



Assessment of Unidimensionality and Differential Item Functioning of WAEC 2021 Physics Multiple-choice Test Items

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ABSTRACT

The study investigated assessment of unidimensionality and differential item functioning of WAEC 2021 Physics Multiple-choice Test items. The sample size for the research is one thousand one hundred and seventy-nine (1,179) students, which was obtained from a population of 7,387, made up of 5,304 students from public schools and 2083 students from private schools in Bayelsa State. The sample size of the study was obtained using multi-stage sampling techniques in stages. WAEC 2021 Physics paper 1 (multiple-choice test items) was used as the research instrument. Its validity was believed to have been obtained because it is a paper owned by an examining body WAEC. Cronbach Alpha was used to obtain the reliability and it yield a reliability coefficient of 0.77 as a measure of consistency, which reveals the instrument was good for the study. Principal Components Analysis (PCA) of Rasch residual was conducted using WINSTEPS to determine the unidimensionality of the instrument. Frequency count and percentage was used to answer the research question while the hypothesis was tested using Chi-square goodness of fit statistic at 0.05 alpha level of significant. Raju Area index an item response theory (IRT) method was used to assess the presence of differential item functioning (DIF) in the study. One major finding revealed, WAEC 2021 Physics Multiple-choice test item do not significantly function differently between male and female testees. Based on the findings it was recommended for item writers at all levels, be it the classroom or examination bodies should be adequately trained on how to identify DIF items and able to construct items free of biasness.

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INTRODUCTION

In school and outside the school system, one foundational practice were teaching and learning occurs is assessment. Also to improve instructional decision, make judgement about the learner progress by the teacher or instructor assessments or appraisal becomes a vital tool. As stated in the National Policy of Education (2014), assessment techniques are needed in achieving the implementation of the continuous assessments policy on education in Nigeria. Achievement test is one of such technique that is needed. A subject teacher produces the assessment test depending on the

content or area he has covered and it comes either as objective test or essay.

Eneja and Ikeh (2016) are of the opinion that testing is seen as any type of tool that can be used for promotion, research, evaluation, teaching, recruiting and admission. Test are also seen as device used in measuring ability, achievement, interest and any other personal traits of students. Scores obtained from student in a multiple-choice test or objective tests measures the ability of the student. An importance of the multiple-choice test is that it measures the lower and higher levels of the cognitive domain of learning. Freedom to construct questions to cover

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the course content can be easily realized with the multiple-choice test or objective test.

Dimensionality of an underlying item is one important aspect that is always ignored in the interpretation of test score. Ogunama et al., (2016) explained test dimensionality as the number of characteristics that are fundamental in a test and leads to change in student's performance in a test. In a simple term, a test is unidimensional if there exist only one characteristic (dimension) leading for a change in the performance of students in a test. Unidimensionality as IRT assumption means that in test construction, an item should only measure one single characteristic or latent trait. This means, a physics test item should measure only physics trait without involving English or Literature traits. Unidimensionality of test item can be obtained once there is reduction of the effect of languages in an item assessing learning in other discipline (Odili,2022). Item and ability parameter estimation is seriously bias once this assumption of unidimensionality is violated. Unidimensionality of the items generating a test scores is important because it shows a proof of the assessment methods in which these generated score is to be used.

Ibrahim (2018) sub-divided differential item functioning (DIF) into two groups, such as: uniform (unidirectional) DIF, and non-uniform (crossing) DIF. Uniform DIF is said to occur when the chances of answering an item correctly is more for a group than another group over-all level of performance. With the concept of IRT, uniform DIF means the item response curve (ICC) for the reference group is not crossing the item response curve of the local group. Also uniform DIF occurs in an item when all test-takers in a group tends to succeed more than another groups of test-takers on the same test item.

As an example, in a Physic test, girls manifested higher chances of answering rightly than their boys counterpart which all have equal ability, due to the content in the test items are biased against boys then such items are showing existence of DIF and should be marked for removal from the test or modified. Non-uniform (crossing) DIF means that the probability of answering an item correctly is not the same at all

level of performance between comparing group and it means the probability of getting an item correctly is more for a group at a given point on the scale and also more for other groups at another point on the scale (Ibrahim, 2017). With the use of the concept IRT non-uniform DIF occurs when the item response curves for a focal and reference group is crossing each other. Non-uniform DIF is said to also exist in an item when the item is more simpler to a group of testees at a lower ability level, but at a higher ability it tends to be more simpler to the other group of test-takers. DIF has so many technique in it detection as proposed over the decades, but this research is focused on the use of Raju Area Index method, because it was found to be powerful in detecting not just uniform DIF but also non-DIF items in a test.

Oribhabor (2019) assessed unidimensionality and occurrence of differential item function (DIF) in the 2017 Nov. /Dec. WAEC Mathematics test item administered in Edo state. The unidimensionality of the instrument was analysed using Principal Components Analysis (PPA). The variance explained by the first factor should be more than 20% to show manifestation of unidimensionality (Reckase,1979). The items studied reveal they are unidimensional because the variance of 31.6% obtained is more than the needed criterion. The study reveals also that the 2017 WAEC Mathematics item shows the existence of DIF in which out of the 50 items 12 items possess DIF (24%) and 38 items (76 %) to not possess DIF. Her finding also reveals a significant difference in the numbers of item functioning differently by sex.

Ajeigbe and Afolabi (2014) assessed unidimensionality and occurrence of differential item functioning (DIF) in Mathematics and English language items of Osun state qualifying examination. Various techniques in testing for unidimensionality is in existence (Tate, 2003). Both the Mathematic and English language multiple-choice test administered by the Osun state ministry of education measured a single construct which shows that the items are unidimensional. The study also showed that a significant numbers of items on OSQ English

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language and Mathematics examination shows a manifestation of DIF. Ubi et al., (2012) using Joint Admission and UME in Cross Rivers state, Nigeria for the year 2002 and 2003, sampled pools of candidates scripts that sat for those two years. The reason was to analyzed the existence of unidimensionality of the Mathematics item using factor analysis. The analysis revealed that JAMB –UME manifested five significant dimensions and conclusion was drawn that examinations of such magnitude for selection of testees must not be really unidimensional because the item are selected from a comprehensive syllabus

A science subject that is mainly connected with matter as it relates to energy generation is called physics. The working of any integrated circuits systems that help man solve problems in our society today depends on the principles of physics. So, the inclusion of physics as a school subjects is important because of its benefits to our society. Nnadi and Anamezie (2018), Physics education researchers noted that physics as a school subject is to make students become more adaptive to the technological age. Despite these benefits Osadebe (2018) explained that the degrading performance of Physics students is a violation of the national goal of education which ought to give equal opportunity to its citizen despite their sex, type of school or location of school.

The expectations of parents, students or the larger society who are aspiring at a higher success in their academic performance is challenged. Their downward performance can be attributed to their lack of knowledge in physics, definition of physics term, spelling, physics applications, understanding of the test items presented or inability to cover the content of the physics scheme of work. Also the student's failure could be link to the fact that the items in the test measure something different rather than the students physics ability in the test.

STATEMENT OF THE PROBLEM

The educational sector in Nigeria has critical challenges that is manifesting in the increasing poor performance of students in their national examinations. The chief examiners report

(2017-2020) for Physics reveals that 25% in 2017, 43% in 2018 and 2019 and 51% in 2020 of students that sat for WAEC got credit in physics and the rest failed. This can be attributed to a number of factors such as; poor conducive learning environment, lack of laboratory equipment or no functioning laboratory.

Also, another contributing factor can be linked to the students lack of knowledge in physics, understanding of the test items presented or items of the test measured different things rather than the students physics ability. Test is seen as a vital instrument that reveals the latent skills the testees possess. The educational sector sees test as a vital parameter in which the larger society makes decision about their products Monigha, (2023). Once, test items functions differently, the test results, its functions and purpose becomes questionable. Also no meaning goal can be realize since test items are functioning differently.

The Federal government goal on education can also be hampered since education is perceived as an instrument in achieving the purpose of oneness. This poor performance of physics students in WAEC can also be linked to the challenges created by differential item functioning in these physics items. Therefore, there is an urgent need for stakeholders in the educational sector, examination bodies even classroom teachers to reduce or eliminate test item that are functioning differently between the various groups such as ; location, type of school or sex. Hence, there is the need in the assessment of unidimensionality and differential item functioning of WAEC 2021 Physics multiple-choice test items.

Purpose of the study

The purpose of the study is the assessment of unidimensionality and differential item functioning of WAEC 2021 Physics multiple-choice test items. The study is specially focused on:

1. Assessment of unidimensionality of the items in WAEC 2021 Physics multiple-choice test

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2. Establishing the existence of DIF in WAEC 2021 Physics multiple-choice test items in term of sex

Research questions

The following research questions were raised to guide the study

1. What is the extent to which WAEC 2021 Physics multiple-choice test items meet the unidimensionality assumption of IRT?
2. Do DIF manifest in WAEC 2021 Physics multiple-choice test items?

Hypothesis

There is no significant difference in the number of items functioning differently in WAEC 2021 Physics multiple-choice test item in term of sex (male or female)

METHODOLOGY

The adopted research design for the study was *survey research design*. The population of the study 7,387 which is made up of 5,304 students from public schools and 2083 students from private schools all of which are SSS 3 physics students in Bayelsa state. The sample size for the study was 1,179 and it was obtained through multi-stage sampling technique in stages. The instrument for the study was the adapted 50 multiple-choice test items of WAEC 2021 Physics paper 1. After the administration of the instrument, the students' response were retrieved, marked and coded. A right response was coded (1) and a wrong response was coded (0). These responses were entered to an excel spread sheet for analysis.

Table 1: Unidimensionality Assumption of IRT of WAEC 2021 Physics Multiple-choice Test Items - Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	15.829	31.657	31.657	15.829	31.657	31.657
2	4.807	9.613	41.270	4.807	9.613	41.270
3	4.122	8.243	49.514	4.122	8.243	49.514
4	3.361	6.722	56.236	3.361	6.722	56.236
5	2.609	5.219	61.454	2.609	5.219	61.454
6	2.377	4.753	66.208	2.377	4.753	66.208
7	1.964	3.927	70.135	1.964	3.927	70.135

The reliability of the instrument was determined using Cronbach Alpha method and it yielded a coefficient of 0.77 as a measure of consisting which was good for the study. To determine the unidimensionality, Principal components Analysis (PCA) of Rasch residual was conducted using WINSTEPS. The DIF was determined using Raju Area method. When the area index is greater than the critical value of 0.22, it is said to be functioning differently while when the area index is zero (0) the item is said not to function differently. The research questions were answered using frequency count and percentages (%) while the hypothesis was tested using Chi-square goodness of fit statistics at 0.05 alpha level of significance.

PRESENTATION OF DATA

Research question one: What is the extent to which WAEC 2021 Physics multiple-choice test items meet the unidimensionality assumption of IRT?

Table 1 shows the factor Analysis revealing the total variance explained. The number of factors with eigenvalue greater than 1, were chosen using the Kaiser-Guttman rule. Table 1 also shows that thirteen components statistics the Kaiser-Guttman rule, with Eigenvalue greater than 1 on the first component. Reckase (1979) states that any factor which is manifesting unidimensionality must exhibit more than 20% of the variance. For this analysis, the first factor accounted for 31.800 % of the total variance, exceeding the criterion and showing the unidimensionality of the items.

Factor analysis

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Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
8	1.786	3.571	73.706	1.786	3.571	73.706
9	1.681	3.362	77.068	1.681	3.362	77.068
10	1.350	2.701	79.769	1.350	2.701	79.769
11	1.311	2.622	82.391	1.311	2.622	82.391
12	1.123	2.247	84.637	1.123	2.247	84.637
13	1.090	2.180	86.818	1.090	2.180	86.818
14	.875	1.751	88.568			
15	.845	1.691	90.259			
16	.706	1.412	91.672			
17	.679	1.358	93.030			
18	.613	1.225	94.255			
19	.460	.921	95.176			
20	.362	.723	95.899			
21	.333	.667	96.566			
22	.327	.653	97.219			
23	.255	.510	97.729			
24	.234	.468	98.197			
25	.208	.416	98.614			
26	.186	.372	98.986			
27	.106	.213	99.199			
28	.101	.202	99.401			
29	.088	.176	99.577			
30	.073	.145	99.722			
31	.064	.127	99.849			
32	.038	.075	99.925			
33	.022	.044	99.968			
34	.016	.032	100.000			
35	3.924E-014	7.849E-014	100.000			
36	3.625E-014	7.249E-014	100.000			
37	2.888E-014	5.777E-014	100.000			
38	1.968E-014	3.936E-014	100.000			
39	1.050E-014	2.100E-014	100.000			
40	9.949E-015	1.990E-014	100.000			
41	7.615E-015	1.523E-014	100.000			
42	1.699E-015	3.398E-015	100.000			
43	-2.980E-015	-5.959E-015	100.000			
44	-8.539E-015	-1.708E-014	100.000			
45	-9.115E-015	-1.823E-014	100.000			
46	-1.287E-014	-2.575E-014	100.000			
47	-1.775E-014	-3.550E-014	100.000			
48	-2.580E-014	-5.160E-014	100.000			
49	-2.967E-014	-5.933E-014	100.000			
50	-3.888E-014	-7.777E-014	100.000			

Extraction Method: Principal Component Analysis

Also to visualize the pattern of the principal component analysis, figure 2 show the

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Scree Plot of the Physics multiple-choice items of the study.

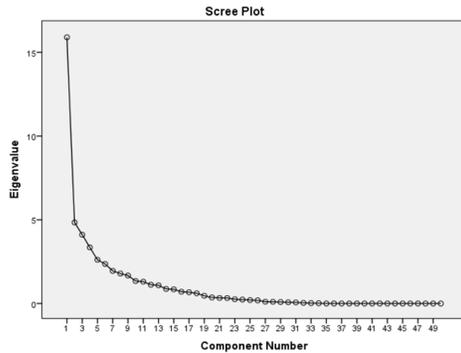


Figure 2: Scree Plot for Physics multiple-choice test items.

The Scree plot from figure 2, reveals that the first factor as it relates to the second is for

more than the second as it relates to the third factor. That is dominance is revealed, showing that the first component accounted more than three times the variance of the second component. This pattern was visually revealed by the Cattell Scree Plot in figure 2, it is also a confirmation that the instrument satisfies the unidimensionality assumption of IRT and it is good for the study.

Research question 2:

Do DIF manifest in WAEC 2021 Physics Multiple-choice Test item?

In answering this question, Raju Area Index technique with critical value of 0.22 was used to identify the manifestation of DIF in WAEC 2021 Physics Multiple-choice test item. And Table two (2) shows a summary of results from the Raju Area Index technique.

Table 2: Summary of Results From The Raju Area Index Techniques Of Identifying DIF In WAEC 2021 Physics Multiple-choice Test Items

Item	Slope (a)male	Threshold (b)male	Slope (a)female	Threshold (b)female	Absolute=Area index	Decision	favoured
Q1	1.172	-4.139	0.445	-8.668	4.505	DIF	Female
Q2	0.498	-4.987	0.328	-9.478	3.302	DIF	Female
Q3	0.300	-7.004	1.048	-2.801	-3.276	NDIF	
Q4	1.117	-2.720	0.314	-9.932	6.574	DIF	Female
Q5	0.892	-3.513	0.782	-6.037	2.519	DIF	Female
Q6	0.478	-5.176	0.782	-6.037	1.040	DIF	Female
Q7	0.769	-3.985	0.782	-6.037	2.052	DIF	Female
Q8	0.528	-5.104	0.782	-6.037	1.018	DIF	Female
Q9	0.519	-6.240	0.782	-6.037	-0.105	NDIF	
Q10	0.578	-5.117	1.478	-2.617	-2.338	NDIF	
Q11	0.829	-3.432	2.122	-2.437	-0.313	NDIF	
Q12	1.005	-3.207	2.122	-2.437	-0.167	NDIF	
Q13	1.059	-2.840	2.122	-2.437	0.169	NDIF	
Q14	0.499	-5.858	2.122	-2.437	-2.886	NDIF	
Q15	0.493	-5.931	1.552	-2.498	-3.324	NDIF	
Q16	0.672	-5.571	0.864	-5.412	-0.159	NDIF	
Q17	0.638	-3.982	0.773	-2.252	-1.720	NDIF	
Q18	0.506	-5.306	0.874	-2.577	-2.652	NDIF	
Q19	1.011	-3.498	3.433	0.547	-2.877	NDIF	
Q20	0.653	-4.586	7.360	0.671	-2.485	NDIF	
Q21	1.038	-4.552	0.864	-5.412	0.823	DIF	Female
Q22	0.835	-2.586	1.458	-1.133	-1.197	NDIF	
Q23	0.647	-3.216	2.913	-2.293	0.289	DIF	Male
Q24	1.341	-2.614	2.913	-2.293	0.400	DIF	Male

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Item	Slope (a)male	Threshold (b)male	Slope (a)female	Threshold (b)female	Absolute=Area index	Decision	favoured
Q25	3.535	-1.654	2.913	-2.293	0.481	DIF	Female
Q26	2.460	-1.813	1.215	-2.836	0.390	DIF	Female
Q27	2.078	-1.932	2.913	-2.293	0.663	DIF	Female
Q28	2.581	-2.060	2.913	-2.293	0.338	DIF	Female
Q29	1.539	-1.701	2.913	-2.293	1.181	DIF	Female
Q30	1.603	-1.467	2.913	-2.293	1.376	DIF	Female
Q31	1.100	-2.568	2.913	-2.293	0.626	DIF	Male
Q32	2.078	-2.060	0.574	-1.093	-1.568	NDIF	
Q33	1.000	-1.886	3.982	-0.345	-0.186	NDIF	
Q34	1.005	-2.559	1.746	-0.901	-1.268	NDIF	
Q35	0.646	-0.961	7.412	0.482	1.359	DIF	Male
Q36	2.411	-2.113	0.756	-2.730	-0.263	NDIF	
Q37	0.731	-2.401	5.672	-0.486	0.288	DIF	Male
Q38	0.774	-2.591	1.536	-1.625	-0.663	NDIF	
Q39	0.553	-4.222	1.751	-2.748	-1.151	NDIF	
Q40	0.589	-3.491	8.252	0.308	-0.651	NDIF	
Q41	0.504	-2.581	6.730	0.411	0.039	NDIF	
Q42	0.407	-3.797	9.017	0.209	0.053	NDIF	
Q43	0.213	-6.249	6.730	0.411	-3.536	NDIF	
Q44	0.439	-6.059	1.702	0.000	-5.948	NDIF	
Q45	0.494	-2.800	8.585	0.354	0.414	DIF	Male
Q46	0.615	-4.844	7.926	0.395	-2.240	NDIF	
Q47	0.463	-5.763	4.982	-0.042	-3.293	NDIF	
Q48	0.455	-5.419	1.014	-2.891	-2.446	NDIF	
Q49	0.545	-4.956	1.247	-1.961	-2.970	NDIF	
Q50	0.864	-3.975	0.947	-3.709	-0.254	NDIF	

Table 2 of the distribution reveals that twenty (20) items or 40% of the items indicated DIF while thirty (30) or 60% revealed No DIF (NDIF) in WAEC 2021 Physics Multiple-choice Test items. Six (6) out of the items that showed the presence of DIF favoured male and fourteen (14) favoured female students.

Hypothesis one:

There is no significant difference in the number of items functioning differently in WAEC 2021 Physics Multiple-choice test in term of sex (male and female)

Hypothesis one was tested using Chi-square goodness of fit statistic at 0.05 alpha level of significance.

Table 3: Chi-square goodness of fit summary of WAEC 2021 Physics Differential item functioning by sex (male or female)

Year	Sex	Observed DIF items	Expected DIF items	df	Chi-square	Sig. (2tailed)	Decision
2021	Male	6	10	1	3.200	0.074	Not sig.
	Female	14	10				
Total		20	20				

$\alpha = 0.05$

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Table 3 shows a Chi-square value of 3.200 and a p-value of 0.074, testing at an alpha level of 0.05. Since the p-value is greater than the alpha level of 0.05 therefore the null hypothesis which states that there is no significant difference between male and female in the differential item functioning of WAEC 2021 Physics Multiple-choice test is accepted and the conclusion is that items of WAEC 2021 Physics Multiple-choice test do not significantly function differently by sex

DISCUSSION OF FINDINGS

Unidimensionality of WAEC 2021 Physics Multiple-choice test was determined using exploratory Principal Component Analysis. Firstly, the numbers of factors with eigenvalue greater than one, were chosen using Kaiser Guttman rule and thirteen components' statistics this rule. Reckase (1979) states that any factor which is manifesting unidimensionality must exhibit more than 20% of the variance. And the first factor accounted for 31.800% of the total variance, exceeding the criterion and showing the unidimensionality of the items.

In addition, the Cattell Scree Plot in the study also visually demonstrated that the items in the instrument satisfy the unidimensionality assumption of IRT. Raju Area Index techniques was used to identify items that function differently. Results from research questions two (2) showed a manifestation of DIF occurrence in WAEC 2021 Physics Multiple-choice test item in which out of the 50 items, twenty (20) items or 40% reveals presence of DIF while thirty (30) or 60% indicated no DIF (NDIF). The results from hypothesis one revealed that there is no significant functioning in the Physics test in terms of sex. In terms of DIF, this result is in agreement with the findings of Oribhabor (2019), who examined the presence of DIF in 2017 Nov./Dec. WAEC Mathematics test item in Edo state. As it relates to the hypothesis this finding is opposed to the findings of Oribhabor (2019) which reveals a significant differential item functioning by sex.

CONCLUSION

Unidimensionality of WAEC 2021 Physics Multiple-choice test items was concluded

in the research due to the fact the test measured a single construct, it was also revealed that WAEC 2021 Physics Multiple-choice test items showed existence of DIF

RECOMMENDATIONS

From the findings and conclusion, the following recommendation are presented:

1. Government and the private sector responsible for examination should include workshops and seminars so as to develop the knowledge of IRT, differential item function detection methods and the operation of IRT software among practioners
2. Test developers should rewrite modify or even discard from a test, item that have been identified of possessing DIF
3. There is urgent need for sensitization of all classroom teachers to ensure that test developed as, continuous assessment tests in our schools for students should be unidimensional before administrating to students.

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