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Determining Thinking Levels Required in West African Senior Secondary School Certificate on Core Mathematics Multiple Choice Items

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Abstract

There have been many criticisms with regard to the low performance of students in the examinations conducted by the West African Examination Council (WAEC) especially in core mathematics which is one of the perquisites for the students to gain admission into the University. This situation presupposes that WAEC mathematics test items are seen to be very difficult by students. It is essential to investigate this claim by the students. This study aimed to determine the thinking levels required in West African senior secondary school certificate on core mathematics multiple choice items. The research design adopted for this study was descriptive and survey was the method employed. The data were gathered from the multiple-choice items of 2013 and 2014 Senior Secondary School Certificate Examination (SSSCE) of WAEC. Data analysis was carried out using frequency, percentage, and chi-square test. Findings revealed that the thinking levels required in the test items varied. Analyzing was the thinking level required to a greater degree in both tests relative to the other thinking levels. There was no significant difference in the thinking levels required in both examinations. Overall, the thinking levels required in the tests are categorized in higher-order cognitive learning domain. The findings may serve as input for WAEC in the review of the test items and for secondary schools in enhancing their mathematics instruction.

Keywords: analyzing, cognitive, instruction, learning, performance

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Introduction

The value of mathematics in all fields of learning such as engineering, medicine, architecture, agriculture, and other areas cannot be left out. It becomes imperative that students excel in mathematics so as to help them in their work places. However, students experience difficulty in solving mathematics problems (Rahman & Ahmar, 2016). In West Africa, there is a persistent failure of students in mathematics examination especially the senior school certificate and this has called for greater concern among the stakeholders in education such as parents, teachers, government, curriculum planners, examiners, and students. There have been many criticisms with regard to the low performance of students in the examinations conducted by West African Examination Council (WAEC) especially in core mathematics which is one of the perquisites for the students to gain admission into the University. Students seem to hold the opinion that their failure is due to difficult test items. This situation presupposes that WAEC mathematics test items are seen to be very difficult by students. Aside from examination difficulties, teaching problem and negative attitude of students are also the factors that contribute to low performance in the test (Karigi & Wario, 2015). Therefore, the poor performance of students in mathematics must be looked at.

Assessment of the examinations conducted by WAEC is important not only to find out if the poor test performance of students is the result of the difficulty of the items in the questionnaires but to also determine the thinking levels required in the tests for the students to pass. The assessment result may help teachers develop the appropriate evaluation practices in order to help the students obtain better results in examinations. Imbalance assessment of students' achievement could arise when test items are not spread to cover different levels of learning objectives. Cognitive (knowledge-based), affective (value, attitude and feeling based) and psychomotor (skill-based) are the three categories of the taxonomy of educational objectives.

In 1956, Benjamin Bloom published a framework for categorizing educational goals known as Bloom's Taxonomy (Armstrong, 2016). It can be used as a guide in writing learning objectives that describe the skills and abilities that the learners need to master and demonstrate (Adams, 2015). The volumes present six categories of educational objectives as Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. During the 1990s, Anderson and Krathwohl updated the taxonomy reflecting relevance to 21st century work (Anderson et al., 2001). The taxonomies of the cognitive domain in the Revised Bloom's Taxonomy were changed to Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating (Darwazeh & Branch, 2015). The primary differences are not in the listings or rewordings from nouns to verbs, or in the renaming of some of the components, or even in the re-positioning of the last two categories. The major differences lie in the more useful and comprehensive additions of how the taxonomy intersects and acts upon different types and levels of knowledge - factual, conceptual, procedural, and metacognitive (Wilson, 2016). The revised taxonomy of cognitive objective is useful in planning curriculum that incorporates low to high level of thinking activities (Limbach &Waugh, 2010).

It is the goal of this study to analyze the nature of WAEC core mathematics multiple choice test items using Bloom's Taxonomy. This study aimed to determine the thinking levels required in the multiple-choice items of 2013 and 2014 Senior Secondary School Certificate Examination (SSSCE) on mathematics of WAEC and to analyze for any difference in these thinking levels. The finding may serve as input for WAEC in the review of the test items in its examination questionnaire. This study also provides secondary schools insights in formulating learning designs that will enhance the critical thinking of students.

Materials and Methods

The research design adopted for this study was descriptive and survey was the method employed. The data were gathered from the multiple-choice items of 2013 and 2014 SSSCE on mathematics of WAEC. Each multiple-choice item of the 2013 and 2014 SSSCE was categorized based on the taxonomies of the cognitive domain using the revised Bloom's Taxonomy to determine the thinking levels required in each set of examinations. Frequency and percentage were the descriptive

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statistics used. Chi-square was then used to analyze for any difference in the thinking levels required in both tests.

Results and Discussion

Table 1 presents the frequency and percentage of the thinking levels required for the multiple-choice items of 2013 SSSCE on mathematics. As shown, the thinking levels required in the test items varied. Analyzing was the thinking level required to a greater degree in the test relative to the other thinking levels, followed by remembering and evaluating with same degree in percentage, and then understanding and applying with the same degree as well. Creating appears to be the less required thinking level.

Table 1. Frequency and percentage of thinking levels required in the 2013 SSSCE multiple choice items on mathematics of WAEC.

Thinking Level	Frequency	Percentage
Remembering	9	18.0
Understanding	8	16.0
Applying	8	16.0
Analyzing	13	26.0
Evaluating	9	18.0
Creating	3	6.0
Total	50	100.0

With analyzing, students are able to draw connections among ideas or able to break concepts into parts, determine how the parts interrelate, or how the parts relate to an overall structure or purpose (Wilson, 2016; Armstrong, 2016). Analyzing is a category of higher-order cognitive learning domain (Kurtulus & Ada, 2017). Mental actions included in analyzing are differentiating, organizing, attributing, distinguishing, relating, and testing. When one is analyzing, he/she can illustrate this mental function by creating spreadsheets, surveys, charts, diagrams, or graphic representations.

Remembering is recognizing or recalling facts or basic concepts (Armstrong, 2016). It is a category of lower-order cognitive learning domain. Evaluating is making judgments based on criteria and standards through checking and critiquing (Wilson, 2016). Critiques, recommendations, and reports are some of the products that can be created to demonstrate the processes of evaluation. It is also one of categories of higher-order cognitive learning domain (Kurtulus & Ada, 2017).

Understanding is constructing meaning from different types of functions be they written or graphic, or activities like interpreting, exemplifying, classifying, summarizing, inferring, comparing, or explaining. This thinking level of the cognitive domain is described as a lower-order skill like Remembering and Applying (Kurtulus & Ada, 2017). Applying is using information in new situations (Armstrong, 2016). Mental actions included in Applying are executing, implementing, solving, using, demonstrating, interpreting, operating, and sketching. Creating on the other hand is a category of higher-order cognitive learning domain (Kurtulus & Ada, 2017). It is putting elements together to form a coherent or functional whole (Wilson, 2016). It is reorganizing elements into a new pattern or structure through generating, planning, or producing. This process is the most difficult mental function in the new taxonomy.

Instructional design developed to involve students in the non-routine problem solving activities, facilitates students to develop the ability to analyze and evaluate (critical thinking) and encourages students to construct their own knowledge to improve higher-order thinking skills in learning mathematics (Apino & Retnawati, 2017). The use of mathematical learning module has also enhanced identification of information, analysis, and evaluating evidence or mathematical arguments (Firdaus et al., 2015).

Using dynamic learning environments may also improve the thinking levels of students particularly in analyzing and evaluating as shown in the study Karadag (2009) with secondary students. Problem-based learning approach has significant impact on the ability of students' mathematics thinking levels (Widyatiningtyas et al., 2015). Visual representation systems in classroom may encourage students to interact with mathematical concepts and advance their mathematical analysis. Visualization has many different and rich roles in the learning and the doing of mathematics (Arcavi, 2003). Students' problem-solving

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skill in mathematics is also shown to improve through writing (Vitoria & Monawati, 2016).

The order of thinking required in the 2013 SSSCE multiple choice items on mathematics is presented in Table 2. It has been shown that 50% of the test items require students to think at lower order while the other half of the items require students to think at higher order. Hence, students should have been able to demonstrate both lower and higher level of thinking skills in order to pass the 2013 SSSCE on mathematics of WAEC.

Sonn (2000) observed that today's classroom learning has been focused on activities by which the learners acquire facts, rules, and action sequences, and the majority of lessons required outcomes only at the lower levels of cognition: knowledge, comprehension, and application. Espeland and Shanta (2001) reported that when teacher-centered approaches are preferred, the learners may be deprived of critical thinking opportunities. In a study in Thailand, students have shown medium level of higher order thinking skills when teachers use more knowledge development and application strategies (Shukla & Dungsungnoen, 2016).

Table 2. Order of thinking required in the 2013 SSSCE multiple choice items on mathematics of WAEC.

Order of thinking	Frequency	Percentage
Lower Order	25	50
Higher Order	25	50
Total	50	100.0

Table 3 presents the frequency and percentage of thinking levels required in the 2014 SSSCE on mathematics. As shown, the thinking levels required for the test items also varied. Analyzing was also the thinking level required in the test to a greater degree relative to the other thinking levels similar to 2013 examination. However, creating was the thinking level that was required for the test next to analyzing. This thinking level was less required in the 2013 test items. Like analyzing, creating is also a high order level of thinking and is regarded as the highest level in a hierarchy of cognitive process (Hassan et al., 2016).

Table 3. Frequency and percentage of thinking levels required in the 2014 SSSCE multiple choice items on mathematics of WAEC.

Thinking Level	Frequency	Percentage
Remembering	7	14.0
Understanding	6	12.0
Applying	3	6.0
Analyzing	20	40.0
Evaluating	4	8.0
Creating	10	20.0
Total	50	100.0

In the study of Siswono (2011) in secondary school students, creative thinking varied into different levels based on fluency, flexibility, and novelty in mathematical problem solving and problem posing. The study of Hassan et al. (2016) showed that the use of thinking map in mathematics could help stimulate higher-order thinking skills among students but teachers play important roles in ensuring the implementation of the program to be a success. In this study, remembering was next to creating, followed by understanding in almost the same degree, then evaluating. Applying appears to be the less required thinking level in the 2014 test.

The order of thinking required in the 2014 SSSCE multiple choice items on mathematics is presented in Table 4. It has been shown that majority of the test items require students to think at higher order. Hence, students should have been able to demonstrate the higher thinking level skills in order to pass the 2014 SSSCE on mathematics of WAEC. Unless students can be brought to the higher levels of thinking, it is unlikely that transfer of knowledge will take place.

Table 4. Order of thinking required for the 2014 SSSCE multiple choice items on mathematics of WAEC.

Order of thinking	Frequency	Percentage
Lower Order	16	32
Higher Order	34	68
Total	50	100.0

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All students can learn higher level thinking skills (Kulm, 1990). The successful implementation of the process for the development of higher-level thinking skills in any learning environment requires consideration of current instructional techniques and the commitment to embrace changes and differences so as to flourish in an active, high-impact, learner-centered learning environment (Limbach & Waugh, 2014). Student-centered learning model could improve high order mathematical thinking ability in problem solving, mathematical understanding, and communication as shown in the study of Saragih and Napitupulu (2015) with high school students. Using structured steps of solving mathematical problems also construct high-level thinking resulting to significant improvement of students' problem-solving ability (Surya & Syahputra, 2017). The teachers' professional components such as teaching experience and qualification are also significantly correlated with strategies used for imparting higher order thinking skills (Shukla & Dungsungnoen, 2016).

Result in Table 5 shows chi-square calculated value of 9.986 with 0.76 p-value at 0.05 alpha level. On this basis, there was no significant difference in the thinking levels required in 2013 and 2014 SSSCE multiple choice items on mathematics of the WAEC. The result implies that although the thinking levels required in each set of examinations vary in frequency, this difference is not significant. Hence, the low performance of students in the examination has become a pattern for years that has brought the attention of stakeholders. Overall, these thinking levels are categorized in higher-order cognitive learning domain. Pedagogical process that can be utilized to develop in students higher order thinking skills could help improve the examination performance of students on mathematics (Mainali, 2012). However, the WAEC should also consider reviewing the examination items to ensure that they are spread to cover different levels of learning objectives.

Table 5. Chi- square analysis of thinking levels.

Thinking levels	2013		2014	
	Count	Expected	Count	Expected
Remembering	9	8.0	7	8.0
Understanding	8	7.0	6	7.0
Applying	8	5.5	3	5.5
Analyzing	13	16.5	20	16.5
Evaluating	9	6.5	4	6.5
Creating	3	6.5	10	6.5
Total	50	50	50	50
df	5			
X^2 value	9.986			
p- value	0.76			

Conclusion and Recommendations

The thinking levels required in the multiple-choice items of 2013 and 2014 Senior Secondary School Certificate Examination on mathematics of the West African Examination Council were categorized in higher-order cognitive learning domain. The test items seemed to have been constructed for brilliant students to pass the examinations without taking account of the average and the slow-learners because the bulk of the questions fall within the higher order level of thinking. The West African Examination Council has to review the test to ensure even distribution of items across the cognitive domain of the revised Bloom's Taxonomy in order to improve the examination performance of students. Meanwhile, critical thinking skills should be included into school curriculum at all levels and teachers should be trained to be highly skilled in item writing and how to include critical thinking skills in their daily lessons plan. Teachers should make use of classroom assessment techniques to enhance and facilitate critical thinking skills among their students.

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