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Assessment of Psychometric Properties of Candidates' Responses in Mathematics Paper II at 2014 - 2016 Junior Secondary School Certificate Examinations in Rivers State, Nigeria.

by

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Abstract

In this study, four research questions were answered; it adopted the evaluation and descriptive survey research design. A sample of 1,068 Junior Secondary School (JSS) 3 students was randomly drawn from 8 Local Government Areas using purposive and proportionate techniques, out of the population of 65,054 JSS 3 students in 677 approved secondary schools in Rivers State. The instruments for this study include a sample of 180 multiple-choice questions from the 3 question papers, drawn from the item bank of JSSCE Mathematics past multiple-choice questions from 2014 to 2016 sessions, JSS curriculum and syllabus. Percentages were used to compare the weights of the curriculum/syllabus with the multiple-choice questions, formulae were used to determine the item characteristics of the test items. The findings were that the JSSCE Mathematics test items lacked content validity, all the tests had good difficulty and discrimination indices except that of 2014; all the tests passed the distracter indices criteria. It was recommended among others, that experts in Measurement and Evaluation should be used to carry out the rigorous process of item analyses. These would bring great improvement in the academic performance in Mathematics in Junior Secondary Schools in Rivers State.

Keywords: Psychometric properties, item analyses, content validity

Assessment of Psychometric Properties of Candidates' Responses in Mathematics Paper II at 2014 - 2016 Junior Secondary School Certificate Examinations in Rivers State, Nigeria

Education brings about the development of intellectual, physical and emotional qualities of children for them to grow into becoming useful and intelligent citizens. Kpolovie, Iderima and Olulube (2014) defined education as a learning process where the skills, knowledge, values, habits and beliefs of a people are transmitted from one generation to the next through discussions, story-telling, training, teaching and/or research. Report from Wikipedia free Encyclopaedia (2015) has it that education is formally divided into stages: primary, secondary and tertiary schools.

This study is concentrated on the Junior Secondary School level of education, which is between the primary and senior secondary school levels. The Universal Basic Education (UBE), comprising the primary and the junior secondary stages of education was introduced in Nigeria in 1988 (FRN, 2004). Thus, the Federal Government through the Nigerian Educational Research and Development Council (NERDC) established the 9-year Basic Education Curriculum (BEC) by arranging all existing primary and junior secondary curricula to achieve the key objectives of the UBE programme. The execution of the 9-year Basic Education Curriculum was established for the realization of Education for All (EFA) goals; acquiring appropriate levels of literacy, numeracy, manipulative, communicative and life-skills in addition to principles, moral and civic values essential for laying a solid foundation for a life-time learning as a basis for scientific and philosophical thinking (FRN, 2008).

The Junior Secondary School Certificate Examination (JSSCE) is conducted by the State Ministry of Education for year 3 Junior Secondary School students in both state-owned, private and technical secondary schools in Nigeria, and it is a compulsory requirement for admission into the Senior Secondary School, and also a tool for employment (Igbokwe, 2015).

Mathematics as a core subject

This study is based on JSSCE Mathematics multiple choice questions. Mathematics is the language of Science and the foundation of numeracy on which literacy depends. Numeracy abilities are the pivot of language in different aspects of life; commerce, education, transport, housing, communication, politics and health. Mathematics was accorded high value, in recognition of the nation's quest for technological development. Thus, it was made a compulsory subject in the school system, and is expected that every student performs very well and pass it in examinations especially school-based and external examinations (FRN, 2004). However, students' performance over the years in Mathematics have been on a descending tendency. Students' performance in a test is dependent on the students' ability and the psychometric properties of the test. Hence, to authenticate students' performance in a test, the test must possess some essential psychometric properties. Researches reveal that sometimes, students' failure is due to the fault inherent in psychometric properties of the test and not just their own inabilities. It is therefore, important to investigate into the psychometric properties of Mathematics multiple - choice questions in the Junior Secondary School Examination (JSSCE). The researchers decided to use the Junior Secondary School Examination (JSSCE) from 2014 to 2016 academic sessions in Rivers State.

Functions of Test

A test is used to assess students' performance in any subject. Onukwo (2002) viewed it as a tool meant for detecting some qualities, traits, characteristics, attributes, a person, an item or a thing possesses. It could be given on paper, orally, on a computer or a restricted area that entails the person taking the test to perform skills physically. The following are the functions of tests:

1. Identifying what has been learned,

2. Identifying students' weaknesses and strengths,

3. Entry into a school programme,

4. Motivation,

5. Placement/Certification

In formal testing, marks or scores are often given; this may be inferred to a criterion or norm. Onukwo further explained that the norm-referenced test permits comparison of students' performance, it determines how each student performs in comparison with the performance of other members of that class. The criterion-referenced test is also known as mastery, competency test which only determines if the students can reach a certain performance level, but does not compare students' achievement. A standardized test is a form of test given and scored in a consistent routine. It is a large-scale test administered to large populations of students, developed by experts, has uniform and standard procedure for administration and scoring, covering a large content area. It obliges all test-takers to answer a selection of questions (free online dictionary, 2015). Thus, the JSSCE is meant to be a standardized test.

Test items are the most important or basic blocks for building any good assessment instrument. It is essential that the characteristics of the test items be examined before the test administration. Item analysis is the re-examination of the response of items of a test applying statistical techniques (Hopkins and Antes in Orluwene, 2012). That means that item analysis is statistical procedures that are utilized to determine the quality of the test at the item level.

Psychometric properties

Psychometric properties of an examination as defined by Orluwene and Igwe (2016), is the reliability, validity and item characteristics of the examination. Reliability is the stability or consistency of measures. It is a vital quality that scores on a test must possess for it to be accepted as a good one. The scores are expected to be similar under repeated testing, alternate forms of the same test, two halves of a single test and individual item measurement of the test (Opara, 2016). Reliability ranges from -1 to +1. Kpolovie (2010) opines that for the validity to be significant statistically, the magnitude of its co-efficient should be high. The higher the reliability of a test, the higher the worth or validity of the test. Validity is concerned with determining if the examination measures what it is intended to measure (Kpolovie, 2010). Poor construction of items, ambiguous statements, unclear instruments, inappropriate terms, use of irrelevant technical terms, non-

coverage of content, difficulty of the instrument, incorrect arrangement of test items and poor arrangement of answer options can reduce the validity of an instrument. These are face validity; content validity involves measuring the content of the test with the construct; a table of specification is drawn up to measure with the weights of the test. The faults in the Junior Secondary School Certificate Examination (JSSCE) multiple choice questions can be identified by ascertaining whether the tests are reliable and valid. Some important psychometric properties include difficulty, discrimination indices and distracters effectiveness. These are determined through a statistical technique known as Item Analysis.

Item Analysis

Item Analysis is a procedure that examines students' responses to individual test items to evaluate the importance of those items and the test itself. It is particularly valuable in improving items that might be sourced in subsequent tests, eliminating misleading ones in a test administration. This analysis is also concerned with reviewing of test item content and statistics which describes testees' performance on the item (Orluwene, 2012). It is the most operational way to improve reliability. It involves calculating item difficulty and discrimination indices and the effectiveness of distracters. In carrying out item analysis, scores of items are arranged, starting from the highest to the least scores. A criterion of 25% to 33% are taken from the top and the bottom, while the middle papers are discarded. Item Analysis offers a brief of the test, and could thereby, detect items which are not functioning well, and those which may be reviewed or expunged.

Item Difficulty: This shows the fraction of students in both the upper and lower ability group that got an item right (Ugodulunwa, 2008). It states the proportion (p-value) or percentage of students who correctly responded to the item. It ranges from 0.0 (none of the students responded correctly to the item) to 1.0 (all responded to the item correctly). The criteria by Sidhu (2005) recommended a difficulty level which range from 0.4 to 0.9. An item that has a low difficulty value of less than 0.4 might have been wrongly keyed, too difficult in comparison to the general level of

ability of the class, vague or not written clearly. An item with difficult index of 1.0 is too easy. Thus, the larger the index, the easier the item while the smaller the index, the more difficult the item. To get the difficulty index of an item, calculate by adding the correct number in the top group and that of the bottom group, then divide the sum by the total number of students in both groups. **Item Discrimination:** This describes how well an item discriminates between the upper and lower ability group of testees (Ugodulunwa, 2008). The item-total correlation gives the p-value of the discrimination or differentiating power of the item. It ranges between -1 and +1. It will be positive if more students from the higher achievers responded to the item correctly more often than the low achievers did, and negative if the opposite occurred. The discrimination is better when the value is closer to +1. The categorization by Ebel and Frisbie as cited in Orluwene (2012) for item discrimination is that an item with a discriminative value of .4 and above is considered effective, while values between .00 and .39 are ineffective. It is calculated by subtracting the number in the bottom group from the number in the top group, then divide by half the number of students involved (Iweka, 2014).

Effectiveness of Distracters: The distracters must be distinctly incorrect (not the best option), just as the correct option (key) must be correct. Distracter index shows how the incorrect options distract the lower ability group from selecting the correct option (key). A good test is a test with a good distracter. It is done by comparing all the students in the upper and lower groups who selected each incorrect alternative. A good distracter should attract more students from the lower ability group than the upper ability group (Iweka, 2014). The distracter indices range from -1 to +1. A zero index indicates that both groups were equally distracted (Orluwene, 2012). It is determined by subtracting the upper group from the lower group, then divide by half the number of students involved.

Table of Specifications

Table of Specifications (TOS), also called Test Blueprint is a table that enables teachers align objectives, instructions and assessments (Notar, Zuelke, Wilson and Yunker, (2004)). By

providing a test blueprint before the items writing stage, the test designer can guarantee that the instrument contains an accurate balance of coverage of the topics and taps a desired array of cognitive skills. Akem and Agbe (2003) agreed that the table of specifications is an outline relating behaviour to topics. It ensures that no content area will be omitted, and the objectives will receive proportional emphasis on the test in line with the emphasis on that objective by the teacher. In designing the table of specifications, the cognitive domain of educational objectives is drawn, emphasizing on the six levels of thinking identified by Bloom. They include knowledge, comprehension, application, analysis, synthesis and evaluation.

A table of specification is arranged in a two-way matrix, with the content area itemised in the table rows and the cognitive process in the table columns. The overall number of items indicated for each column specifies the relative weight of each content area. Wolming and Wilkstrom (2010) opined that evidence centered on test content is the levels to which a test measures what it is supposed to measure. The test items to be included on any test is determined by the objectives in the unit, the time earmarked for the test and the necessity of the assessment. Validity and reliability of an achievement test depend largely on its blueprint, and it gives a balance to the test and frees it from testing the wrong thing or giving unfair advantage to one group at the expense of the other (Kpolovie, 2010).

Classical Test Theory

This theory was an emanation of the 20th century approach to individual differences in measurement (Schumacker, 2009; Embreston and Reise, 2000). This study is anchored on the Classical Test Theory (CTT), which assumes that the students' observed score is a combination of true and error scores. It shows that there is no perfection in the observed score, which is mainly due to influence in random errors in the measuring instrument (Iweka, 2014). The observed score is the real score an examinee gets on the test, the true score is the score that shows the exact number of the trait an examinee possesses and demonstrates at every given time, the error score has to do with the

inconsistency, variance between the true score and the observed score (Kpolovie, 2010). The model of CTT is $X = T + E$

Classical Test Theory is useful for the comparison of students' performance among the group and the assessment of item characteristics (Iweka, 2014). It focuses on the examination of item difficulty, discrimination and distracters. Thus, this theory is appropriate to this study on the psychometric properties of the tests.

Research Questions

The following research questions guided the study:

1. What is the content validity of the Multiple-Choice Test items of Mathematics in JSSCE from 2014 to 2016?

2. What are the difficulty indices of the Multiple-Choice Test items of Mathematics in JSSCE from 2014 to 2016?

3. What are the discrimination indices of the Multiple-Choice Test items of Mathematics in JSSCE from 2014 to 2016?

4. How effective are the distractive indices of the Multiple-Choice Test items of Mathematics in JSSCE from 2014 to 2016?

Method

This study adopted the evaluation and descriptive survey research. It deals with systematic setting of worthwhile goals for passing value judgment based on the set goals, to ascertain whether the objectives should be modified or improved on. The population of the study is all the 65,054 JSS 3 students of 2016/2017 academic session in Junior Secondary Schools in the 280 public and 397 approved private secondary schools in the 23 Local Government Areas in Rivers state. A sample of 1,068 Junior Secondary Schools students were randomly drawn from 16 selected Junior Secondary Schools in 8 selected Local Government Areas of Rivers state using a multi-stage sampling method. At the first stage, purposive sampling technique was employed to select only 18 of 23 Local Government Areas that have both public and approved privately-owned secondary

schools. At the second stage, proportionate stratified random sampling techniques by geographical terrain (riverine and upland) was employed to select 6 Local Government Areas from upland and 2 Local Government Areas from riverine areas. At the third stage, a non-proportionate stratified random sampling technique was used to select two secondary schools from each of the 8 Local Government Areas selected (I public school and 1 privately-owned school). This gave rise to a total of 16 secondary schools used for the study. Finally, an intact class method was used to obtain a sample of 1,068 JSS 3 students.

For the purpose of this study, past Mathematics JSSCE questions from 2014 to 2016 were used, each having 60 multiple-choice items. The Junior Secondary School curriculum and scheme of work were also used to generate data for the study. The instruments are valid instruments verified by experts and used overtime in JSS 3. The Instrument (Mathematics Multiple-Choice items in 2014, 2015 and 2016 JSSCE) was administered by the researcher and trained research assistants under the supervision of the researcher in 2016/2017 academic session to an equivalent group to those that wrote the past examinations. It was administered to the students at the beginning of the third term; it therefore, served as a "mock exam" in preparation for their JSSCE which they wrote immediately after. Each student answered the Mathematics Multiple Choice questions for 2014, 2015 and 2016. Out of the sample of 1,068 JSS 3 students, only 1,035 students participated in all the tests, representing 97% of the sample. The data collected were analysed using percentages as the statistical techniques to calculate difficulty, discrimination and distracters indices. However, for the purpose of item analysis where only high and low ability groups are used, a sample of 558 students was used in each examination.

Results

Research Question One: What is the content validity of the Multiple-Choice Test items of Mathematics in JSSCE between 2014 and 2016?

Table 1

Weights Assigned to Weeks Used to Teach Each Topic in Jss Scheme of Work and Topics in the Multiple-Choice Test Items of Jssce Mathematics from 2014 To 2016.

S/NO. TOPICS	Weights Based on Number of Weeks Used to Teach Each Topic	Weights Based on Number of Questions from Each Topic			Expected Weights Based on Number of Questions from Each Topic
	Scheme of Work	2014 Maths	2015 Maths	2016 Maths	
1 Whole numbers: Prime factors, L.C.M., H.C.F, Perfect squares and square root, Binary and Standard form	14 (16%)	3 (5%)	12 (20%)	9 (15%)	10 (16%)
2 Fractions, Addition and subtraction, Multiplication and division, Simple Equations, Ratios, Percentages and Decimal numbers	12 (13%)	12 (20%)	21 (35%)	19 (32%)	8 (13%)
3 Transactions in the home and offices: Interest, Discount and Commission	3 (3%)	1 (2%)	3 (5%)	-	2 (3%)
4 Approximation/ Estimation	4 (5%)	3 (5%)	4 (7%)	3 (5%)	3 (5%)
5 Factorization, Algebraic expressions	7 (8%)	17 (28%)	11 (18%)	7 (12%)	5 (8%)
6 Plane figures, Shapes, Use of symbols, Trigonometry and Area; Angles: Lines, construction	23 (27%)	12 (20%)	2 (3%)	18 (30%)	16 (27%)
7 Need for statistics: Probability, Data collection and presentation	12 (14%)	9 (15%)	5 (8%)	1 (2%)	8 (14%)
8 Linear equations and graphs	9 (10%)	1 (2%)	1 (2%)	2 (3%)	6 (10%)
9 Use of Mathematics in ICT	2 (2%)	-	-	-	1 (2%)
10 Direct and inverse proportion	2 (2%)	2 (3%)	1 (2%)	1 (2%)	1 (2%)
TOTAL	80 Weeks	60 Items	60 Items	60 Items	60 Items

(Researcher's Design: 2024)

Table 1 indicated that the JSS Mathematics scheme of work of covered 10 topics. The weights assigned to each of the topics were based on the number of weeks spent in teaching the topics (80 weeks). It also shows that the 60 multiple-choice questions of the JSSCE Mathematics from 2014 to 2016 covered 10 topics. Weights assigned to each topic were based on the number of questions arising from each topic. The JSS scheme of work for Mathematics had the greatest weight in (Plane figures, shapes, use of symbols, trigonometry and area; angles: lines construction) – 23 (27%), which was not consistently covered in the multiple-choice questions across the 3 years under study. The table also revealed that (Use of Mathematics in ICT) was not covered in any of the multiple-choice items. Therefore, the JSSCE Mathematics lacked content validity.

Research Question Two: What are the difficulty indices of the Multiple-Choice Test items of Mathematics in JSSCE between 2014 and 2016?

Table 2

Difficulty indices of multiple test items of JSSCE Mathematics.(Criteria set by Sidhu (2005): Good items = 0.4 – 0.9).

	2014	2015	2016
Good Items	12 (20%)	49 (82%)	36 (60%)
Difficult Items	48 (80%)	11 (18%)	24 (40%)

(Researcher's Design: 2024)

Table 2a indicated that 2014 JSSCE Mathematics multiple-choice had 48 (80%) difficult items, 12 (20%) good/adequate items. In 2015 JSSCE Mathematics, the test had 11 (18%) difficult items, 49 good/adequate items. For 2016 JSSCE Mathematics, test items were 24 (40%) difficult, and 36 (60%) good/adequate.

Table 2b

Multiple-Choice Test items of JSSCE Mathematics Arranged in Order of Difficulty

	EASIEST ITEMS	MOST DIFFICULT ITEMS
2014 Mathematics	18, 24	26, 4
2015 Mathematics	1, 2	26, 44
2016 Mathematics	2, 4	24, 55

(Researcher's Design: 2024)

Having done item analysis on difficulty index, the multiple-choice items were arranged in order of difficulty. Table 2b indicated that 2014 JSSCE Mathematics had items 18 and 24 as the easiest items, while items 26 and 4 were the most difficult items. The easiest items in 2015 JSSCE Mathematics were items 1 and 2, while the most difficult ones were items 26 ad 44. In the 2016 JSSCE Mathematics, the easiest items were items 2 and 4, while the most difficult items were items 24 and 55.

Research Question Three: What are the discrimination indices of the multiple-choice test items of Mathematics in JSSCE between 2014 and 2016?

Table 3

Discrimination indices of the Multiple-Choice Test items of JSSCE Mathematics. (Criteria set by Ebel and Frisbie (1986): Good items = 0.30 and above).

	2014	2015	2016
Good Items (0.3 & Above)	26 (43%)	46 (77%)	46 (77%)
Marginal Items (0.20 – 0.29)	22 (37%)	13 (21%)	9 (15%)
Poor Items (0.00 - 0.19)	11 (18%)	1 (2%)	5 (8%)
Bad Item (Negative Values)	1 (2%)	-	-

(Researcher's Design: 2024)

In Table 3, 2014 JSSCE Mathematics multiple-choice questions had 1 (2%) bad item, 11 (18%) were poor items, 22 (37%) were marginal items, the remaining 26 passed the discrimination indices criteria and represented 43% of the total number of questions constituting the test. In 2015, the test items had 1 (2%) poor items, 13 (21%) marginal items and 46 (77%) passed the discrimination indices criteria. Then in 2016, the multiple-choice test items had 5 (8%) poor items, 9 (15%) marginal items and 46 (77%) passed the discrimination indices criteria.

Research Question Four: How effective are the distracter indices of the Multiple-Choice Test items of Mathematics in JSSCE from 2014 to 2016?

Table 4

Distracter indices of Multiple-Choice Test Items of JSSCE Mathematics.

	2014	2015	2016
Effective Items	60 (100%)	57 (95%)	59 (98%)
Ineffective Items	-	3 (5%)	1 (2%)

(Researcher's Design: 2024)

Table 4 revealed that for 2014 JSSCE Mathematics multiple-choice questions, all the 60 items passed the distracter criteria, representing 100% of the test items. This means that each of those options were selected by more than 5% of the students who did not select the key, so all the options are effective distracters. In 2015 JSSCE Mathematics Multiple-Choice Test, options, A, B, D in item 1, options B, C, D in item 2 and options A, B, C in item 43 did not distract effectively. The remaining options in the 57 (95%) items passed the distracter indices criteria. In 2016 JSSCE Mathematics MultipleChoice questions, options A, C, D in item 2 did not distract effectively. The remaining options in the 59 were effective distracters, representing 98% of the 60 items.

Discussion

The findings of this research study are discussed as follows:

❖ Comparing the JSS Scheme of work with the Junior Secondary School Certificate Examination (JSSCE) Mathematics from 2014 to 2016, the tests lacked content validity. The Mathematics course contents were not adequately covered in the Junior Secondary Certificate Examination (JSSCE).

❖ The 2014 JSSCE Mathematics had more difficult items when compared to the other 2 tests since the proportion of those that got the items right was low; it also had more items that did not discriminate between the upper ability group and the lower ability group.

❖ The occurrence of the difficult items may be owing to some faults in their psychometric properties, which indicates that there are some errors in the items. For example, illegible items, it could also be that adequate instructions were not given when these topics were taught, which contributed to the difficulty, leading to unfamiliarity of the contents. It could also be as a result of the test being above the students' level, etc.

❖ All the tests had few distracters. Therefore, the test options were able to effectively distract the lower ability group from selecting the correct option (key). Any distracter that is selected by less than 5% of the students is an ineffective distracter. For all the options of the 2014 JSSCE Mathematics multiple-choice test to distract effectively, it may be due to the fact that majority of the items were difficult.

❖ It was also observed that the 2014 JSSCE Mathematics was 5-optioned, while those of 2015 and 2016 were 4-optioned.

❖ The JSSCE Mathematics objective test items from 2014 to 2016 are not valid and reliable instruments

Conclusion

Based on the findings of this study, it was concluded that:

The objective test items for 2014, 2015 and 2016 JSSCE Mathematics Multiple-Choice items lacked content validity. These 3 tests vary in the characteristics of their constituent items. Of all the tests, 2014 Mathematics objective tests had more difficult items and have more items that do not discriminate between the upper ability and lower ability groups. The 2015 JSSCE Mathematics Multiple-Choice items had the best difficulty and discrimination indices, indicating that it was the best among the 3 tests.

Recommendations

The following recommendations were made on the assessment of the psychometric properties of Mathematics Test Scripts in Junior Secondary School Certificate Examination: 2014 -2016 academic sessions in Rivers state, Nigeria:

1. Experts in Measurement and Evaluation should be used to carry out the rigorous process of item analyses, instead of hand-picking items from past questions.

2. Wordings and clarity of the test items should be revisited by psychometricians. For example, the correct options should be given in the objective test items 43, 44, 45, 46, 49, 50 and 51 in 2015 JSSCE Mathematics.

3. Test options should be arranged in order of difficulty so as not to confuse the testees and markers.

4. Test items that failed to meet the difficulty, discrimination criteria should be eliminated.

5. Test Blue Print should be strictly followed to ensure topics in the scheme of work/curriculum are proportional to test items in JSSCE.

6. Course contents should be covered especially in Mathematics; teaching methods and

instructional materials should be made available to students, especially in the JSS 3 level.

7.   Government should reduce the occurrence of industrial strike since it negated the adequate coverage of the scheme of work.

If the above recommendations were considered, the psychometric properties of the Junior Secondary School Certificate Examination (JSSCE) scripts, especially that of Mathematics would bring great improvement in the academic performance in Mathematics in Junior Secondary Schools in Rivers State.

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