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Differential Item Functioning In Basic Education Certificate Examination in Mathematics in Akwa Ibom State, Nigeria

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ABSTRACT

This study investigated differential item functioning in Basic Education Certificate Examination. It focused on the students' examination scripts in the 2020/2021 mathematics test concerning their gender. The research design adopted for the study was a descriptive survey. The population was all 62145 Basic Education Certificate Examination (BECE) students in all public secondary schools in Akwa Ibom State who wrote the 2020/2021 Basic Education Certificate Examination. A sample of 870 students' scripts was randomly selected using a multi-stage sampling procedure. An instrument for data was the 2020/2021 mathematics test developed and administered by the Examination Unit of the Akwa Ibom State Ministry of Education. The Split-half statistic determined the reliability of instruments and obtained a coefficient of 0.81. Data were analyzed using a one-parameter item characteristics model. The findings showed that some items functioned differentially for gender. Consequently, the Akwa Ibom State BECE mathematics test for the 2020/2021 academic session, like other examinations, contained function items differentially among different sub-groups. Hence, test developers should conduct a proper field test of all items developed before any item is in the Akwa Ibom State Junior certificate examination or any other education decision-making instrument.

Keywords: *Differential item, basic education certificate, mathematics*

INTRODUCTION

In the western form of education enjoyed in Nigeria, Mathematics is indeed one of the most fascinating subjects humans have created. Githua and Mwangi (2003) stated that life without Mathematics is almost impossible and that it would be difficult to live a normal life in many parts of the world. That is why Mathematics is a compulsory subject for all students at the secondary school level in Nigeria and one of the O'Level Credit requirements for admission into a higher institution. For instance, the social, economic, political, geographical, scientific, and technological aspects centered on numbers. The inter-relationship between Mathematics and the development and advancement of human beings shows the importance of

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Mathematics in life due to its numeral and symbolic nature. It is a subject that is related to other school subjects in areas like number and numeration, variation, graphs, fractions, logarithms and indices, algebraic processes, and solution of equations in area and volume (Maliki, Ngban and Ibu, 2009). It explains why Mathematics is one of the core subjects for every student in secondary school (Federal Republic of Nigeria, 2013). Mathematics test items should not function differentially for any candidate exposed to a test in Mathematics. The gender of examinees should not be a determinant of their performance in an examination. The performance of students in Mathematics is determined through testing. The test could be for promotion, certification, recruitment, and placement. The quality of a measuring instrument lies mainly in the quality of items used in the instrument. There is a need to ensure that items are reliable and fair to all across the subgroup of examinees (male and female). Test fairness is a crucial issue in testing, and it reflects the same constructs for all candidates and scores have the same meaning for all individuals in the intended population.

The first step in constructing assessment instruments is to ensure that no individual or group responding to the instrument is disadvantaged (Kanjee, 2007). For instance, in an achievement test, students of equal ability, usually drawn from the same population but belonging to different subgroups (such as male or female), should have the same probability of getting an item correct. Biased test items can differentially inhibit individuals from showing their true abilities, thereby measuring irrelevant constructs. Such items are said to be displaying differential item functioning (Penfield and Camilli, 2007). Indeed, DIF occurs when examinees from different sub-groups have different likelihoods of success on items after they have matched the ability of interest (Umoinyang, 2011).

The presence of DIF is a result of some characteristics in an item that results in differential performance for individuals of equal ability but from different sub-groups. Items may be judged relatively more or less difficult for a particular sub-group by comparison with the performance of another sub-group drawn from the same population. Differential item functioning of an item can therefore be understood as a lack of conditional independence between item response and group membership (often gender, location, or ethnicity) given the same latent ability or trait (Omorogiuwa and Iro-Aghedo, 2016). Gender is the range of physical, biological, mental, and behavioural characteristics of masculinity and feminity (Wordu and Iwok, 2018). In the study, gender is a matter of grave concern, especially among academics and policy formulators. The importance of examining achievement concerning gender is based primarily on the sociocultural differences between males and females.

The presence of differential item functioning in a test is determined using differential item functioning analysis. Pagano and Gotay (2015) referred to Differential Item Functioning analysis as a procedure used to determine if test questions are fair and appropriate in assessing the knowledge of various groups present among the testees. Based on the assumption that test takers with similar knowledge (based on the total score) should perform in the same ways in the individual test items regardless of their sex, race, or ethnicity (Effiom, 2021). It is worthy of note that a valid and reliable measuring instrument should provide all candidates with the same ability and equal opportunity of choosing the correct answer. The Akwa Ibom State Ministry of Education is saddled with the responsibility of developing examination questions for the junior secondary three students preparing to move

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into the senior secondary. Umoinyang (2002) states that it is difficult to consider that an achievement test designed for use nationally could be free from differential item functioning irrespective of the comparative groups of the test-taking population. It states that the Akwa Ibom State BECE Mathematics test is devoid of differential item functioning.

Ogbogo and Okpara (2019) investigated differential item functioning using item response theory in the West African Senior School Certificate English language test in South-South Nigeria. Their result revealed that the differential item functioning significantly depends on ethnic groups. It, therefore, recommends the Item Response theory as a DIF detection method by large-scale public examination. Olufemi and Oluseyi (2015) investigated items that show differential item functioning (DIF) in the English Language Multiple-Choice Uniform Promotion Examination Questions (ELMCUPEQ) of Ekiti State Ministry of Education for Senior Secondary School examinees based on gender and location. The results revealed that nine items possessed DIF in terms of gender and eleven items in terms of location. Their results revealed that items significantly function differentially in terms of gender. However, it was otherwise in terms of location. Based on the findings, it recommended that the research and evaluation unit of the Ministry of Education should ensure that its test developers remove gender and location-biased items. Shanmugam (2018) examined gender Differential Item Functioning in a school culture that is mathematically 'thriving'. The findings suggest that with only two moderate DIF Mathematics items, there is insufficient evidence that the Mathematics items functioned differently between boys and girls. Omorogiuwa and Iro-Aghedo (2016) studied the differential item functioning (DIF) by gender in National Business and Technical Examinations Board 2015 Mathematics Multiple Choice Test Items Examination in Nigeria. It was to determine the items that functioned differentially by male and female examinees. The results indicated that male and female examinees functioned differentially in seventeen items (34%) and no difference in 33 items (66%). Out of the seventeen items, six items were in favour of male students, while 11 items were in favour of female students. Based on the findings, for bias-free items to be produced, examination bodies, test experts and developers should use the Area Index method of DIF to detect and remove the items that function differentially by gender.

Madu (2012) investigated which items show differential item functioning (DIF) for male and female students in the Mathematics examination conducted by the West African Examination Council in 2011 in Nsukka Local Government Area. The analysis indicated that male and female examinees function differently in some items. It becomes necessary that the examining bodies such as WAEC should set and administer items that are fair to quality education in terms of certification. Based on the importance of ensuring a fair test for all sub-population of students taking the test, this study determines if items in the Akwa Ibom State Junior Secondary Mathematics Examination function differentially for gender.

In Akwa Ibom State and every other State in Nigeria, the State Ministry of Education is saddled with the responsibility of conducting the Junior School Certificate Examination for students in the Junior Secondary Three classes. The students' performance in the Mathematics in Junior School Certificate examination determines whether the students can proceed to the Senior Secondary School level. It also determines the computational ability of these students after nine years of basic education. However, such a test is valid, reliable, and

credible if it is fair to all examinees regardless of their sub-groups. That is, it gives all examinees with the same ability level equal opportunity of responding to items in the test. The validity, reliability, and usefulness of such test can be affected if a test contains items that give members of various sub-groups with the same ability level different opportunities of responding correctly to the item. To determine the quality of Mathematics examination questions by the Akwa Ibom State Ministry of Education in the Basic Education Certificate Examination, this study assesses the extent that the 2021 Basic Education Certificate exhibits gender differential item functioning.

The purpose is to ascertain whether the Akwa Ibom State Basic Education Certificate Examination (BECE) in Mathematics differentially functions for Akwa Ibom State candidates in gender. The findings on differential item functioning of the Junior Secondary School Certificate Examination in Akwa Ibom State would be of great significance to teachers, test developers, counsellors, the Ministry of Education, and future researchers. To the teachers, the findings would help to identify topics or areas in which students of a gender or location might want and help them to compete favourably with their counterparts. It can involve stressing such issues in the class to the group that might likely suffer deficiency.

This study would help test developers, counsellors, the ministry of education, and researchers to identify items that might hinder students of gender from performing uniformly with their counterparts. With such knowledge, they would have to reconsider the terms used in wording the examination questions to provide all the students with equal opportunity of responding to the items. The findings would also help to identify topics that might be difficult for students in different groups to understand and avoid when developing test items. The result of this study is also likely to improve the comparability of tests, test takers, and instructional and curricular performance over time and across public and private educational establishments.

However, to accomplish the purpose of the study, this hypothesis was tested at a 0.05 level of significance. Items in Akwa Ibom State Basic Education Certificate Examination in Mathematics administered in 2021/2022 do not significantly function differentially between male and female examinees.

METHOD

The design of the study was a descriptive survey. The study seeks to establish a causal relationship between the dependent variable (probability of correct response to test items) and the independent variables (gender). The State Ministry of Education conducts the Junior Secondary Certificate Examination. The population for this study was the 62,145 JS3 Basic Education Mathematics Examination students in the 2020/2021 session in public secondary schools in Akwa Ibom State.

A sample of 870 (351 male and 519 female) BECE Mathematics examination answer scripts representing 30% was used in the study. The answer scripts were selected using a multi-stage sampling procedure. The instrument for data collection was the Akwa Ibom State Junior Secondary School Mathematics examination objective test for the 2020/2021 school sessions. Since the items in the test were from a standard examination, the validation had

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been conducted on the instruments. Hence, there was no additional validation on the instruments. The instrument was administered to 30 students in a school not among those used for the study to obtain internal consistency reliability. The Split-Half method determined the reliability, and a coefficient of 0.81 was obtained for the instrument.

Relevant authorities permitted the use of the answer scripts. The complete number of answer scripts requested for each school were selected and used in the study. The coded data were analyzed using a one-parameter item characteristics model, logistic regression, and the modified Mantel-Haenszel Delta (M-H Delta) statistics to test the hypotheses at a 0.05 level of significance. Data were subjected to the Mantel-Haenszel method of detecting differential item functioning, one-parameter item characteristic model, and logistic regression. It was computed using the R-Studio software. The results are presented in Tables.

RESULTS AND DISCUSSION

As shown in Table 1, two items (items 36 and 46) indicated as differential item functioning at 0.05 levels of significance in favour of male candidates. The Items in the Akwa Ibom State BECE Mathematics test administered in 2021 do not significantly function differentially between male and female examinees. It indicates that there are differentially functioning items based on Gender in the Akwa Ibom State BECE Mathematics test administered in 2021. Also, testing of gender DIF using 1-Parameter IRT was conducted. As shown in Table 2, all the items except items 6, 19, 54, and 58 indicated differential item functioning at 0.05 levels of significance. It is evidenced from the table that items 1, 9, 10, 22, 52, 57, and 59 favour male candidates, while others favour female candidates. It indicated that there are differentially functioning items based on Gender in the Akwa Ibom State BECE Mathematics test administered in 2021.

However, further testing with Logistic Regression was conducted. As shown in Table 3, four items (2, 12, 36, and 46) indicated differential item functioning at a 0.05 level of significance. These are indications that there are differentially functioning items based on Gender in the Akwa Ibom State BECE Mathematics test administered in 2021. The differential item function identified was in favour of the male students, who were the focal group in the analysis. It is clear that the results from Mantel-Haenszel and Logistic Regression are similar and deviate significantly from that of the 1-parameter IRT model.

As shown in Table 4, a proportion (3.33%) of the differential items was spotted as exhibiting differential item functioning in favour of male students by the Mantel-Heanszel detection method, while no differential item favours females based on the method. The 1-parameter IRT model spotted a proportion of 11.67% as exhibiting differential item function in favour of males, while a proportion (83.33%) of the items was spotted as displaying differential item function for females. Also, the logistic regression spotted a proportion (6.67%) of the items as exhibiting differential item functioning in favour of male students, but no item was detected in favour of female students. It is clear from the table that items 36 and 46 were detected as exhibiting differential item functioning across the three methods.

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Table 1: DIF Result for Gender Using Mantel-Haenszel Statistics

Item	M-H Alpha	M-H Delta	Item	M-H Alpha	M-H Delta
1	1.4584	-0.8867	31	1.5170	-0.9793
2	0.6518	1.0059	32	0.6356	1.0649
3	1.1136	-0.2528	33	1.1206	-0.2676
4	0.8819	0.2953	34	0.8782	0.3051
5	0.9522	0.1152	35	1.1310	-0.2893
6	1.1193	-0.2648	36	0.5089	1.5872*
7	1.4244	-0.8313	37	0.8705	0.3259
8	0.7046	0.228	38	0.8528	0.3741
9	1.1439	-0.3160	39	0.8738	0.3171
10	1.4106	-0.8084	40	0.8368	0.4187
11	1.4663	-0.8995	41	0.9895	0.0248
12	1.6406	-1.1634	42	1.3435	-0.6939
13	1.1999	-0.4283	43	0.9342	0.1600
14	1.6088	-1.1173	44	1.2092	-0.4465
15	1.0745	-0.1200	45	0.6575	0.9853
16	1.0745	-0.1689	46	0.5761	1.2960*
17	0.7843	0.5710	47	0.9244	0.1847
18	1.0778	-0.2017	48	0.7728	0.6055
19	1.0896	0.2597	49	0.9086	0.2252
20	0.8954	-0.4705	50	1.0517	-0.1185
21	1.2217	-0.2659	51	1.1535	-0.3355
22	1.1198	-0.2547	52	1.3282	0.6670
23	1.1193	-0.8793	53	0.9659	0.0816
24	1.4538	0.1663	54	0.9073	0.2287
25	0.9317	0.1654	55	1.1051	-2348
26	0.8818	0.2955	56	0.9706	0.0702
27	0.6829	0.8961	57	0.8938	0.2640
28	0.8687	0.3308	58	1.0141	-0.0328
29	1.3156	-0.6445	59	0.5628	1.3510
30	0.9971	0.0068	60	0.9775	0.0536

Significant code: '*' 0.05

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Table 2: DIF Result for Gender Using 1-Parameter IRT

Item	mF-mR	deltaLord	Item	mF-mR	deltaLord
1	-0.4907	1.1531***	31	0.8414	-1.9773***
2	0.4699	-1.1043*	32	1.7204	-4.0429***
3	0.3763	-0.8843***	33	1.0265	-2.4123***
4	0.7638	-1.7949***	34	1.7430	-4.0960***
5	0.6280	-1.4758***	35	1.0025	-2.3559***
6	0.0712	-0.1673	36	2.0017	-4.7040***
7	0.0773	-0.1817***	37	0.1602	-0.3765***
8	0.8303	-1.9512***	38	1.3614	-3.1993***
9	-0.5388	1.2662***	39	1.4735	-3.4627***
10	-0.1142	0.2684***	40	1.0795	-2.5368***
11	1.0562	-2.4821***	41	1.0936	-2.5700***
12	0.4338	-1.0194***	42	0.5509	-1.2946***
13	0.3904	-0.9174***	43	0.5315	-1.2490***
14	1.0210	-2.3994***	44	0.4508	-1.0594***
15	0.6911	-1.6241***	45	0.5929	-1.3933***
16	1.2019	-2.8245***	46	0.8657	-2.0344***
17	1.5628	-3.6726***	47	0.6694	-1.5731***
18	0.9692	-2.2776***	48	0.4167	-0.9792***
19	0.0091	-0.0214	49	0.8841	-2.0776***
20	1.3225	-3.1079***	50	0.8948	-2.1028***
21	0.1202	-0.2825***	51	1.1220	-2.6367***
22	0.6418	1.5082***	52	0.6963	1.6363***
23	1.0516	-2.4713***	53	0.8874	-2.0854***
24	0.7047	-1.6560***	54	0.2206	-0.5184*
25	0.9322	-2.1907***	55	0.5115	-1.2020***
26	1.4414	-3.3873***	56	1.0930	-2.5686***
27	0.8630	-2.0280***	57	-0.1616	0.3798***
28	2.5121	-5.9034***	58	0.0048	-0.0113
29	1.3050	-3.0667***	59	-0.0607	0.1426*
30	0.7259	-1.7059***	60	1.0512	-2.4703***

Significant code: '*' 0.05

Table 3: DIF Result for Gender Using Logistic Regression

Item	R^2	p-value	Item	R^2	p-value
1	0.0086	0.3449	31	0.0048	0.4388
2	0.0270	0.0394*	32	0.0063	0.2916
3	0.0116	0.1415	33	0.0008	0.8581
4	0.0027	0.6656	34	0.0036	0.4818
5	0.0075	0.2518	35	0.0018	0.7129
6	0.0052	0.4666	36	0.0205	0.0135*
7	0.0124	0.1537	37	0.0095	0.2148
8	0.0055	0.4430	38	0.0054	0.3821
9	0.0021	0.7225	39	0.0023	0.6492
10	0.0095	0.2447	40	0.0022	0.6525
11	0.0026	0.6405	41	0.0009	0.8567
12	0.0238	0.0193*	42	0.0033	0.5657
13	0.0013	0.8308	43	0.0051	0.4544
14	0.0135	0.0706	44	0.0030	0.6026
15	0.0001	0.9921	45	0.0067	0.3272
16	0.0084	0.2116	46	0.0199	0.0342*
17	0.0033	0.5600	47	0.0011	0.8306
18	0.0013	0.7964	48	0.0075	0.3.81
19	0.0005	0.9356	49	0.0025	0.6348
20	0.0022	0.6717	50	0.0000	0.9987
21	0.0070	0.4188	51	0.0002	0.9563
22	0.0044	0.4687	52	0.0042	4873
23	0.0007	0.8810	53	0.0042	0.4486
24	0.0060	0.3781	54	0.0041	0.5280
25	0.0013	0.8094	55	0.0025	0.6525
26	0.0007	0.8828	56	0.0005	0.9107
27	0.0060	0.3724	57	0.0002	0.9760
28	0.0075	0.2225	58	0.0005	0.9239
29	0.0006	0.8865	59	0.0103	0.2486
30	0.0026	0.6355	60	0.0006	0.9041

Significant code: '*' 0.05

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Table 4: Items that Displayed Differential Item Function Based on Gender in the Three Detection Methods

	Mantel-Heanszel		**1-Parameter IRT**		**Logistic Regression**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
	36, 46		1, 9, 10, 22, 52, 57, 59	2, 3, 4, 5, 7, 8, 11, 12, 13, 14, 15, 16, 17, 18, 20, 21, 23, 24, 25, 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, 51, 53, 54, 55, 56, 60	2, 12, 36, 46	
Total	**2(3.33%)**	**0(0%)**	**7(11.67%)**	**50(83.33%)**	**4(6.67%)**	**0(0%)**

In testing for the gender factor, two items were flagged as exhibiting differential item functioning about students' gender. Also, when tested using logistic regression, four items were flagged as indicating differential item functioning based on gender. However, when tested with the 1-parameter IRT model, all the items except five were flagged as exhibiting differential item functioning. It appears misleading since it is far from what is in other methods. The reason could be that the items did not fit into the 1-parameter IRT model or did not satisfy the IRT assumptions.

However, the inference from the result of testing for gender differential item functioning Akwa Ibom State BECE Mathematics achievement test in 2022 is the gender-based differential item functioning. One cannot conclude that the result is due to the differential level of instruction at school as argued by Fennema and Sherman in Umoinyang, Nenty, and Falayajo (2003), who stated that males typically receive more and higher levels of Mathematics instruction than females. The reason is that the sample for the study was not restricted to single-sex schools. Also, the examination analyzed was not a school examination but a State examination in which all the students that participated had an independent opportunity to prepare.

Furthermore, item 36 and item 46 favour male candidates, which was the focal group since the M-H delta values, are all positive. A close examination of the items revealed that the items that favour male students were word problems that must be translated into a mathematical equation. Items that favour males require higher cognitive ability. The reason for differential item functioning could be a result of the wording of item 36, which stated thus, If 6 men clear a plot of land for 5 days, how many days will it take 10 men to clear the same piece of land working at the same rate? This item suggests to female students that the male gender is preferred against them, thus, discouraging most female students much attention to the question. It can also be that most of the male students are excited about giving preference to their gender. Male students who have engaged in land clearing most of the time can easily reason the answer to the question more than many female students who have not engaged in land clearing. Also, item 46 stated thus; "find the curved surface area of a cylinder whose radius is 7cm and height 6cm". The reason for the DIF to favour male students over females could be that male students like playing and working with objects like the cylinder, which would make it easy for them to have a clear picture of the object in question and understand how to proceed with the solution. On the other hand, many female students might

have difficulty getting a clear picture of the object in question, thus, hindering their ability to work out the answer correctly.

CONCLUSION AND RECOMMENDATIONS

The Akwa Ibom State Junior Secondary School Mathematics Examination is not free from differential item functioning with the gender of testees. There is a differential item functioning in the junior secondary school certificate examination in Akwa Ibom State. The following recommendations were based on the findings of the study:

1. Test developers should conduct a proper field test of all items developed before being selected for the Akwa Ibom State Junior certificate examination or any other education decision-making instrument. It would help them to identify terms and areas that can be problematic to candidates based on gender.

2. The Akwa Ibom State Ministry of Education should sponsor the differential item analysis on all items to be used for the Akwa Ibom State Mathematics Examination not to give any examinees undue advantage.

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