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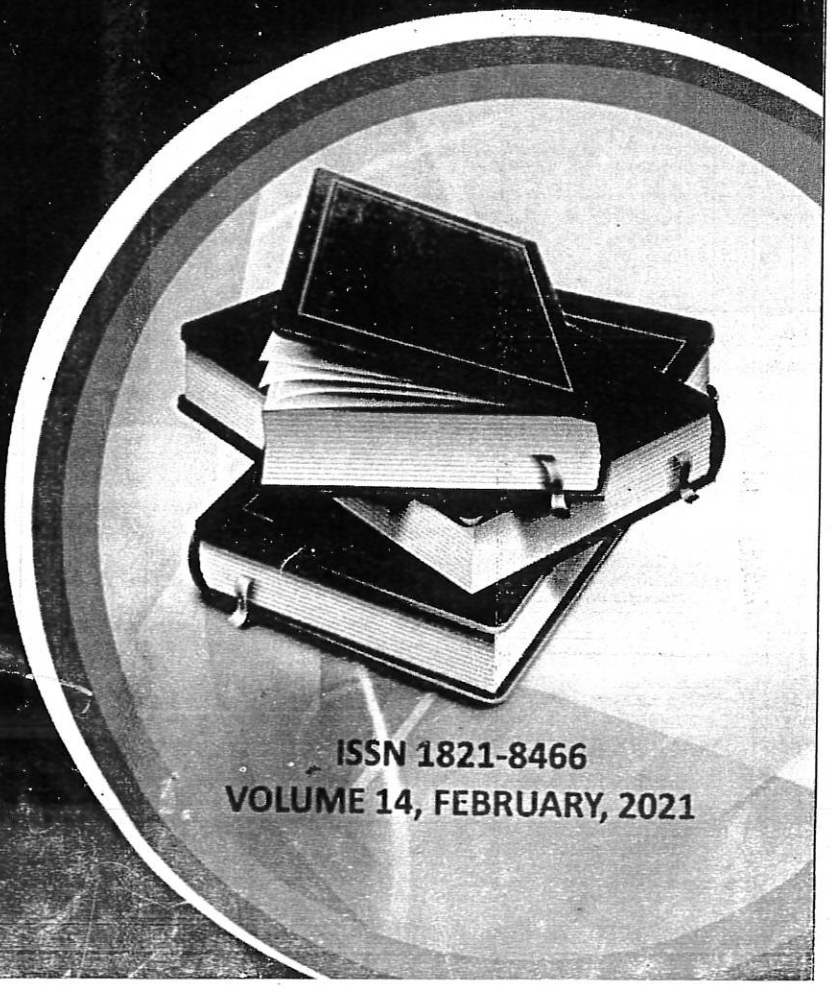

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CONTENTS

EVALUATION OF ITEM RESPONSE THEORY IN THE DEVELOPMENT AND VALIDATION OF MULTIPLE CHOICE TESTS IN MATHEMATICS AMONG ADOLESCENTS IN LAGOS METROPOLIS

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Abstract

The concern with measures of psychological traits is old and many studies and proposals of methods were developed to achieve this goal. Among these proposed methods is the Item Response Theory (IRT) which in principle completes the limitations of the Classical Test Theory. The study applied item response theory in the development and instrumentation research design. A sample of 300 Mathematics junior secondary school II students was randomly selected from a population of 23,768 Mathematics students in Lagos Education District 11. To guide this study, two hypotheses were formulated at 0.05 level of significance.. The Mathematics Multiple choice test items numbering fifty items were developed by the researcher and used for data collection. The reliability index of 0.89 was obtained when tested during the pilot study. The data generated from the study were analyzed using maximum likelihood estimation technique of BILOG-MG computer programming (a software program for the development, analysis, scoring and maintenance of educational and other measurements within the statistical framework of item response theory. The analysis of the data revealed that 50 test items of Mathematics survived therefore, the final instrument developed for assessing students' ability in Mathematics contained 50 items with the appropriate indices. The result of the study showed that 49 items of the multiple choice question in Mathematics were reliable based on the three parameter model (3pl) model (item difficulty parameter; item discrimination parameter and item guessing). The findings also

showed that thirty-one (31) items of the mathematics multiple-choice test in mathematics were difficult. The findings further revealed that items functions differential in mathematics among male and female students. Based on the findings, recommendations were made which include that the examination bodies and teachers should encourage and adopt IRT (Item Response Theory) in developing test items used in measuring students' ability in Mathematics.

Key words: Evaluation, Item Response Theory, Development, Validation and Multiple Choice Items.

Introduction

Mathematics has been of social and practical influence, its place in man's way of life and development cannot be over-emphasized. There is however more to Mathematics than numbers and calculations. It is this importance of Mathematics in everyday life that justifies its inclusion in the curricula at all levels of education. Every man requires a certain amount of mathematical knowledge in order to survive in the present highly technological and complex society. In order to be able to compare and estimate values of articles, determine prices of foodstuff, reckon distances and time, weigh evidences and sift substance from chaff. The ordinary citizen needs a certain level of Mathematics. Mathematics abounds everywhere from the mundane issues that are taken for granted to the most of sophisticated breath-taking inventions and discoveries. There is no single and all-embracing answer to what Mathematics is. Mathematics means many and various things to different people. In view of its universality and diversity, it is referred to as the language of science and technology; queen of science; the science of counting, science of numbers, quantity and space, study of abstraction and their relationship; (Adedayo,2016; Abakporo, 2015; Usman 2012).

Mathematics is a basic tool in the development of any science based knowledge such as technology, industry and even for sound analytical reasoning in daily living in a modern society such as ours (Babalola, 2011). Mathematics is one of the most powerful and adaptable tools that has aided man intelligence over the centuries (Usman, 2012). The extra rigour that mathematics gives to our thinking is unparalleled. Mathematics is also a subject that has a major influence on all aspects of human endeavours and it has been

described as the life wire in the studies of various disciplines (Smith, 2012). In a developing country like Nigeria, one cannot over emphasize the need to help students, particularly those in high schools, to understand how they can use mathematical knowledge to investigate, interpret and make decisions in their daily activities. In Nigeria, mathematics is a compulsory subject for all students at the secondary school level. Although, not all the students are expected to become mathematicians, yet, it is compulsory because of its application in everyday life (Oladele, 2014). For a person to be able to function very well within his immediate environment, the professional knowledge of rudimentary Mathematics is very necessary.

The role of mathematics in the commercial, scientific and technological development of the civilized nations is always acknowledged. The general objectives of school Mathematics, irrespective of the level can be summarized as follows:

> *Develop computational skills; develop ability to think deductively; produce the mathematical background needed in other school subjects; develop originality, creativity and curiosity in the students; develop and appreciate the aesthetic values of Mathematics; develop ability to solve mathematical problems and provide solid foundation for further studies in Mathematics (Usman, 2012; Adedayo, 2016).*

Mathematics is a compulsory subject offered in Nigerian secondary school and is taught daily in all the schools or perhaps four times a week. It is a core subject in the junior secondary school that requires assessment to ascertain students' basic knowledge, skills and understanding of the concepts and the nature of mathematical problems in any society.

Mathematics is a form of learning and Learning is simply described as a change in behaviour as a result of experience (Madueweso, 2009). Learning is unpredictable, and so, assessment is necessary to make adaptive adjustments to instruction, but assessment processes themselves impact the learner's willingness, desire, and capacity to learn (Harlen & Deakin-Crick, 2002). Assessment is the systematic collection, review and use of information about educational programs to improve student learning. In the view of Huba and Freed (2000), assessment is the process of gathering and discussing information from multiple and

diverse sources in order to develop a deep understanding of what students know, understand, and can do with their knowledge as a result of their educational experiences. The following are some objectives of achievement tests according to Okolie (2015):

- To measure whether students possess the pre-requisite skills needed to succeed in any unit or whether the students have achieved the objectives of the planned instruction.
- To monitor students' learning and to provide on-going feedback to both students and teachers during the teaching-learning process.
- To identify the students' learning difficulties- whether persistent or recurring.
- To assign grades.

These objectives can be achieved by the use of different assessment instruments such as; essay tests and objective tests which are utilized by the teacher depending on the aims of the measurement. However, all assessment instruments must satisfy the criteria of reliability, validity, objectivity as well as usability (Anene & Ndubisi, 2013). Reliability is conceived in relation to the extent of consistency or dependability of a measuring instrument (Abonyi, 2011). Validity refers to the extent to which an instrument measures what it is designed to measure (Nworgu, 2006). A test with high validity will measure accurately the particular qualities it is supposed to measure. Nevertheless, instrument development in Mathematics requires more than determination of reliability, validity, objectivity and usability of the items. Some other indices such as item difficulty, item discrimination, distractors are required for determination of the quality of the instrument.

Unfortunately, teachers of Mathematics do not take these things into cognizance when administering tests. The reason may be that the questions do not require these qualities or teachers lack the knowledge of setting quality items. This may be one of the reasons, among others, why students perform poorly in the Senior Secondary Certificate Examinations of the West Africa Examination Council (WAEC).

Therefore, to ensure effective teaching and learning of Mathematics in schools, an achievement test that focuses on attainment of individual items will have better utility than one on

students' aggregate scores. An educational measurement scale that has ratio scale (a measurement scale that allows researchers not only to determine the absolute difference between each scale point but also to make comparison between the raw responses), sample independent attributes and students' ability reported on both item and total instrument levels can be developed with the measurement theory called Item Response Theory (IRT) otherwise known as Modern Theory. Item response theory is a modeling technique that tries to describe the relationship between an examinee's test performance and the latent trait underlying the performance (Henard, 2000).

IRT models are extremely helpful in assessment instrument like Mathematics achievement test when trying to understand students' abilities by examining their test performance. To ensure that Mathematics achievement test is fair for all examinees, the instrument should be fair. This implies that differential item functioning would occur in Mathematics achievement test if the Item Response Function (IRF) for an item is different for two groups. In the view of this, Meredith, Joyce and Walter (2017), opine that differential item functioning means individuals of equal ability but from different subgroup (e.g., males and females) do not have the same probability of earning the same score. However, the type of measurement theory that ensures item level performance instead of aggregate level performance in analyzing mathematics achievement test is the Item Response Theory. Therefore, the purpose of this study is to evaluate the development and validation of multiple choice tests in mathematics using Item Response Theory.

Statement of the Problem

Tests and examinations can accurately or inaccurately reflect the current level of students' learning. However, a test can be studied from different angles and the items in the test can be evaluated accordingly to different theories or models that can provide better perspective on the relationship that may exist between the observed score on an examination and the underlying capability in the domain which is generally unobserved. These two theories are popular measurement frameworks for identifying measurement problems such as test-score equating, test development and the identification of biased items (Lawson 2016).

The two main test theories models that has been proposed for creating and evaluating test items are Classical Test Theory (CTT) and Item Response Theory (IRT). Unfortunately, there are some obvious weaknesses of Classical Test Theory .Consequently, the researcher designed this study using a modern measurement theory to ensure objectivity in measurement of the students' scores in analyzing Mathematics multiple choice test items. Therefore, the statement of problem, if put in a question format, is: how to evaluate item response theory in the development and validation of multiple choice tests in mathematics among adolescents in Lagos metropolis?

Purpose of the Study

The main purpose of this study is to evaluate Item Response Theory in the development and validation of the multiple choice tests in Mathematics. Specifically, the study is set to determine the:

1. Fit of the items of the mathematics multiple choice tests using three-parameter logistic (3PL) model;
2. Differential item functioning of the test items of the multiple choice test in Mathematics with respect to gender.

Research Hypotheses

The following null hypotheses (H0) are formulated and tested at .05 level of significance.

1. H01: There is no significant fit between the items of mathematics multiple choice test based on three-parameter model.
2. H02: There is no significant differential item functioning of the test items of the multiple choice test in Mathematics with respect to gender.

Research Design

The design of this study is an instrumentation research design subsumed under descriptive research designed. Instrumentation design according to Ali (2006) is when the major thrust of the study is geared entirely towards the development and standardization of an instrument whose different psychometric properties (validity, reliability, usability etc) have been empirically determined.

Population of Study

The population of study comprises of the entire Junior Secondary School 2 in Lagos Education District II.

Sample and Sampling Techniques

Lagos State has six education district, Education District II was chosen by purposive sampling. The district is made up of three educational zones /local government area. namely Somolu, Kosofe and Ikorodu. Firstly, simple random sampling was used to select one school from each of the educational zones that form the district. Secondly, proportionate stratified random sampling technique was adopted to drawn students approximately from each local government area. The sample assigned for the study consists of 300 respondents from JSSII class among the Junior Secondary Schools in the area of study.

Research Instrument

The instrument for data collection for this study was the Mathematics Multiple Choice Test (MMT) developed by the researcher. The Mathematics Multiple – Choice Test (MMT) was based on the following topics: whole numbers; square root and prime factors; fractions, proportions, ratio, rate, Algebra, factor, factorization, fraction; Arithmetic in the home and office. This is a 50-item multiple choice standardized objective test compiled and prepared by the researcher from the past Mathematics question papers of BECE/NECO for years (2012-2017) The items covered only the topics studied during the experimental period. The MMT was constructed using a test blue print or table of specification. The test blue print was used to establish the content validity of the MMT. The blue print is a test plan aimed at systematic coverage of the course contents and instructional objectives. The research instrument was validated using face, content and experts validity procedure. Their responses were scored and analyzed using Kuder-Richardson (KR-20) formula to determine the internal consistency of reliability of the instrument. Reliability index of 0.89 was obtained.

Item Analysis on the Mathematics Multiple –choice Test (MMT).

According to Ilogu (2005), item analysis is the statistical technique of reviewing every item on the test with a view to refining the whole

test. Item analyses were carried out by the determination of the difficulty and discriminating index of each item.

Item Difficulty Index: According to Ilogu (2005), Item difficulty is the degree of easiness or difficulty of items it is determined by:

Difficulty Index = $P/_N$ x 100%

P = No of students who got the right answer
N = the entire student who sat for the test.
For a test to be good, index of difficulty should range from 40% to 60%

Item Discriminating Index According to Ilogu (2005), Item discriminating power (D) as an estimate of item validity is the extent to which each item distinguishes between those who are low or high on the test. In other words, the discriminating power of a test item refers to the degree to which it discriminates between students with high and low scores. Formula for calculating discriminating index is given as Index of

Discrimination: The formula $\frac{H - L}{N/2}$

H = Students in the high achiever group who got the right answer
L = Students in the low achiever group who got the right answer
N = Number of Students who sat for the test.

Analysis of Item Choice
Ilogu (2005) says that poor test items such as items which are too easy, too difficult or with zero and negative discriminations can be diagnosed through the analysis of the choices per item. This analysis of item choices merely involves the comparison of the responses of the upper and lower groups of students for each choice.

Step- Wise Procedure for Item Analysis.
1. Administer the test, score the items and arrange the students' scores in order of merit (highest to lowest.)
2. Select the item analysis group (N). This is made up of:
   (i) The Upper Group (best 30% or so)
   (ii) The Lower Group (last 30% or so).

3. Beginning with item number one, count how many students in the upper group (U) that got it right. Thereafter, count how many students in the lower group (L) that got the item right.
4. Repeat step 3 for other items.
   1. For each item, compute the item difficulty.
   2. For each item, compute the item discrimination power.
   3. Identify the poor items and analyze their item choices or the effectiveness of the distracters.

Results

Table1: Demographic Information of the Respondents

Local Government	Number of students	%
Ikorodu	180	60
Somolu	44	15
Kosofe	76	25
Total	300	100
Gender	**Number of students**	**%**
Males	153	51
Females	147	49
Age group	**Number of students**	**%**
9 years	5	1.6
10 – 11 years	120	40
12 – 13 years	146	48.6
14 – 15 years	29	9.6

Test of Hypotheses
Research Hypothesis One: There is no significant fit between the items of Mathematics multiple choice test based on three-parameter model.

Table 2; Fits between Mathematics Test Items based on 3pl Model

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Prob	0.00	0.03	0.09	0.18	0.00	0.06	0.00	0.13	0.02	0.06	0.07	0.00	0.00	0.08	0.00	0.01	0.24	0.00	0.10	0.00	0.12	0.00	0.20	0.00
Items	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49
Prob	0.00	0.14	0.05	0.00	0.16	0.03	0.01	0.08	0.00	0.07	0.00	0.00	0.00	0.26	0.00	0.04	0.00	0.00	0.00	0.09	0.00	0.13	0.00	0.02

As revealed in the table 2 above, twenty nine (29) items (58%), that is, items 1, 2, 5, 7, 9, 12, 13, 15, 16, 18, 20, 22, 24, 26, 29, 31, 32, 34,

36, 37, 38, 40, 41, 42, 43, 44, 46, 48 and 49 do not fit the three-parameter model because the items are below .05 level of significant. Twenty one (21) items (42%), that is, items 3, 4, 6, 8, 10, 11, 14, 17, 19, 21, 23, 25, 27, 28, 30, 33, 35, 39, 45, 47 and 50 fit the three-parameter model because the items are above .05 level of significant. Based on this premise, the null hypothesis which states that there is no significant fit between the items of Mathematics multiple choice based on three-parameter model is accepted for 29 items and rejected for 21 items.

Research Hypotheses Two: : There is no significant differential item functioning of the test items of the multiple choice test in Mathematics with respect to gender.

Table 3: Fits Statistical Gender Differential

Items	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Male	30.1	13.2	9.5*	27.5	2.1	80.2	20.7	16.1	107.2*	4.0	15.2	23.8	10.4	9.2	6.9	9.0	9.9	15.7	120.2	68.2	6.3	7.4	3.5	11.9	26.3
Female	30.0	20.3	9.5*	14.7	4.2	134.8	40.5	71.9	107.2*	6.7	200.0	45.0	101.8	61.0	5.9	21.0	60.6	12.4	266.8	113.5	22.2	13.5	16.8	40.8	36.9
Items	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Male	23.7	6.2	3.0	5.0	6.6	40.0	10.7*	6.3	49.4	92.8	89.8	10.4	10.1	44.9	10.4	31.1	31.1	22.8	5.3	99.8	13.3*	4.7	18.1	17.9	141.6
Female	37.6	6.5	3.2	6.4	19.8	105.6	10.7*	22.3	109.2	242.6	90.4	9.4	4.2	78.9	14.5	11.1	68.4	11.2	24.5	82.0	13.3*	2.0	18.0	76.2	228.0

The table 3 above indicates that forty-six (46) items that is items 1, 2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 49 and 50 in the Mathematics test were identified as

significantly exhibiting differential item functioning between male and female students at 0.05 level of significant while four (4) items that are 3, 9, 32 and 46 do not differential function between male and female students. The results also indicate that out of 50 test items of Mathematics multiple choice questions, male and female students perform differently in 46 items and none in 4 items.. Based on this premise, the null hypothesis which states There is no significant differential item functioning of the test items of the multiple choice test in Mathematics with respect to gender was accepted.

Discussions of Findings

Findings from hypothesis one revealed that there is no significant fits between the items of mathematics multiple choice test based on three-parameter model.

The findings of this study as shown in table 3 shows that twenty nine (29) items (58%), that is, items 1, 2, 5, 7, 9, 12, 13, 15, 16, 18, 20, 22, 24, 26, 29, 31, 32, 34, 36, 37, 38, 40, 41, 42, 43, 44, 46, 48, 49 do not fit the three-parameter model while twenty-one (21) items (42%) that is, items, 3, 4, 6, 8, 10, 11, 14, 17, 19, 21, 23. 25, 27, 28, 30, 33, 35, 39, 45, 47 and 50 fit the three-parameter model. The criterion for all the item fit/misfit in research question 2 is determined at 0.05 level of significance. Hence, no significant fit between the items of mathematics multiple choice test based on the 3PL model. Nkpone (2011) asserts that in the latent trait models, a fit to the model implies validity that item discrimination is uniform and substantial, and there is no error in terms of scoring. The findings correspond with Adedoyin (2010) who in his study used chi-square test with probability greater than alpha level of 0.05 significant level to select items that fit model.

Findings from hypothesis two revealed that the test items of multiple choice test in mathematics do not function differentially between male and female JSS11 Mathematics.

The findings of this study reveal that forty-six (46) items have Differential Item Functioning (DIF), that is, 1, 2, 4, 5,6, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 49 and 50, excluding items 3, 9, 32 and 46. Four (4) items (8%), that is, item

14, 21, 27 and 46 are identified as not exhibiting differential functioning among male and female students. The findings are determined at 0.05 level of significance. Hence, test items of multiple choice test in mathematics do function differentially between male and female JSS II mathematics. This finding is of the same view with Davis (2012) that however, sometimes items are found to behave differently in distinct groups such as gender or language (such as loading on different dimensions in a multi-dimensional factor analysis, or having largely different mean item scores). In other words, two examinees with the same latent trait value but differing in other characteristics may have differing probabilities of response. The findings of Madu (2012) is in submission with the findings of this study when it concludes in a study that thirty nine (39) items in the mathematics test are identified as significantly exhibiting differential item functioning between male and female examinees at .05 level of significant while 11 items do not have differential function between male and female examinees.

Conclusions

The researcher observed from the study that:

1. Forty nine (49) items indicate high reliability of the test while one (l) item indicates low reliability.
2. Twenty-one (21) items fit the three-parameter model while twenty-nine (29) items do not fit the three-parameter model.
3. Thirty-three (33) items indicate difficult items while seventeen (17) items indicate easy items.
4. Ten (10) items indicate very low discriminating values; eighteen (18) items indicate low discriminating values; twenty (20) items indicate discrimination moderate values and two (2) items indicate high discriminating values.
5. forty-five (45) items are considered desirable, meaning that the probability of getting an answer correctly by mere guessing is low while five (5) are considered not very good, and the probability of getting an answer correctly by mere guessing is high.
6. The findings further reveal Items Functions Differential in Mathematics among male and female students.

Recommendations

Based on the findings of the study, the following recommendations were made:

1. Psychometricians and measurement expert should organize workshops to educate teachers on the implications of quality tests. They should as well train teachers to the modern measurement frame work called IRT as well as the necessary interpretations involved.
2. Examination bodies and teachers should be encouraged to adopt (IRT) in developing test items used in measuring students' ability in Mathematics.
3. Education ministry and Universities should assist students who are interested +++on Item Response Theory to get software and necessary computer packages.
4. It is imperative to determine how the items in an instrument fit the IRT parameter model, such as one-parameter, two-parameter and three-parameter logistic models.
5. Differential Item Functioning effects of items should be properly determined in the test instrument to avoid gender differences.

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