Classification of End-of-Chapter Questions in Senior School Chemistry Textbooks used in Nigeria

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Abstract

Textbooks are a prominent part of science teaching and learning. For science teachers and students, textbooks are the major source of information for planning and classroom practice. In addition to the content of textbooks are end-of-chapter questions that should consolidate students learning and enhance their thinking processes. Therefore, this study adopted the framework of the revised Bloom's Taxonomy to classify and analyze end-of-chapter questions from three senior school chemistry textbooks used in Nigeria. The results from this study indicated that majority (76%) of the questions were at the lower order of (*understand, remember,* and *apply*), while 46% and 32% measure c*onceptual* and *procedural* knowledge respectively. The results further revealed that the number of questions in the categories of *evaluate* and *create* differs significantly at, F (5, 1744) = 5.61, $\rho < .01$, from the other categories of the cognitive process skills. The following conclusions were drawn: *understand* and *analyze* categories recorded the highest number questions in the cognitive objectives; and there was no metacognitive questions. Implications for textbook authors and teachers were discussed.

Keywords: End-of-chapter questions, cognitive process skills, knowledge dimensions, chemistry textbooks

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Introduction

The major source of information that is readily available to students for reading/studying, class- and homework is the science textbooks. In addition to the content of textbooks are the in-chapter, end-of-chapter and bank of questions to consolidate the theory students have learnt in the respective chapters. These questions could be exercises in form of drills and repetition that only require students to apply an algorithm to arrive at the solution, or problems that are novel in nature and require students' conceptual understanding of what they have learnt in class and from the textbooks. The types of questions included in science (chemistry) textbooks could facilitate and enhance students' thinking processes and encourage them to work on their own.

Textbooks are a prominent part of teaching and learning. Research in science education has shown that teachers rely, depend and use textbooks for planning and classroom practices

(Britton, Woodward & Binkley, 1993; Chambliss & Calfee, 1998). Studies on science teachers' attitude and preference for science textbooks have also shown that while science teachers do not have consistent expectations from the texts, questions and other tasks are reported as one of the topmost criteria for textbook selection and their subsequent recommendation for students (Cook & Tulip, 1992; Dávila & Talanquer, 2010; Pappa & Tsaparlis, 2011; Spiegel & Wright, 1984).

Conceptual Framework

This research is conceptualized within the framework of taxonomy of cognitive domain provided by Bloom (1956) and revised by Anderson and Krathwohl (2001). Bloom's taxonomy provides a foundation for developing learning objectives designed for learners to acquire knowledge. The taxonomy is designed to build content knowledge from basic foundation (*remembering)* to more complex manipulation of content (*creating).* The taxonomy was originally designed as an assessment tool. Although it has provided a framework for learning, teaching and assessment that has been adopted in almost all environments where learning takes place. This may have influenced its adoption in the design of science curricula and instructional systems in Nigeria.

Anderson and Krathwohl (2001) updated and redefined Bloom's original classification, which is the specific taxonomy employed in this research to classify end-of-chapter questions in chemistry textbooks. The revised taxonomy promotes two dimensions to guide the processes of stating learning objectives and instruction that will lead to sharper, more clearly defined assessments. These will consequently, provide a stronger connection of assessment to both the learning objectives and instruction. The two dimensional taxonomy of Anderson and Krathwohl (2001) place emphases on the need to assess higher order cognitive processes and metacognitive knowledge. 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.

In the original taxonomy, cognitive processes assume a hierarchical order that 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 textbook authors in the developing in-chapter and end-of-chapter questions, 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 concepts), may be more complex than a questions in the *apply* category, that require students to execute/perform a routine algorithm to arrive at the possible solution.

Literature Review

Recently, studies have been conducted to underscore the importance of the varying demand of questions assessed in examinations and in chemistry textbooks (Dávila & Talanquer, 2010; Gillette & Sanger, 2014; Pappa & Tsaparlis, 201; Tikkanen & Aksela, 2012; Tsaparlis & Zoller, 2003). This is because assessment could impact students' future, especially in situations where students have to integrate and apply textual information into their personal experiences.

Tsaparlis and Zoller (2003) conducted three research studies: two in Greece and one in Israel on students' performance in chemistry examinations that require Higher Order Cognitive Skills (HOCS) and Lower Order Cognitive Skills (LOCS) at the high school and university levels. The research indicates that the chemistry examination used for entry into higher education in Greece selects the best LOCS-performing students because LOCS-type of questions were emphasized in the examination. 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 requiring 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.

According to Tsaparlis and Zoller (2003), the Israeli study was within an introductory freshman general and inorganic chemistry course to compare students' stated preferences with regard to LOCS-and HOCS-type of questions after being exposed to HOCS-teaching for a period of two months and their actual choice in examinations. Findings from the study revealed that, top performing students freely selected and answered the LOCS-type questions. Therefore, the researchers could not classify as either LOCS or HOCS students based on their results. 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.

Dávila and Talanquer (2010) conducted a study to investigate the nature of end-of-chapter questions and problems used in the United States. The findings indicated that the majority of the questions and problems included in the general chemistry textbooks were at the *application* and *analysis* levels of the original Taxonomy. The results further revealed that questions and problems at the *application* level were such that require students to use algorithms to arrive at the solutions. At the *analysis* level, the questions were mostly to draw inference and make predictions rather than ask students to apply their understanding to hypotheses, create models, and make valid and critical judgments.

Pappa and Tsaparlis (2011) evaluated forms of questions and the question-answer relationship in general chemistry textbooks using the case of intra- and intermolecular chemical bonding. The kind of knowledge tested by the questions was only declarative and procedural knowledge. None of the questions require students' metacognitive knowledge.

Tikkanen and Aksela (2012) adopted the framework of the revised Bloom's Taxonomy to analyze the kind of cognitive skills and knowledge measured by the Finnish chemistry matriculation examination questions. The research indicated that the questions were cognitively demanding, with the majority (77%) of the questions requiring HOCS. Though, the questions were not evenly distributed among analyze, evaluate and create categories of the cognitive process dimension.

Gillette and Sanger (2014) analyzed the distribution of questions in the gas law chapters of secondary and introductory college chemistry textbooks from the United States. The questions in these chapters were not significantly different based on the cognitive skill (lower order and higher order) measured by the questions. In other words, the distributions of questions in the gas chapters were homogeneous for the cognitive skill across the textbooks.

Dávila and Talanquer (2010) classified and analyzed end-of-chapter questions and problems using a one-dimensional approach of the old Bloom's Taxonomy of cognitive objectives, but this study will use the two-dimensional framework of the revised Taxonomy to classify end-of-chapter questions. Tikkanen and Aksela (2012) study, which is related to this research, used the revised Bloom's Taxonomy to measure the dual perspective of learning and cognition in a summative assessment of matriculation examinations. This study was designed to analyze end-of-chapter questions that prepare students in view of summative assessment. Other studies (Gillette & Sanger, 2014; Pappa & Tsaparlis, 2011) only analyzed the distribution of questions in chemical bonding and gas laws' chapters in some textbooks based on some forms of questions and variables among which are cognitive skills and knowledge dimension respectively.

From the literature reviewed, these studies reported that questions included in some chemistry textbooks were largely of the lower-order cognitive domain. There were comparatively few questions on HOCS; which were sparsely distributed among the categories of *analyze*, *evaluate* and *create*. Tsaparlis and Zoller (2003) had earlier observed that the availability of inadequate, convincing, relevant and research-based findings with respect to the predominant lower-order cognitive skills-type assessments (as evident in examination and textbook end-of chapter questions) is frequently cited as a strong case against any tangible change. If the current reform in science education with a strong advocacy for developing students' HOCS through question-asking, critical thinking, decision making and problem solving is an implied aim of science teaching, then, it is imperative for nations of the world to critically analyze the writing of textbooks, as well as the inclusion of in-chapter or end-of-chapter questions, whether such questions tap into students' HOCS.

In the midst of the current reforms in science education, Nigeria as a nation has realized that science education is instrumental in achieving a developmental goal of becoming one of the developed economies of the world by 2020. Upon this realization, it became necessary to update existing science curricula to accommodate contemporary issues shaping and influencing the development of nations. The chemistry curriculum was revised for relevance and to enable students (even those who do not intend to proceed to higher education) to become self-reliant and competent enough to meet global challenges.

The chemistry curriculum operational in Nigeria was prepared in 2007 and made available for teachers use in 2009. The curriculum has completed 2-cycles of implementation at the senior school level. In preparing the science (chemistry) curricula, it was imperative that grounds were prepared for the translation of the documents into syllabi, textbooks and classroom processes that articulate the newly emerging instructional goals of science education. As a corollary, chemistry textbooks have also been revised to accommodate the reforms, and these textbooks ought to reflect the relevant issues by integrating the text with questions or problems that aim to foster thinking process and problem solving among users, particularly, the students. This study, therefore, classify and analyze all the available end-of-chapter questions in selected chemistry textbooks based on the two-dimensional framework of the revised Bloom's taxonomy The study was guided by one research question and a research hypothesis:

- What type of cognitive process skills and knowledge dimensions are measured by the end-of-chapter questions in the chemistry textbooks used in Nigeria?
- There is no significant difference in the categories of the cognitive process skills measured among the three selected chemistry textbooks used in Nigeria.

The Nigerian Secondary School Education

The senior secondary school education starts in senior school I, and ends in senior school III. Chemistry is an elective subject, but all students who seek to make a career of science-related courses, must take chemistry as a compulsory subject in the senior secondary school. Chemistry textbooks, curriculum and syllabus are the main resources for the teaching and learning of chemistry in the senior school. Each chemistry teacher is given copies of the recommended textbooks and a copy of the curriculum to guide the scope and content of the topics to be taught. For the students, each one is given a copy of the textbook the teacher intends to use for the session. There are 4 – 5 periods of chemistry instruction in a week for a class, and each period is 40 minutes long. There are three school terms in one academic year: September to December, January to April, May to August, and each term is about 12 – 13 weeks long. By the end of the senior school education, students would have taken 120 hours of chemistry instruction. At the end of the senior school III, students sit for public examinations, equivalent of Cambridge Local Examination Syndicate in the British system, for certification, university admission, training and employment. The national chemistry examinations are prepared by experienced chemistry teachers and university chemistry lecturers in conjunction with Examination Councils in Nigeria The examiners use the syllabus, curriculum and textbooks as guides for preparing examination questions. The chemistry textbooks used in schools are written by international and Nigerian science educators within the broad guidelines of the national curriculum framework.

Research Methodology

The source of data for this study comprised 1750 questions drawn from three widely used chemistry textbooks among students and teachers in Nigeria. These chemistry textbooks were selected because they were approved for use in the senior school by the States' Ministries of Education. For ease of analysis, questions with multiple parts, each part of the questions were reviewed, classified, coded and separately analyzed.

This study is a quantitative research that employs content analysis to classify the end-of-chapter questions in the three selected chemistry textbooks used in Nigeria. The end-of-chapter questions were classified using the framework of the revised Bloom's Taxonomy that reflected a dual perspective of the cognitive process skills and the knowledge dimension. The revised Bloom's Taxonomy was used in this research because of its wider usage across the education communities to classify performance objectives, test items and questions (Anderson & Krathwohl, 2001). For the cognitive process skills, the questions were also classified into LOCS and HOCS, since the six categories of the revised taxonomy *remember, understand, apply, analyze, evaluate* and *create* can be arranged in a hierarchical structure, but not as rigid as the original Taxonomy.

To ensure the reliability of the classification of end-of-chapter questions, 10% of the questions were randomly selected and analyzed independently by one of the authors and a Professor of science education who have a clear understanding of the revised Bloom's taxonomy and its application for classifying questions. The value of Kappa's measure of agreement was calculated based on the classification of the peer reviewers, for each of the cognitive processes and the knowledge dimension. The Kappa-values for the cognitive process and knowledge dimensions were .91 and .94 respectively. The high values ($\kappa > .85$) 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 2 presents the distribution of the 1750 questions drawn from the three selected chemistry textbooks according to the cognitive process skills of the revised Bloom's taxonomy. Only about 24% (421) of the questions asked in the three textbooks require higher order cognitive skills of (analyze, evaluate, and create). On the other hand, 76% of the questions were at the lower order cognitive level with the *understand* component taking about 41% of the questions, which arguably the category into which the largest number of the questions could be classified.

Table 2

Distribution of Questions in the Analyzed Chemistry Textbooks according to Cognitive Process Skills

Analyzed Textbooks	**Remember**		**Understand**		**Apply**		**Analyze**		**Evaluate**		**Create**		**Total**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Comprehensive Chemistry	111	27.19	169	41.3	32	7.8	85	20.8	3	.7	9	2.2	409	23.4
Essential Chemistry	241	28.5	330	39.0	95	11.2	147	17.4	13	1.5	21	2.5	847	48.4
New School Chemistry	83	16.8	219	44.3	49	9.9	110	22.3	22	4.5	11	2.2	494	28.2
Total	**435**		**718**		**176**		**342**		**38**		**41**		**1750**	

Figure 1 shows the graphical representation and the quick summary of the distribution of the questions from the three selected chemistry textbooks into the categories of the cognitive process skills. The graph presented suggests that *understand* of the lower order cognitive skills has the highest number of the chemistry questions in each of the three textbooks, and this difference appears to be more pronounced in the Essential and New School Chemistry textbooks.

Comparable to *understand* category of the LOCS, is the *analyze* category in the higher order cognitive skills, HOCS. The graph further shows that *analyze* had the highest number of questions among the other categories of the HOCS (analyze, evaluate and create).

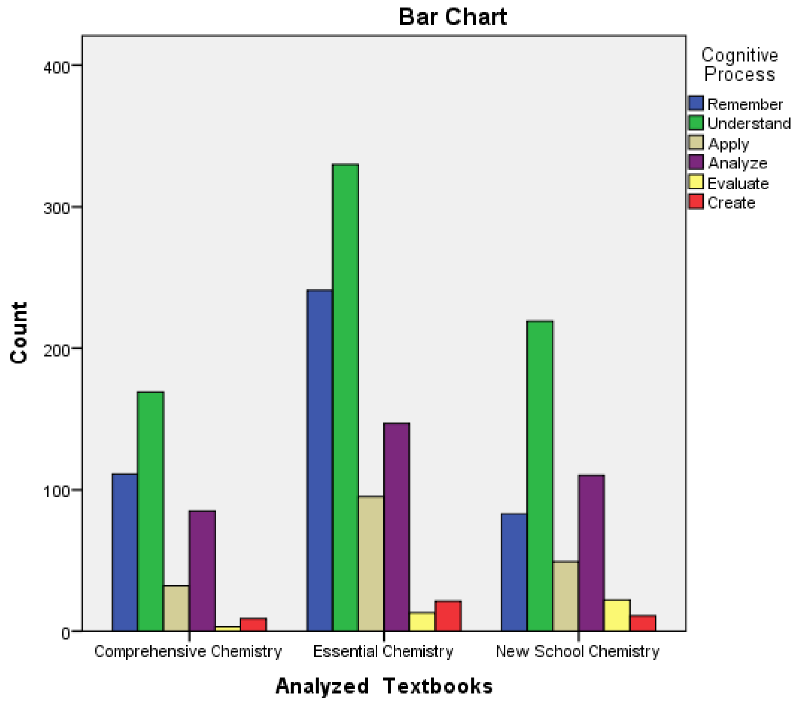

Figure 1. Frequency of Questions in the three Chemistry Textbooks according to Cognitive Process Skills

Table 3 presents the distribution of the questions obtained from the textbooks according to the knowledge dimension of the revised Bloom's taxonomy. It is shown that 46% of the textbooks' questions were designed to measure conceptual knowledge, while 32% and 22% of the questions could measure procedural and factual knowledge respectively.

Table 3

Distribution of Questions in the three Selected Chemistry Textbooks according to Knowledge Dimensions

Analyzed Textbooks	**Factual knowledge**		**Conceptual Knowledge**		**Procedural Knowledge**		**Total**	
	Freq.	**%**	**Freq.**	**%**	**Freq.**	**%**	**Freq.**	**%**
Comprehensive Chemistry	72	17.6	181	44.3	156	38.1	409	23.4
Essential Chemistry	223	26.3	390	46.0	234	27.6	847	48.4
New School Chemistry	85	17.2	233	47.2	176	35.6	494	28.2
Total	**380**		**804**		**566**		**1750**	

Figure 2 shows a graphical representation of the percentage distribution of the textbooks' questions in the three categories of the knowledge dimensions. The graph suggests that the conceptual knowledge has the highest number of questions in each of the three textbooks, followed by the procedural and factual knowledge. However, the number of questions designed to measure factual knowledge is more pronounced in the Essential chemistry textbook than in New School and Comprehensive chemistry textbooks.

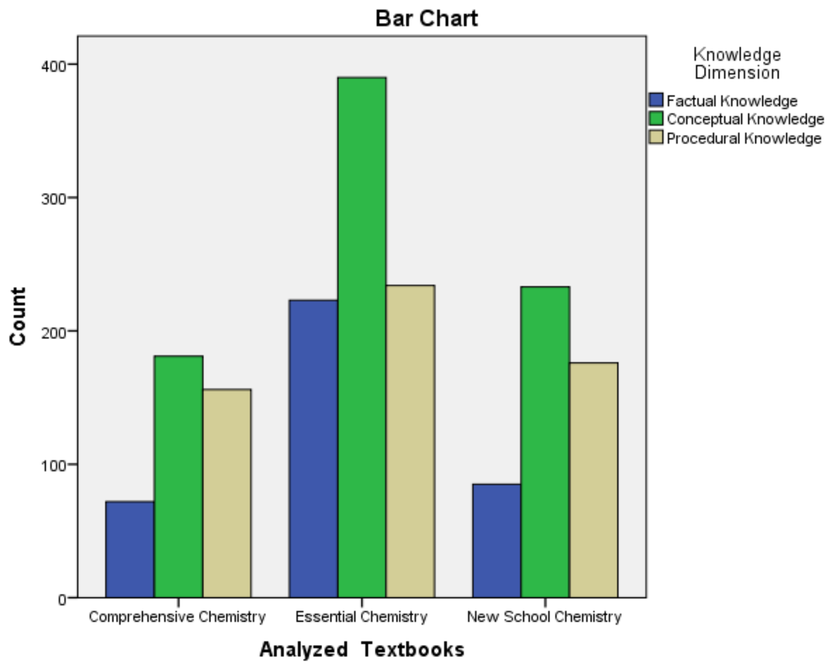

Figure 2. Frequency of Questions in the three Chemistry Textbooks according to Knowledge Dimension

Table 4 presents One-way between-groups Analysis of Covariance (ANCOVA) conducted to compare the cognitive process skills measured in the three selected chemistry textbooks. There was a statistically significant difference in the cognitive process skills measured by the selected textbooks F (5, 1744) = 5.61, $\rho < .01$, partial eta squared = .20. Preliminary analyses were conducted to ensure that there was no violation of the assumptions of normality, linearity, homogeneity of variances and regression slopes, and reliable measurement of the covariates. The results of the Post hoc comparison using the Tukey HSD test indicated that the mean score of *evaluating* (*M* = 2.50, *SD* =.65) differs significantly from *remember* (*M* = 1.94, *SD* = .67), understand (*M* = 2.07, *SD* = .73), *apply* (*M* = 2.10, *SD* = .67), *analyze* (*M* = 2.07, *SD* = .75). The mean scores of *understand* (*M* = 2.07, *SD* = .73) and *remember* (*M* = 1.94, *SD* = .67) also differs significantly.

Table 4

A One-way ANCOVA of the Cognitive Process Skills in the Selected Chemistry Textbooks

Analyzed Textbooks	**Type III Sum of Squares**	***Df***	**Mean Square**	***F***	**Sig.**	**Partial Eta Squared**
Cognitive	14.22	5	2.85	5.61	.00	.20
Error	884.65	1744	.51			
Corrected Total	898.87	1749				

Discussion, Conclusion and Implications

This study was designed to classify and to analyze whether or not, the end-of-chapter questions drawn from chemistry textbooks reflects a dual perspective on learning and cognition, and the advocacy of the current reform on the need to develop assessment methodologies that are HOCS-oriented. The selected chemistry textbooks have wider usage among students and teachers in Nigeria, which was one of the major criteria for selecting the textbooks for categorization and subsequent analysis.

Table 2 presents the result of the cognitive process skills measured by the textbooks where only 24% of the end-of-chapter chemistry questions were of the higher-order cognitive domain. The *understand* category recorded 41% of the remaining 76%. These results slightly corroborate the findings of (Dávila & Talanquer, 2010), who conducted a similar study and found that 64% of end-of-chapter questions in three introductory college chemistry textbooks were lower-order and 36% were higher-order cognitive skills. Though, the majority of the end-of-chapter questions were *application* and *analysis* levels of the Bloom's cognitive categories. The authors argued that the questions were at the intermediate levels of cognitive demand, which they considered appropriate for a college level. Our classification shows that the majority of the questions included at the end-of-chapter in the selected chemistry textbooks for this study were not as cognitively demanding as in the introductory chemistry college textbooks used in the United States. This difference is due to the higher level of education for which the textbooks are prepared and used in the United States. For the analyzed textbooks in this study, the authors realized that the *understand* category is a transfer-based educational objective that must first be emphasized in chemistry textbooks. For students to *understand* chemical concepts and for meaningful learning to take place, the new knowledge to be gained should have been connected to their prior knowledge (Ausubel, 1963).

The results further revealed that the *analyze* sub-category of the cognitive process skills recorded 19.5% as the highest in the higher order cognitive domain across the textbooks. The textbook authors have also realized that it is educationally more defensible to consider analysis as an extension of understanding or as a prelude to *evaluate* and *create*–which were less emphasized in the end-of-chapter questions across the three textbooks.

Table 3 and Figure 2 shows the percentage distribution and graphical representation of the sub-categories of the knowledge dimension measured by the chemistry textbooks. About 46% of the end-of-chapter questions require students to *understand conceptual knowledge* of chemical principles, theories and structures, while 32% of the questions require *apply procedural knowledge* of connecting conclusions with supporting statements; to distinguish relevant from extraneous materials in solving algorithmic questions; and to use appropriate procedures. These results are fairly consistent with the findings of (Tikkanen & Aksela, 2012), which indicated a similar proportion of the questions that measured procedural knowledge, but differs significantly from the questions that measured conceptual knowledge. Though, these studies looked at questions for different assessment purposes (matriculation exam questions *versus* end-of-chapter questions in chemistry textbooks). Therefore, it becomes difficult to attribute these differences to one variable. However, these differences could be because summative assessment questions should be more cognitively demanding by measuring higher dimensions of knowledge of students' cognition than end-of-chapter questions in textbooks.

The result of the ANCOVA in Table 4 compared the cognitive process skills measured by the three chemistry textbooks, and revealed a statistically significant difference in the number of questions that measure the six categories of the cognitive process skills (*remember*, *understand, apply, analyze, evaluate* and *create)* among the three textbooks [$F(5, 1744) = 5.61$, $\rho < .01$]. To identify which of the six categories of the cognitive process skills was the main contributor to the significant difference, we performed a Tukey HSD Post-hoc comparison and found that, what contributed to the significance is the number of end-of-chapter questions in the *evaluate* category which was the least emphasized, followed by the *create* category across the three textbooks. This finding is consistent with the results of (Dávila & Talanquer, 2010), which indicated low percentages of questions and problems in the *synthesis* and *evaluation* categories in all the chapters analyzed in each textbook. These similarities could be attributed to the less emphasis placed on the inclusion of end-of chapter questions that require students to apply what they have learned in a new context, make valid and critical judgments about chemical concepts, for instance, to validate conclusions that follow from the results of an experiment.

The statistical analyses arising from the classification of end-of-chapter questions in chemistry textbooks indicated that majority of the questions falls within the lower order cognitive domain in the order of *understand, remember* and *apply*. To compare the number of questions in the categories of the LOCS with the HOCS, *understand* and *analyze* were the categories that recorded the highest number of questions.

Our classification shows that the majority of the questions were at the conceptual knowledge level followed by the procedural knowledge. No single question in the three chemistry textbooks tested students' metacognitive knowledge as evident in knowledge dimensions presented in Table 1. This implies that the textbook authors did not make provision for questions that could aim at checking the extent to which students has acquired self-directed thinking in developing an action plan to solve problems.

The significant difference identified in the number of questions that were classified into the categories of the cognitive process skills further revealed the unequal distribution of questions among the categories across the three textbooks. This comparison was necessary to determine the contributor to the disproportionate distribution of questions among the categories, and to probably attempt to delineate what accounts for such distributions in the analyzed textbooks.

From the findings of this study, we could conclude that there were low percentage distribution of questions in *evaluating* and *create* categories, and this is liable to limit students' chances to develop meaningful understandings of chemical knowledge through questions or problems that taps into HOCS. The questions that were drawn from chemistry textbooks and analyzed in this study were predominantly of the LOCS–basic recall of memorized information or simply applying basic or memorized information to familiar situations, and/or applying algorithms to repetitive exercises. The dominance of such questions in chemistry textbooks has not justified the HOCS-promotion advocacy of the current reforms in assessment methodologies that necessitated chemistry curriculum revision and the subsequent review of chemistry textbooks in Nigeria.

The results of this study make it imperative to draw implications for textbook authors, teachers, and students–who depend or rely on science textbooks for instruction. It is important that textbook authors adopt a balanced approach in the inclusion of end-of-chapter questions in their subsequent revision of the textual materials that reflects the categories of the cognitive process skills and the knowledge dimensions, if not equally, at least proportionately. This is because the majority of the questions were front-loaded in the lower-order cognitive domain, leaving comparatively fewer questions to measure students higher order cognitive skills and no metacognitive question in the knowledge dimension. The end-of-chapter questions in the chemistry textbooks should be such that requires students to apply new knowledge in new contexts; generate hypotheses and design experiments to validate the hypotheses and make critical judgment about chemical phenomena.

Having established that end-of-chapter questions in chemistry textbooks were lopsided, it is equally important to alert the teachers of these discrepancies and the need for them to develop their own questions, such that will reflect the categories of the dual perspective of the revised Bloom's Taxonomy emphasized in this study, and not rely solely on textbook questions for testing.

Once the textbook authors and teachers start to feature questions that tap into students' higher-order cognitive skills, even though, there could be some initial resistance, the teachers should assist the students to actively construct knowledge in the teaching and learning of chemistry. The students could be engaged in team work, problem solving and decision making; as such activities enhance higher order cognitive skills.

Acknowledgments

The authors would like to thank Prof. I. O. Abimbola of the Department of Science Education, University of Ilorin, Ilorin, Nigeria for assisting to rate 10% of the chemistry questions analyzed in this study. The authors also wish to acknowledge Dr. Molly H. Weinburgh and the anonymous reviewers for their insightful comments that has contributed immensely to the improvement of the manuscript.

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Supplementary Materials

The classified and analyzed end-of-chapter questions were three selected chemistry textbooks commonly used in Nigeria. Table 5 presents the supplementary materials of the chapters analyzed, alongside labels assigned to each of the chapters for reference purposes. All the questions analyzed in each of the chapters were only essay questions. For questions with multiple parts, each part was taken as a single question that was coded, classified and analyzed.

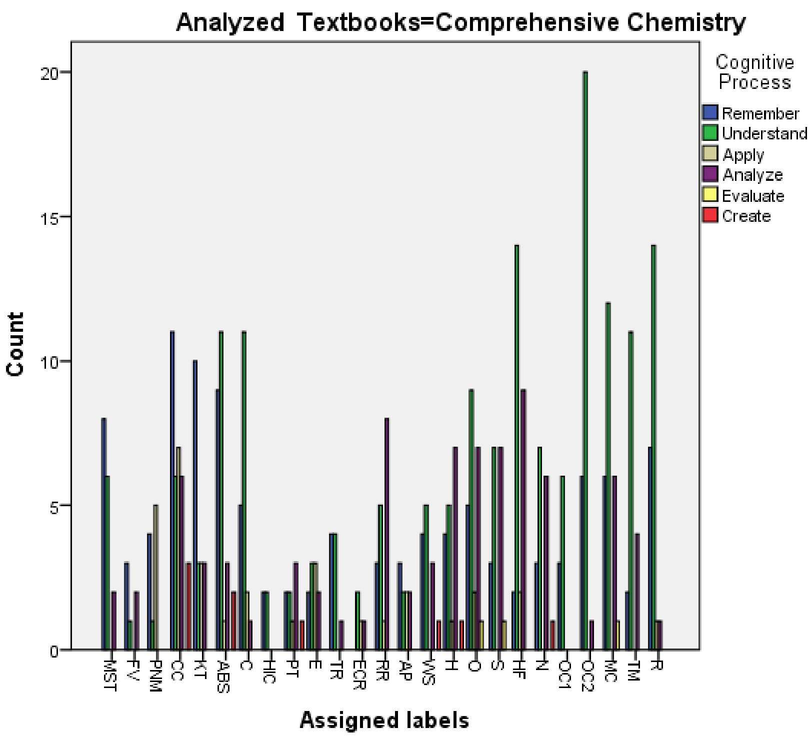
Figures 3 (a-f) in the supplementary materials present the distribution of the questions according to the cognitive process and knowledge dimensions for each of the chapters analyzed in the New School, Comprehensive and Essential Chemistry Textbooks. The assigned labels correspond with the topics in Table 5. The graphs show differences and similarities in the end-of-chapter questions in each of the chapters and the selected chemistry textbooks.

Table 5

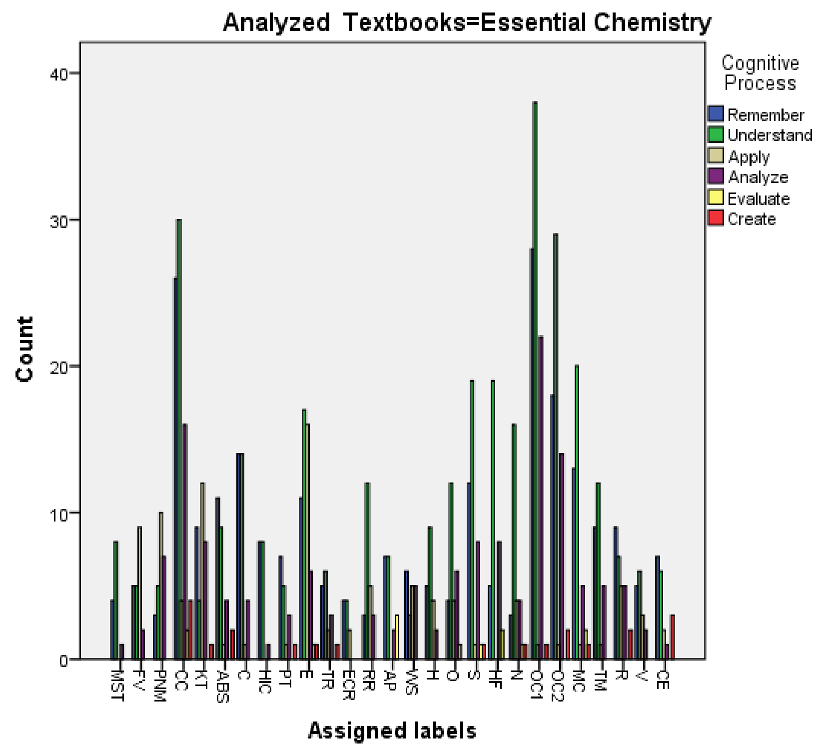
Chapters of Textbooks Analyzed and the Assigned Labels

Comprehensive Chemistry by Jumoke Ezechukwu	**Essential Chemistry by I. A. Adesina**	**New School Chemistry by Osei Yaw Ababio**	**Label**
Introduction To Chemistry	–	Introduction to Chemistry	IC
Nature of Matter and Separating Techniques	Nature Of Matter and Separation Techniques	Nature Of Matter and Separation Techniques	MST
Formulae and Valency	Symbols, Formulae and Equations	Atoms, Moles, Formulae and Equations	FV
Particulate Nature Of Matter	Particulate Nature of Matter	–	PNM
Chemical Laws And Chemical Combination	Orbitals, Electronic Structure of Atom and Chemical Combination	Atomic Structure and Chemical Combination	CC
Kinetic Theory and State Of Matter	Kinetic Theory of Matter and Gas Laws	Kinetic Theory of Matter and Gas Laws	KT
Acids, Bases and Salts	Acids, Bases and Salts	Acids, Bases and Salts	ABS
Carbon and its Compounds	Carbon and its Compounds	Carbon and its Compounds	C
Hydrocarbons and Industrial Chemistry	Hydrocarbons, Crude Oil and Industrial Chemistry	Hydrocarbons, Crude Oil and Industrial Chemistry	HIC
The Periodic Table and Periodicity Of Properties of Elements	Periodic Table	Periodic Table and Families of Elements	PT
Electrical Nature of Chemical Substances	Electrolysis	Electrode Potentials, and Electrolysis	E
Types of Reaction	Oxidation and Reduction	Types of Reaction, Oxidation and Reduction	TR
Energy Changes in Chemical Reactions	Energy and Chemical Reactions	Energy and Chemical Reactions	ECR
Rates of Reaction	Chemical Reaction	Rates of Reaction	RR
Air and Pollution	Air and Air Pollution	Air and Air Pollution	AP
Water and Solution	Water, Solution and Solubility	Water, Solution and Solubility	WS
Hydrogen	Hydrogen and its Compounds	Hydrogen and Hydrides	H
Oxygen and its Compounds	Oxygen and its Compounds	Oxygen and its Compounds	O
Sulphur and its Compounds	Sulphur and its Compounds	Sulphur and its Compounds	S
Halogens and their Compounds	The Halogens	The Halogen Family	HF
Nitrogen and its Compounds	Nitrogen and its Compounds	Nitrogen and Its Compounds	N
Introduction to Organic Chemistry	Organic Chemistry (I)	Organic Chemistry (I)	OC(I)
Alkanols, Alkanoic, Alkanoates, Carbohydrates and Giant Molecules	Organic Chemistry (II)	Organic Chemistry (II)	OC (II)
Metals and their Compounds	Metals and Their Compounds (I)	Metals and their Compounds (I)	MC
Transition Metals	Metals and Their Compounds(II)	Metals and their Compounds (II)	TM
Radioactivity	Nuclear Chemistry	Radioactivity and Nuclear Chemistry	R
–	Mass, Volume Relationships in Reaction	Volumetric and Qualitative Analysis	V
–	Chemical Equilibrium	Chemical Equilibrium	CE

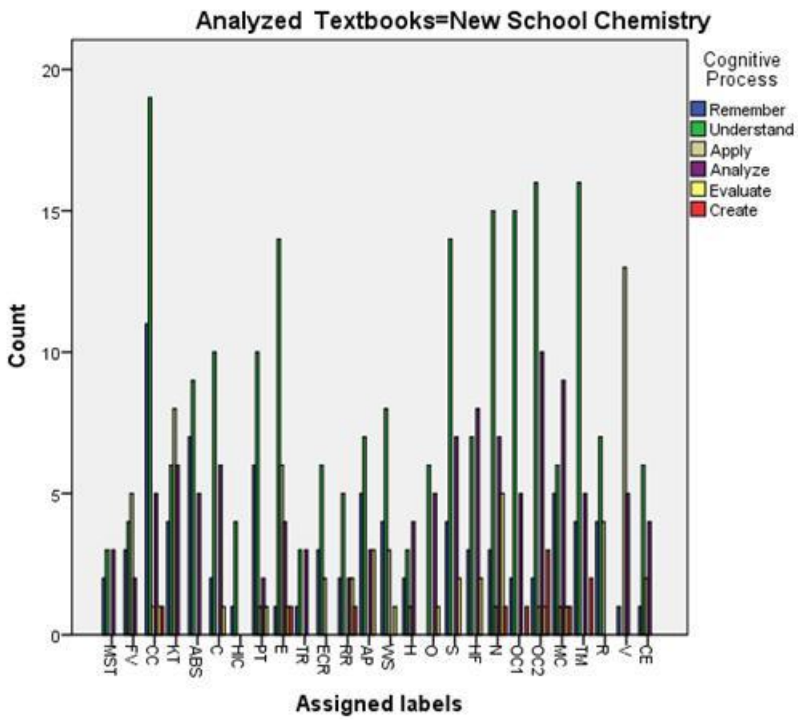
Figure 3 (a-f). Classification of questions in the categories of the cognitive process skills and the knowledge dimensions for each of the analyzed chapters of Comprehensive, Essential and New school chemistry textbooks. The assigned labels correspond to each of the chapters presented in Table 5 of the supplementary materials.



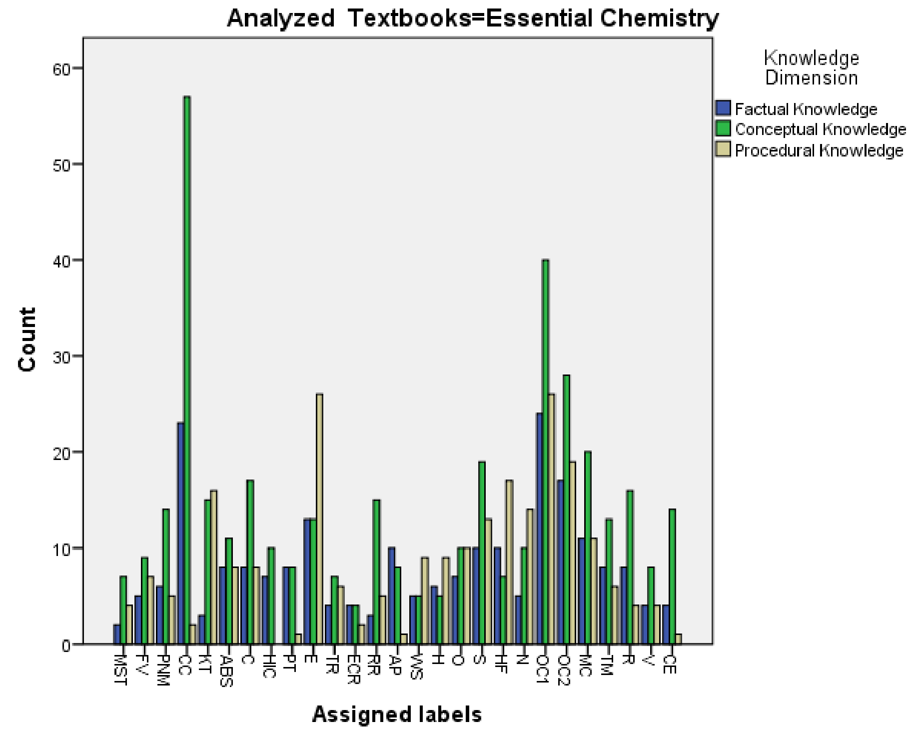
(a) Comprehensive Chemistry Textbook



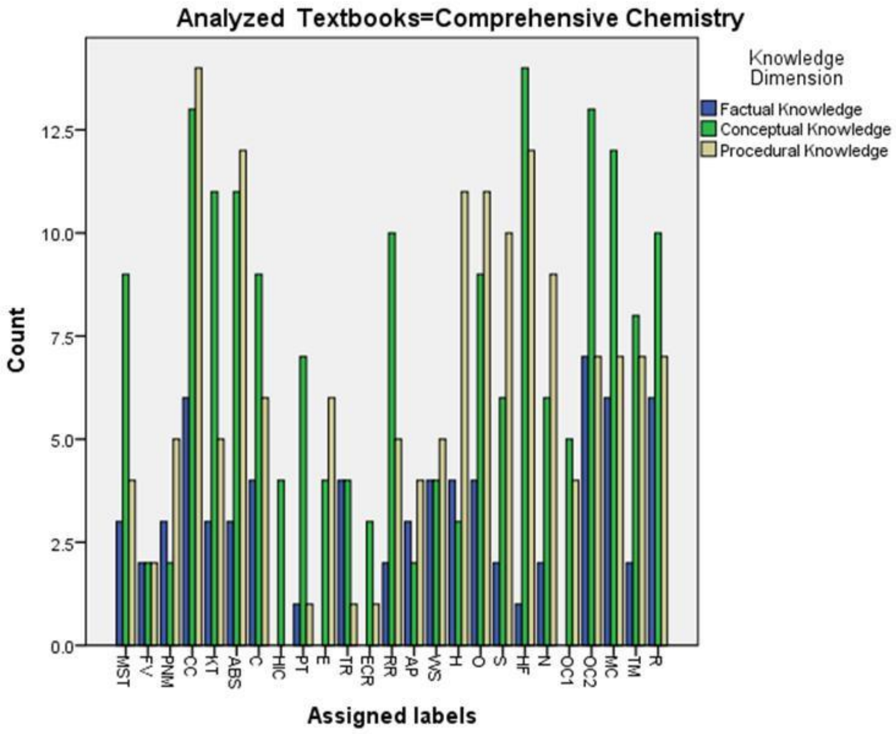
(b) Essential Chemistry Textbook



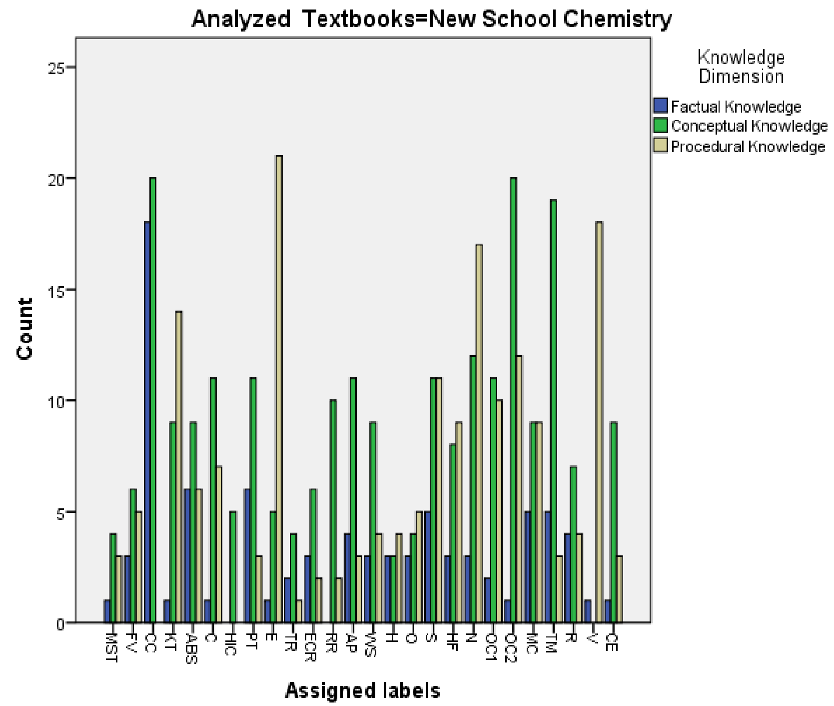
(c) New School Chemistry Textbook



(d) Essential Chemistry Textbook



(e) Comprehensive Chemistry Textbook



(f) New School Chemistry Textbook