learning objectives does the chemistry examination questions constructed by the two examination bodies (between the periods of 2008 - 2012) require the learners to operate?
2. What discrepancies, if any, exist in the characteristics features of LOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008-2012?
3. What discrepancies, if any, exist in the characteristics features of HOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008- 2012?
4. Are all categories of LOCS- and HOCS – type of chemistry examination questions featured in the test items constructed by the two examination bodies?

2. Theoretical Framework

2.1. Cognitive Complexity of Chemistry Examination Questions.

Learning objectives and assessment can be aligned on the category of content covered and also on the complexity of knowledge required. While assessing the senior secondary school students, the SSCE must also reflect this goal. It is very important to construct examination questions that elicit student responses that demonstrate the complexity of knowledge and skills required to meet the specified learning objective. In specifying the learning objectives teachers clarify the performance that students should be able to demonstrate as a result of what they have learned. The learning objective typically begins with a directive verb and describes the observable behaviour, action or outcome that students should demonstrate. The focus is on what students should able to do and not on the learning and teaching process.

Reviewing a list of directive verbs can help to: (1) clarify what ability students should demonstrate (2) clearly define the learning objectives to be assessed. Thus, in developing chemistry examination questions that require the type of thinking which defines each level of Revised Bloom's Cognitive Taxonomy Scale to be reflected in test items, the following guidelines are suggested as presented in Table 1.

Table 1: Development of Chemistry examination questions using revised Bloom's Cognitive Taxonomy Scale.

Revised Bloom's Cognitive level	**Test taker activity**	**Action words/ Illustrative Phrase for test item construction**	**Sample test item**
Create	producing something new or original from various pieces of information	predict, produce, design, synthesize, revise, construct, what would happen if, can you devise generate, com-pile, compose, develop.	what would happen if measures to prevent Ozone depletion are not. put in place?
Evaluate	making a judgment based on a pre established set of criteria	evaluates, judge, argue appraise, defend, justify, critique, question, rate, assess, value	evaluate this diagram that shows a student's illustration of a nitrogen cycle. Is it well-draw?
Analyze	breakdown information into its components such that the relationship among parts is made year.	diagnose, categorize, re-solve, elucidate, divide/ subdivide, differentiate, distinguish between, illus-state how, point out, determine evidence.	Distinguish between electrolytic cells and galvanic cells
Apply	using a concept or principle is new and concrete situations to solve problems that have a single or best answers.	compute, solve, operate manipulate, find, use, verify, employ, apply, demonstrate an understan-ding, relate, explain how.	Explain Boyle's law in terms of the kinetic theory.
Understand	explaining/interpreting the meaning of material (putting other's ideas into their own words)	interpret, clarify, discuss, explain, translate, restate, rewrite, paraphrase, express, summarize, illustrate, extend, infer, describe.	Explain why graphite is used as a lubricant.
Remember	Remembering fact, terms concepts, definitions, principles and laws without necessarily understanding	define, state, list, mention, name, write, label, identify, underline, reproduce, outline who, what, where, when.	what is the major component of synthetic gas?

The degree of challenge of test items is currently categorized in two ways, namely, item difficulty and cognitive complexity. Item difficulty refers to the actual percentage of students who chose the correct answer in response to a test item. Easy test item means more than 70 percent of the students are likely to respond correctly. Average test item means between 40 percent and 70 percent of the students are likely response correctly. Challenging test item means less than 40 percent of the students are likely to respond correctly. It should be realized that interpretation of item difficulty is not always an easy task. The item may be easy either because its construction makes the answer obvious or because the students have learned the material in the item. On the other hand, it may be difficult either because it is constructed poorly or because the students have not learned the material.

Cognitive complexity refers to the cognitive demand associated with an item. Determination of cognitive complexity of a Chemistry examination question can be done through the use of Bloom's cognitive Taxonomy scale. Although, it's use requires making inference about the skill, knowledge and background of the students responding to the item. The categories (low-complexity, moderate- complexity, and high complexity) form an ordered description of the demands an item may make on a student. For example, low-complexity items may require a student to solve a one-step problem. Moderate complexity items may require multiple steps. High-complexity items may require a student to analyze and synthesize information. Table 1 provided description of the three categories for ease of reference; however, caution must be used in referring to this table of descriptors for each cognitive complexity level. The ultimate determination of an item's cognitive complexity should be made considering the intent of the overall cognitive demand place on a student.

Table 2: Classification of science activities according to the levels of cognitive complexity.

Examples of Science Activities across Cognitive Complexity Levels		
Low-Complexity Science	Moderate-Complexity Science	High-Complexity Science
• Identify a common example or recognize a concept. • Retrieve information from a chart, table, diagram or graph. • Recognize a standard scientific representation of a simple phenomenon. • Calculate or complete a familiar single-step procedure or equation using a reference sheet.	• Apply or infer relationships among facts, terms, properties, or variables • Describe examples and non-examples of scientific processes or concepts. • Predict or determine the logical next step or outcome. • Compare or contrast structure or functions of different organisms or systems. • Choose the appropriate formula or equation to solve a problem and then solve it. • Apply and use concepts from a standard scientific model or theory.	• Construct models for research. • Generalize or draw conclusions. • Design an experiment, given data and conditions. • Explain or solve a problem in more than one way. • Providing a justification for steps in a solution or process. • Analyze an experiment to identify a flaw and propose a method for correcting it. • Interpret, explain, or solve a problem involving complex spatial relationships. • Predict a long-term effect, outcome, or result of a change within a system.

For the purpose of categorization of chemistry examination questions two classification models can be used. These are revised Bloom's Taxonomy and the Expanded Framework for Analyzing General Chemistry Examination (EFAGCE). The revised taxonomy presents learning objectives categorized hierarchically along two interacting dimensions, the knowledge dimension (content taught) and the cognitive process dimension (thought process used to demonstrate learning). The knowledge dimension on the other hand, contains the hierarchical categories of factual knowledge, conceptual knowledge, procedural knowledge and meta-cognitive knowledge. The cognitive process dimension contains the hierarchical categories of remember, understand, apply, analyze, evaluate, and create. According to Domin (1999), these hierarchical categories are often dichotomized into lower-and higher-order mental processes. Behaviours that would encompass the lower levels of cognition include recognizing, recalling or applying a learned rule. Higher-order thinking is exemplified by such behaviours as inferring, planning, or appraising.

The revised taxonomy recognizes the interactions between the knowledge dimension and the cognitive process dimension. The interactions between the two dimensions lead to the emergence of the Taxonomy Table (Table3) otherwise known as the Cognitive Demand Matrix (CDM).

Table 3: The Taxonomy Table (Cognitive Demand Matrix) as designed by Anderson and Krathwohl (2001)

THE KNOWLEDGE DIMENSION	**THE COGNITIVE PROCESS DIMENSION**					
	1. Remember	**2. Understand**	**3. Apply**	**4. Analyse**	**5. Evaluate**	**6. Create**
A. Factual knowledge						
B. Conceptual Knowledge						
C. Procedural Knowledge						
D. Metacognitive Knowledge						

The knowledge dimension forms the vertical axis of the Taxonomy Table and the cognitive process dimension forms the horizontal axis of the Taxonomy Table. The intersections of the two axes form the cells of the Taxonomy Table. A cell represents a category of examination question with distinct characteristic features. Taxonomy Table as a two-dimensional scheme provides a useful framework for characterizing chemistry learning objectives and examination questions in knowledge and cognitive process dimensions. The Taxonomy Table is a hierarchy in which the cognitive complexity is assumed to increase from left to right in the cognitive process dimension. Similarly, the categories of the knowledge dimension are assumed to lie along a continuum from concrete (factual) to abstract (meta-cognitive). However, the hierarchical structure of the revised taxonomy is not as strict as in the original Taxonomy, and the categories are allowed to overlap one another. For example, some chemistry examination questions classified into the category 'understand' (e.g., questions in which students have to explain chemical phenomena) may be more cognitively complex than some questions classified into the category 'apply' (e.g., routine stoichiometric problems).

In order to achieve accurate characterization (categorization) of chemistry examination questions, the Expanded Framework for Analyzing General Chemistry Examinations (EFAGCE) developed by Smith *et al.,* (2010) is used simultaneously with the Taxonomy Table. This is because EFAGCE utilizes the kind of information presented to the students in the problem statements as well as the thinking process likely employed by the students during the characterization process. In contrast, the Taxonomy Table (i.e., Cognitive Demand Matrix) utilizes only the thinking process likely employed by the students. In spite of its shortcoming, it proves useful in data presentation because of its clarity. Hence, it is used to present the outcomes of data analysis in this study.

3. Methodology

This study is qualitative in nature. Specifically, the study involved content analysis of data collected. Content analysis is described as a research technique for objective, systematic and quantitative description of the manifest content of a document. In this study, the documents are senior school certificate chemistry examination questions. The collected data were qualitatively analyzed in order to compare and contrast the characteristics features of chemistry examination questions constructed by the two national examination bodies in Nigeria.

The data source comprises senior school certificate examination questions constructed by the WAEC and the NECO between 2008 and 2012 from which 230 (from WAEC) and 245 (from NECO) chemistry questions emerged. All together the two data sources yielded 475 chemistry examination questions as data for this study. Data were collected from the records and examinations offices of two schools of science which were purposely established by the state Ministry of Education for teaching science subjects at senior secondary school level. Prior to the data collection, letter requesting for the chemistry examination questions constructed between 2008 and 2012 by both examination bodies was sent to the school counselors in charge of examination record keeping to facilitate data collection.

The goal of qualitative analysis is to determine pattern in the data collected. Thus, in this case the focus is on patterns of cognitive complexity of chemistry examination questions. To accomplish this, chemistry examination questions were analyzed using a coding system based on the Cognitive Demand Matrix (CDM). Each identified category was given an appropriate predefined code (Table 4). For example, an examination question is coded as Con-Ap if it requires an application of facts, rules and principles as well as putting other's ideas into their own words.

Table 4: A code system for categorizing senior school certificate chemistry examination questions

THE KNOWLEDGE DIMENSION	**THE COGNITIVE PROCESS DIMENSION**					
	1. Remember	**2. Understand**	**3. Apply**	**4. Analyse**	**5. Evaluate**	**6. create**
A. Factual knowledge	**Fac-R**	**Fac-U**	**Fac-Ap**	**Fac-An**	**Fac-E**	**Fac-C**
B. Conceptual Knowledge	**Con-R**	**Con-U**	**Con-Ap**	**Con-An**	**Con-E**	**Con-C**
C. Procedural Knowledge	**Pro-R**	**Pro-U**	**Pro-Ap**	**Pro-An**	**Pro-E**	**Pro-C**
D. Metacognitive Knowledge	**Met-R**	**Met-U**	**Met-Ap**	**Met-An**	**Met-E**	**Met-C**

When utilizing the coding system for categorization of chemistry examination questions, the following assumptions were made:

1. It is assumed that the lower-order cognitive process categories are included in the higher categories.
2. It is assumed that in the revised Bloom's Taxonomy scale the classes (levels) of objectives were arranged in order of increasing cognitive complexity.
3. It is also assumed that the lower-order knowledge categories are included in the higher categories.
4. It is assumed that students have not solved exactly similar tasks in the chemistry lessons when preparing for the examinations.

Two main phases were involved in the coding process. In the first phase, senior school certificate chemistry examination questions are classified into six Cognitive Process categories of the Taxonomy Table. The three lowest categories of the Cognitive Process dimension are defined as lower-order cognitive categories (LOCS) in this research. The three highest categories are defined as higher-order categories (HOCS). In the second phase of the research, the test questions are classified into the four knowledge categories of the Taxonomy Table. The classification of senior school certificate chemistry examination questions using the cognitive demand matrix is challenging and partially interpretative. Hence, the Expanded Framework for Analyzing General Chemistry

Examination (EFAGCE) was concurrently applied to obtain accurate characterization of examination questions in this study. More importantly, the correspondence between the Taxonomy Table and EFAGCE has been established by Sanabria-Rios and Bretz (2010) and this informs its utilization in this research. EFAGCE as a supporting classification tool, in this study, is especially useful while analyzing questions which lie between the categories, apply and analysis of the Taxonomy Table.

In order to guarantee the reliability of the results, two coders (the researcher and a specialist in chemistry education) individually coded two groups (i.e., WAEC group and NECO group) of examination questions constructed by the two examination bodies, compared classifications, and resolve differences in categorization via discussion. Several rounds of classification, confirmation and modification were conducted to satisfactorily summarize the data presented in Table 5 an 6. The results of reliability test showed an acceptable level of inter-rater agreement of 80% (concordance) and 85% (concordance) for chemistry examination questions constructed by the WAEC and NECO respectively. Prior to the peer review, the classification procedure was demonstrated by the coders in which some sample chemistry questions taken from NABTEB examination papers were categorized. This question categorization process was employed to activate the coders' prior knowledge concerning the usage of revised Bloom's Taxonomy as a classification tool. The researchers believed that through this strategy a good common understanding about the classification process can be achieved.

4. Findings

The findings are based on the content analysis of Senior School Certificate Chemistry Examination (SSCE) questions constructed by the West African Examinations Council (WAEC) and the National Examinations Council (NECO) between the periods of 2008 to 2012. The findings (Tables 5 and 6) were presented according to each research question.

Table 5: Distribution of the Senior School Certificate Chemistry Examination questions (n=230) constructed by WAEC according to the highest knowledge and cognitive process level from 2008-2012

The highest knowledge	**The highest cognitive process**					
	Questions requiring lower-order cognitive skills (LOCS)			**Questions requiring higher-order cognitive skills (HOCS)**		
	145 (63%)			**85 (37%)**		
	Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual knowledge	48 (20.8%)	-	-	-	-	-
Conceptual Knowledge	-	51 (22.2%)	32 (13.9%)	24 (10.4%)	-	14 (6.1%)
Procedural Knowledge	6 (2.6%)	-	8 (3.5%)	38 (16.5%)	-	9 (3.9%)
Metacognitive Knowledge	-	-	-	-	-	-

Table 6: Distribution of the Senior School Certificate Chemistry Examination questions (n=245) constructed by NECO according to the highest knowledge and cognitive process level from 2008-2012

The highest knowledge	**The highest cognitive process**					
	Questions requiring lower-order cognitive skills (LOCS)			**Questions requiring higher-order cognitive skills (HOCS)**		
	191 (78%)			**54 (22.0%)**		
	Remember	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual knowledge	56 (22.9%)	-	-	-	-	2 (0.8%)
Conceptual Knowledge	-	54 (22.0%)	40 (16.3%)	29 (11.8%)	-	8 (3.3%)
Procedural Knowledge	13 (5.3%)	-	28 (11.4%)	15 (6.1%)	-	-
Metacognitive Knowledge	-	-	-	-	-	-

Research question 1: At what level of the revised Bloom's cognitive Taxonomy of learning objectives does the chemistry examination questions constructed by the two examination bodies (between the periods of 2008 - 2012) require the learners to operate?

The answer to this question is based on the content analysis of chemistry examination questions. As revealed in Table 5 and 6, the majority of the examination questions require the test takers (i.e., the final year senior secondary school chemistry students) to operate predominantly at the three lower levels of the revised Bloom's Taxonomy (remember, understand, apply). For instance, 63% of SSCE questions constructed by the WAEC between the periods of 2008 and 2012 were LOCS- type chemistry examination questions. Similarly, 78% of SSCE question developed by the NECO test developers learnt information from long-term memory and application of algorithms (formula) to a familiar task.

Research question 2: What discrepancies, if my, exist in the characteristics features of LOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008-2012?

Similarly, the answer to this question is based on the content analysis of the chemistry examination questions in which the questions were read line-by-line to discover categories of LOCS-type examination questions. Through qualitative analysis it was revealed that there were no discrepancies in the characteristic features of LOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008- 2012. Table 5 and 6 revealed that large proportion of LOCS-type questions that featured prominently in both examinations fall into three similar categories although five categories of examination questions with distinct characteristics can be identified in both examinations. The first category (**Fac-R**) comprises examination questions that require remembering and utilization of factual knowledge. This category of question constitutes 20.8% (for WAEC) and 22.9% (for NECO) of the total number examination questions constructed. They were short-answer questions that call for retrieval of knowledge from long-term memory without necessarily understanding them (e. g., question 6 in the appendix). The second category (**Con-U**) consists of examination questions that required demonstration of understanding of the previously learned information (e.g., concepts, theories, principles) through putting other's ideas into their own words. In other word, they were examination questions in which students have to explain/describe how or why (e.g., question 2 in the appendix). This category constitutes 22.2% (for WAEC) and 22.0% (for NECO) of the total number of examination questions. The third category (**Con-Ap**) comprises examination questions that require using understanding of core concepts, principles and theories to complete a task or solve a problem. They were typically examination questions in which students need to apply knowledge that is rich in relationships (e.g., question 1 in the appendix). This category constitutes 13.9% (for WAEC) and 16.3% (for NECO) of the total number of examination questions. The remaining two categories of LOC-type examination questions are: (1) the category (**Pro-R**) of examination questions requiring remembering of procedural knowledge. They were typically questions in which students have to recall a fact, concept or perform a routine procedure (e.g., question 8 in the appendix). This category constitutes 2.6% (for WAEC) and 5.3% (for NECO) of the total number examination questions. (2) The category (**Pro-Ap**) of examination questions requiring students to apply procedural knowledge (e.g., question 9 in the appendix). They were typically questions in which students have to recall mathematical expressions (formulae) of chemical laws and subsequently substitute data into formulae. This category constitutes 3.5% (for WAEC) and 11.4% (for NECO) of the total examination questions for the period considered in this study.

Research question 3: What discrepancies, if any, exist in the characteristics features of HOCS-type chemistry examination questions constructed by the two examination bodies between the periods of 2008-2012?

Through qualitative analysis it was also revealed that four categories of chemistry examination questions constructed by the two examination bodies fall under HOCS – type questions. But out of the four categories only one category differs and this is the only noticeable difference. A category(**Pro-C**) of examination questions (constitutes 3.9% of the total test items) requiring creating and planning a series of discrete laboratory activities to be performed (e.g., question 12 in the appendix) were featured in the WAEC examination questions whereas such category was not used for students' assessment (Table 5) in NECO examination questions instead, a category(**Fac-C**) of examination questions (constitutes 0.8% of the total test items) requiring creating and utilization of factual knowledge (e.g., question 5 in the appendix) featured in examination questions constructed by the NECO test developers (Table 6). The remaining three categories that featured as HOCS-type examination questions in both WAEC and NECO examinations papers are: (1) The category(**Con-An**) of examination questions requiring analysis of problem-solving process to be employed when solving non-routine problems using conceptual understanding (e.g., question 11 in the appendix). This category constitutes 10.4% (for WAEC) and 11.8% (for NECO) of the total number of examination questions. (2) The category(**Pro-An**) of examination questions requiring (a) building a clear, stepwise path between the given data and solution by following a simple procedure and (b) analysis of problem statement to determine a series of discrete operations to be performed and to identify any steps that require ancillary operation (e.g., question10 in the appendix). This category constitutes

16.5% (for WAEC) and 6.1% (for NECO) of the total number of examination questions for the period considered in this study. (3) The third category (**Con-C**) constitutes examination questions requiring creating and usage of conceptual knowledge. They were questions in which students have to compile information (previously learnt materials) in different ways to produce a new pattern or alternative solution (e.g. question 4 in the appendix). This category constitutes 6.1% (for WAEC) and 3.3% (for NECO) of the total number of examination questions for the period considered in this study.

Research question 4: Are all categories of LOCS- and HOCS – type of chemistry examination questions featured in the test items constructed by the two examination bodies?

Content analysis of the chemistry examination questions provided answer to this question. It is evidence from the result of qualitative analysis presented in Table 5 and 6 that the examinations conducted by the two examinations bodies between the periods of 2008-2012 did not include any questions that required evaluation (e.g.,**Con-E**,**Pro-E**). Similarly,categories(e.g.,**Met-Ap**,**Met**-**An**) questions that demanded the use of meta-cognitive skills (knowledge concerning knowing why a procedure works, under what conditions it works and why a procedure is better than another) were not found in the examination questions constructed by the two examination bodies (Table 5 and 6).

5. Discussion

The findings of this study indicate that senior school certificate chemistry examinations are less cognitively demanding. Some studies reported similar findings. For example, Zoller *et al.*, (1999) and Karamustafaoglu *et al.*, (2003) reported that examination questions at application and lower levels of Bloom's Taxonomy dominated current assessment methods. According to them, the implementation of assessment methods that attempt to capture more complex aspects of learning is needed in a rapidly changing and increasingly complex world. The percentage of examination questions that were designed for the assessment of lower-order cognitive knowledge and skills is greater than the percentage of examination questions requiring students to solve complex, non-routine problems or in general, to think at higher levels. The premium today is not merely on students' acquiring information, but on recognizing what kind of information matters, why it matters, and how to combine it with other information to produce a new pattern or alternative solution.

Remembering pieces of knowledge is no longer the highest priority for learning (diSessa *et al*., 2004; Stamovlasis *et al*., 2013); what students can do with knowledge is what counts. However, from pedagogical perspective, when new material is being introduced, an assessment probably should include at least a check that basic new facts have been learned. This is because basic knowledge of facts or data is a prerequisite for deep learning which require students to operate at any of the three higher cognitive levels (analyse, evaluate, create). Deep learning involves the critical analysis of new ideas, linking them to already-known concepts and principles and to personal experiences. This leads to the understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts.

Some educators propose that if test items constructed by national examination bodies can successfully focus on higher-order cognitive skills, then it will encourage and assist teachers to teach for HOCS in their classrooms (Yeh, 2001; Tankersley, 2007). From this point of view, the development of national examinations that assess whether students can frame a problem , develop hypotheses, evaluate outcomes, demonstrate scientific understanding, use scientific facts and terminologies, organize information, solve non-routine problems or not is key to facilitating the development of higher-order cognitive skills by all the students (Zoller and Tsaparlis, 1997). Evidence abounds in the literature to support this view; for those nations that have examinations that include problem-solving and open-ended tests (i.e. HOCS), teachers are found using more tasks in the classroom similar to those on the test (Pedulla *et a*l., 2003).

The LOCS-type senior school certificate examination questions can still be utilized in subsequent examinations by transforming them into HOCS-type chemistry questions. This can be achieved in several ways. One way to increase the cognitive complexity of a LOCS-type question is by not supplying all the necessary information (e.g., gas constant or Avogadro's constant) in the problem statement or by providing hidden information (e.g., when density (D) is needed, it can be given as mass (M) and volume (V) so that students need to first analyze the situation and then find all the required information by locating needed information from an ancillary table or performing ancillary operation.

Another way to increase the cognitive complexity of routine quantitative problems is to include short verbal sections into questions that require students to evaluate if the answer and/or the solving process makes sense and is meaningful. In addition, it is possible to include previously unknown ancillary materials (e.g. charts, tables, pictures) in the questions when the examinations will more likely measure students' higher-order cognitive skills than rote memorization of textbook content or well-rehearsed routine skills (Zoller and Tsaparlis, 1997).

This study also reveals non-inclusion of test items that only required the test takers to make a judgment based on a pre-established set of criteria (i.e., evaluation). An example of such question can be given as:

critically evaluate the Dalton's Atomic theory in the light of modern advancement in the study of atom's interior structure. The researcher considered this as a serious shortcoming on the part of the two examination bodies. In the senior school assessments, students should be exposed to tasks aimed at developing their higher level cognitive abilities. Any assessor who engages senior schools students with activities involving the lower-order cognitive levels does a disservice to students. In addition, this study shows that any question that required processing of meta-cognitive knowledge were not at all captured in the examination questions constructed by the two examination bodies. This is understandable because meta-cognition is a hidden level of behavior that involves students engaging in the following activities: (1) evaluating whether they are learning or not; (2) employing strategies when needed; (3) knowing whether a strategy is successful or not; and (4) making changes when needed. So, it is very challenging to assess the metacognitive levels or their development both the aid of a summative assessment instrument like Senior School Certificate Examination (SSCE).

6. Conclusion

This study, aiming to shed light on similarities and differences in the characteristic features of Senior School Certificate Chemistry Examination questions constructed by the West African Examinations Council (WAEC) and the National Examinations Council (NECO) has arrived at the following specific findings:

1. Senior School Certificate Chemistry Examinations conducted by the two examination bodies primarily focus on lower-order cognitive skills (e.g. retrieval of information from long-term memory, application of concepts to familiar situations, application of well-known algorithms in problem solving) at the expense of higher-order cognitive skills (e.g., non-routine application of concepts and principles).
2. There were no discrepancies in the characteristics features of LOCS-type chemistry examination questions constructed by the two examinations bodies between the period of 2008-2012.
3. There were slight discrepancies in the characteristics features of HOCS-type chemistry examination questions constructed by the two examinations bodies between the period of 2008-2012 in the sense that out of the four categories of HOCS-type chemistry examination questions that appeared in both examinations only one categories differs. That is, a category of examinations questions requiring creating and planning a series of discrete laboratory activities to be performed were featured in the WEAC examination questions whereas such category was not used for students' assessment in NECO examination questions instead, examination questions requiring creating and remembering of words and facts without necessarily understanding them featured in examination questions constructed by the NECO test developers.
4. Both the HOCS-type questions and LOCS-type questions were not evenly distributed for the periods of examination considered in this study.

7. Implications

In the researcher's view, two important implications can be drawn for teachers, students and examining bodies from the findings of this study. This is because an understanding of the findings that had emerged will help all those concerned to play their roles effectively in promoting new assessment. This is the assessment that fosters students' ability to apply and explain their knowledge in ways that demonstrate a deep understanding of the chemistry contents as officially prescribed in the curriculum.

As revealed in this study, the senior school certificate chemistry examinations are less cognitively demanding due to high proportion of LOCS-type chemistry questions it contained. This result can exert powerful influence on chemistry instructions in two ways. First, teachers can be discouraged from teaching more challenging skills and thereby preventing students from engaging in all sorts of intellectually challenging activities that pique students' interest in learning chemistry. This is because teachers tend to teach what is tested by the national examination bodies especially when assessment is used for decision-making purposes (e.g, award certificate). Second, knowing fully well that senior school certificate examinations are not well designed to assess students' ability to frame question, develop hypotheses, evaluate outcomes, demonstrate scientific understanding and display other advance skills, students may tend to adopt a surface approach to learning. Students using a surface approach usually focus on the completion of their most obvious task requirements, and often distort the intent of the task in order to achieve their extrinsic goals (Bliuc *et al*., 2011). In contrast, students who adopt a deep approach to learning aim at achieving a better personal understanding of new ideas and information, and are more likely to value the pedagogical intentions underlying the learning task.

Another important implication of this study is that senior school certificate chemistry examinations are not suitable enough for distinguishing between the 'wheat' and the 'chaff' because of the under representation of the higher-order cognitive skills test items in the examination questions constructed by the examination body Researchers (e.g., Atjoren, 2007; Kraska, 2008) argue that, by tapping into students' advanced thinking skills and abilities to explain their thinking a valid assessment yields a more complete picture of students' strengths and weaknesses. At present, a complete picture of senior secondary school students cannot be obtained from senior school certificate chemistry examination because LOCS-type questions outnumbered HOCS-type questions as revealed in this study.

8. Recommendations

The results of this study make two important recommendations. First, it is recommended that the instructional objectives formulated on chemistry topics should incorporate higher-order cognitive skills and knowledge so that examination questions can be tailored towards these objectives. Second, based on the evidence from this study, it is also recommended that all categories of chemistry examination questions should be more evenly presented as test items in Senior School Certification Chemistry Examination.

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Appendix

Illustrative examples of the classification process of the chemistry examination questions.

Question 1. Explain boyle's law in terms of the kinetic theory
Question Category: Cognitive Process: **Apply**
Knowledge: **Conceptual knowledge**
Question Code: Con-Ap
Justification for grouping: The question demands explanation of a law in terms of the kinetic molecular theory. The fact that the verb **explain** appeared in the question, one may be tempted to group it into understand as the cognitive process category. But it can be rightly grouped as **application** since the explanation of the law should be done in terms of the kinetic theory. Explaining a law requires conceptual knowledge so the knowledge category is **conceptual knowledge**

Question 2: Explain with the aid of appropriate equation why it is not advisable to build a house with limestone in an environment polluted by sulphur(IV) oxide

Question Category: Cognitive Process: **Understand**
Knowledge : **Conceptual knowledge**
Question Code: Con-U
Justification for grouping: In other words, the task is to explain action of dilute acid on calcium trioxocarbonate(IV). Thus, the cognitive process category is **understand**. Making cognitive connections in the students' cognitive structure is required in providing correct explanation to the question. This is because student should recognize limestone as $CaCO_3$ and sulphur(IV) oxide as acid anhydride. So, the knowledge category is **conceptual knowledge** (i.e., knowledge rich in relationships.

Question 3: What type of bond(s) exist(s) in: (I) ammonia (II) ammonium ion?
Question Category: Cognitive Process: **Analyze**
Knowledge : **Conceptual knowledge**
Question Code: Con-An
Justification for grouping: students need to possess knowledge of how to draw structural formulae of ammonia and ammonium ion because this will enable them see how atoms bonded together in the ammonia molecule and ammonium ion. Thus, the cognitive process category is **Analyze** due to structural analysis that is involved. Naming the type of bonds, in the molecule/ion require conceptual understanding of the concept of bond formation so the knowledge category is **conceptual knowledge.**

Question 4: Give THREE Isomers of C_4H_8
Question category: cognitive Process: **Create**
Knowledge : **Conceptual knowledge**
Question Code: Con-C
Justification for grouping: This examination question requires putting elements (i.e., carbon and hydrogen) together in three different ways to form three coherent or functional whole known as Isomers. Thus, the cognitive process category is **create**. Since creation of three Isomers of C_4H_8 requires meaningful understanding of the concept of isomerism and chemical bonding, so the knowledge category is **conceptual knowledge.**

Question 5: Draw a well-labelled diagram for laboratory preparation of DRY chlorine gas
Question category: Cognitive Process: **Create**
Knowledge : **Factual knowledge**
Question Code: Fac-C
Justification for grouping: The knowledge category is **factual knowledge** because students need to have knowledge of the names of lab apparatus (e.g., round bottom flask, tap funnel, gas jar, comical flask, delivery tube) and reagents to be use for the lab preparation of the dry gas. Students need to draw a well-labelled diagram in which separate apparatus must be connected together to form a workable setup for laboratory preparation of dry chlorine gas. Thus, the cognitive process category is **create.**

Question 6. State (i) Pauli's Exclusion principle (ii) Hund's rule of maximum multiplicity **Question Category:** Cognitive Process: **Remember** Knowledge : **Factual knowledge** **Question Code: Fac-R** **Justification for grouping:** The examination question requires stating laws which involve rote memorization. Thus, the cognitive process category is **remember**. The knowledge category is **factual knowledge** because students need to make declaration.
Question 7: Outline how a pure sample of sodium chloride crystals can be obtained from a mixture of iron fillings, ammonium chloride, sodium chloride and sand **Question Category:** Cognitive Process: **Apply** Knowledge : **Procedural knowledge** **Question Code: Pro-Ap** **Justification for grouping:** The activity involves in answering the question is application of knowledge and understanding. Students need to apply their understanding of the physical properties of the constituents of the mixture in outlining a procedural for the separation. Thus, the cognitive process category is **apply**. Because students need to point out step-by-step actions to be taken in achieving the required separation, the knowledge category is **Procedural knowledge.**
Question 8: Outline the industrial preparation of ammonia by Haber process. **Question Category:** Cognitive Process: **Remember** Knowledge : **Procedural knowledge** **Question Code: Pro-R** **Justification for grouping:** Students need to list industrial processes for the preparation of ammonia. The verb *outline* in this context refers to the category **remember.** Because students need to outline step-by-step industrial processes to be taken, the knowledge category is **procedural knowledge.**
Question 9: A given volume of methane diffuses in 40 seconds. How long will it take the same volume of sulphur(IV) oxide to diffuse under the same conditions. [C=12, H=1, S=32,0=16] **Question category**: cognitive Process: **Apply** Knowledge : **Procedural knowledge** **Question Code: Pro-Ap** **Justification for grouping:** This examination question requires a routine application of Graham's law of diffusion, and does not require higher-order cognitive process. It requires substitution of numerical data into mathematical expression of Graham's law of diffusion that is recalled from memory. Thus, the cognitive process category is **Apply**. Because students need to build up sequence of steps that make up the solution pathway to the algorithmic problem, then the knowledge category is **procedural knowledge.**
Question 10: If 3.08g of Fe completely reacted with $50.0cm^3$ of $2.20mol\ dm^{-3}$ HCl, calculate the relative atomic mass of the metal. **Question category:** Cognitive Process: **Analysis** Knowledge : **Procedural knowledge** **Question Code: Pro-An** **Justification for grouping:** Because students need to build up sequence of steps that make up the solution pathway to the problem using their knowledge of mole concept and striochiometric principles, the knowledge category is **procedural knowledge**. In this research, the highest possible category is considered, Although we may be tempted to group the question in the knowledge category of conceptual knowledge. Students also need to analyze the problem statement thoroughly while engaging in problem-solving task. So, the cognitive process category is **Analyze.**

Question 11: The solubility of potassium trioxonitrate (V) at 27^0C is 0.72 mol dm^{-3}. If 11.10g of the salt is added to $500cm^3$ of water at 27^0C, determine whether the solution is saturated or unsaturated.

Question Category: Cognitive process: **Analysis**
Knowledge: **Conceptual Knowledge**
Question Code: Con-An
Justification for grouping: The knowledge category is **conceptual knowledge** because students need conceptual understanding of the concepts of solubility, saturated and unsaturated solution in planning the solution strategy. Because straight forward applications of learned or routine steps do not **apply**, students need to analyze the problem solving process involved by identifying relationship between what is given and what is required, identifying sub-problems to be solved and clarifying existing information in problem statement.
The cognitive process category is **Analyze**.

Questing 12: Outline the steps involved in testing for a reducing agent in the laboratory.
Question Category: Cognitive process: **Create**
Knowledge: **Procedural Knowledge**
Question Code: Pro-C
Justification for grouping: The knowledge category is **Procedural knowledge** because students need to have knowledge of how to carry out inorganic qualitative analysis in a laboratory. Stepwise laboratory procedure has to be followed in testing for a reducing agent. Students need to outline the steps involved in testing for a reducing agent in the laboratory. One may be tempted to identify the cognitive process category as factual knowledge. But the context in which the phrase '*outline the steps'* is used depicts '*plan a procedure'*. So, the verb plan refers to the cognitive process category **create.**