



Estimation of the Psychometric Properties of 2023 West African Examination Council Physics Multiple Choice items using a Three Parameter Logistic Model

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Abstract

The study assessed the psychometric properties of 2023 West African Examinations Council Physics multiple choice test using a three-parameter logistic model. Descriptive survey design was adopted for the study. A sample of 1,097 Senior Secondary three (SS 3) students offering Physics was drawn from a population of 1,610 SS3 students who offer Physics in Enugu education zone. Instrument for data collection was the 2023 WAEC Physics multiple choice items. Data were collected through Direct Delivery Technique (DDT). Research questions were answered using Multidimensional Three Parameter Logistic Model of Item Response Theory (M3PLMIRT). The results showed that, 33 of the items were within acceptable range of item difficulty, while 17 of the items were above the acceptable range indicating that they are very difficult items. Also, 40 items out of 50 items discriminated between high and low ability examinees with good discrimination indices. All the 50 items were within the acceptable guessing factor range, indicating that the items are not susceptible to guessing. The high difficulty of the few items could account for the poor performance of students for that year because it has the implication of the inefficiency of those items of the test to classify examinees based on their correct ability levels. The study recommended that, item analysis of test (examinations) using the Item Response theory approach should be used to find out the difficulty of test items, so as to classify examinees based on their ability levels and make meaningful evaluation of students' academic progress. Thus, it is recommended that, schools should make use of assessment feedbacks from assessment bodies to improve on teaching strategies and provide more effective instruction to improve students' performance.

Keywords: Item Analysis, difficulty indices, discrimination indices, guessing indices.



Introduction

The persistent poor academic performance of students in the West African Senior School Certificate Physics examination as evidenced in the Chief examiners' report of West African Examinations Council has been a cause of concern for Physics educators and stakeholders in Education. Despite the efforts put in by researchers and other relevant bodies; like changing teaching strategies and provision of laboratory equipment for effective teaching and learning of the subject, the achievement of students in Physics internal and external examinations keeps declining yearly, making one to wonder the nature of West African Examination Council Physics test items.

The knowledge of Physics is essential in our everyday living. Physics is one of the science subjects that studies matter in relation to energy. Physics according to Assem, Nartey, Appiah and Aidoo (2023), is one of the most fundamental natural sciences which involves the study of universal laws, and of the behaviours and relationships among a wide range of physical phenomena. Owing to the fact that Physics plays a great role in technological advancements, serious consideration could be given to the procedures involved in its teaching and learning and most importantly testing of students, as this will contribute to a great reform in the world of science (Okagbare, Ossai & Osadebe, 2023). To determine if effective learning of this essential subject has taken place in students, the role of assessment comes into play.

Assessment is an essential part of the educational processes, as it helps teachers understand what students have learned and identify areas where additional support or instructions might be needed. This helps track a student's progress in learning over time. Pellegrino (2023) describes assessment as a tool designed to observe students' behaviour and products data that can be used to draw reasonable inferences about what students' know. Assessment is clearly a procedure that provides feedback to students on their progress, informs teachers about the effectiveness of their instruction, help identify learning gaps, and used to make decisions about the academic achievement of students. Formative and Summative assessments are very important because they are majorly used to ascertain the academic achievement of students. Summative assessment in test form is specifically used by the West African Examination Council every year to assess the academic achievement of SS3 students.

West African Examination Council are responsible for the award of the West African Senior School Certificate Examination certificate which is one of the major criteria for admission into higher institutions of learning. The WAEC chief examiners' reports for five consecutive years 2019-2023 have shown a decline in the mean performance of students in Physics. The reports showed that there was a greater decline in the 2023 students' performance with percentage pass of 32%, as compared to that of 2019, 2020, 2021, 2022 having percentage pass of 43%, 57%, 37% and 42% respectively. The results of SS3 Mock examination, which is a preparatory examination for the WASSCE, collected from different schools in the area of study also showed poor performances of students in the subject where only 13%, 25%, 16%, and 39% of SS3 students in the four schools respectively got an average of up to 50 out of 100. According to recent studies, it has been revealed that students' achievement in Physics is declining (Ugwuanyi, Okeke & Okeke, 2021). Thus, this study focused on the 2023 WAEC Physics multiple-choice item because it has a greater decline in the mean performance of students as compared with other years. Studies have also shown that one of the major factors responsible for the poor performance of students is the quality of the test items used in examining them. This could result in inappropriate measurement of students' performance and in turn lead to poor decisions about students' academic achievement. Hanging on to this fact, the item analysis of the 2023 WAEC Physics multiple choice test was determined as it helps to portray the standard and quality of the West African Senior School Certificate Examination.

The West African Senior School Certificate Examinations have gone through many processes of standardization, which has to do with the psychometric properties of test, ranging from dimensions underlying the test, to the validity of the test. Psychometric properties are internal components of a test that reveals information about its adequacy and usefulness. Psychometric properties of tests are associated with generated data from assessment conducted to decipher how well the test evaluates the construct of interest (Ohiri & Nnennaya, 2024). For a test to be acceptable, its reliability and validity must be assessed. Reliability is the extent to which a test measures what it purports to measure consistently. Validity according to Bolarinwa (2015), is the degree to which an instrument measures what it purports to



measure. According to Nworgu (2015), a valid test measures what it is designed to measure and nothing else.

The West African Senior Certificate Examinations like other testing instruments, go through item analysis. Item analysis is the process of collecting, summarizing and using information from students' responses to assess the quality of test items. It is the systematic application of statistical methods in ascertaining the standard of items of a test. According to Rezigalla (2021), item analysis is a statistical analysis of student's responses on exam items and the relationship between them. Item analysis possess validity indices which include; item difficulty, item discrimination, and guessing factor (Ricky, 2024). These validity indices assess the quality of test items and the test as a whole.

Item difficulty (b) is the percentage of learners who answer an item correctly (Kocdar, Karadag & Sahin, 2016). For items with one correct alternative response option, the item difficulty of that particular item is the percentage of students that answer the item correctly. To balance the difficulty of test items is to create quality assessment that measures a latent construct.

The discrimination index (a) distinguishes for each item between the performance of students who did well in the exams and those who did poorly. According to Maxinity (2019), item discrimination shows how well an item can differentiate between good candidates and less able ones. Items with good discrimination increases the overall validity and reliability of a test.

Guessing factor on the other hand is one that provides examinees with the opportunity to get an item correct even when the examinee does not have sufficient knowledge of the subject matter. Delavar and Zahrakar (2013) stated that, guessing is a strategy employed by examinees to earn more marks. The guessing factor index (c) has a grave implication on assessment in that the more the items in the examination administered to examinees are susceptible to guessing, the more tasking it becomes to correctly ascertain the true abilities of the examinees. Guessing contributes greatly to measurement error and is a serious threat to the construct validity of items of a test. The quality of test items is therefore assessed through Item analysis. Item analysis is the statistical analysis of examinee's response on test items that provides constructive feedback about the quality of items. Item response

theory was propounded by Fredrick Lord (1950) as a family of mathematical models that seek to explain the relationship between latent traits (unobservable attributes) and their manifestations (performances or responses). The major role of IRT is to decipher the unobserved traits of an examinee.

Item analysis can be carried out using the Item Response Theory (IRT). There are various models of IRT which are the One-Parameter Logistic Model (1PLM), Two-Parameter Logistic Model and Three-Parameter Logistic Model. The One Parameter Logistic Model is the simplest form of the IRT models. It is comprised of one parameter that describes the latent trait (ability θ) of the person responding to the items as well as another parameter for the item (difficulty). This model predicts the probability of giving a correct response given the examinees' ability and the difficulty of the item. The Two-parameter logistic model (2PLM) on the other hand predicts the probability of a successful answer using two parameters (difficulty and discrimination).

The Three-parameter logistic model (3-PLM) predicts the probability of endorsing a correct response in the same way as the 1PLM and 2-PLM but it is constrained by a third parameter known as the guessing parameter (pseudo chance parameter) which limits the probability of choosing a correct response when the ability of the respondent approaches $-\infty$. Items answered by guessing indicate that the examinees' ability is lesser than its difficulty. The two parameter logistic model is often used because of its nice mathematical properties and its plausible response mechanisms, but is limited to only two parameters. The three parameter logistic model works better than 2PLM in model mis-specification and it assesses a third parameter; the guessing parameter which affects the quality of test items.

Due to the detrimental consequences, errors in measurement can bring, it is important that these validity indices mentioned above are determined through item analysis. Various studies on item analysis on multiple-choice items have been carried out by various researchers. For instance, Thomas, Uchegbue and Ugbe (2016) compared the item analysis (difficulty and discrimination indices) of WAEC and NECO mathematics multiple-choice items and discovered that item difficulty and discrimination indices of WAEC differ significantly from that of NECO in terms of items. Chidozie and Orluwene (2021) investigated the discrimination and difficulty indices of WAEC and NECO Senior



Secondary Certificate multiple choice Physics questions from 2016-2018. Findings revealed that all the instruments in the years studied had good discrimination and difficulty indices, but the WAEC Physics items were more difficult than NECO Physics items for those years studied. Cobbinah and Ntumi (2022) studied the difficulty, discrimination and pseudo-Guessing indices of WAEC core Mathematics multiple choice items. The study revealed that averagely the items were within the difficulty level, most of the items discriminated among the examinees and most items were subjected to pseudo-guessing. Ohiri (2023) carried out a study to investigate item analysis of the West African Examinations Council May/June mathematics multiple-choice items from 2019 to 2021 using IRT and it was discovered that the multiple-choice questions had reasonable item difficulty and discrimination levels.

In most of the studies mentioned above, the researchers focused on determining item difficulty and discrimination indices of multiple-choice items neglecting the guessing factor. Studies that determined guessing indices are very few. The performance of students in WAEC Physics examination keep declining despite efforts put in by Government and other educational stakeholders. Studies also show that prominent among the factors responsible for the poor performance of students in Physics is the quality of the test items used in assessing them. It is therefore paramount that this third parameter 'guessing parameter' be estimated because guessing distorts the measurement of true knowledge, as a score can reflect luck, rather than proficiency, which can lead to poor decisions about students' academic achievements. Based on this, it is essential to determine the item analysis of Physics test items using the three parameter logistic model.

Purpose of the Study

This research aimed to determine:

1. item difficulty indices of the 2023 WAEC Physics multiple-choice test items in Enugu Education zone;
2. item discrimination indices of the 2023 WAEC Physics multiple-choice test items in Enugu Education zone;
3. guessing factor indices of the 2023 WAEC Physics multiple-choice test items in Enugu Education zone

Research Questions

The following research questions were posed for the study:

1. What are the item difficulty indices of the 2023 WAEC Physics multiple choice test items?
2. What are the item discrimination indices of the 2023 WAEC Physics multiple choice test items?
3. What are the guessing factor indices of the 2023 WAEC Physics multiple choice test items?

Methodology

The study employs descriptive survey research design. Descriptive survey research design according to Nworgu (2015) is a design which aims at collecting data and describing in a systematic manner, the characteristic features or facts about a given population. This design primarily aims at describing a group or situation as it is, without manipulating any variable. The study was conducted in Enugu Education Zone of Enugu state. Enugu Education Zone, located in the south eastern part of the country. Population of the study comprised 1,610 SS3 Physics students of thirty-three (33) government-owned secondary schools in Enugu Education Zone. Sample size for the study was 1,097 SS3 Physics students using a two-stage sampling procedure. The instrument for data collection is the adopted 2023 West African Examination Council Physics multiple-choice items with a total of 50 items. Each of the items has four response options A, B, C and D in which only one among the options is correct for each item and one mark is given to each item. The instrument has been measured by experts and have undergone test development processes. Hence, there was no need for validation. A reliability coefficient of 0.864 was obtained for the instrument using the Kuder-Richardson method. The instrument was administered to the students using the Direct Delivery Technique (DDT). Data collected was analyzed using the Multidimensional 3 Parameter Logistic model (M3PLM) of Item Response Theory using jMetrik software.



Results

Research Question One: What are the item difficulty indices of 2023 WAEC Physics multiple choice test items?

Table 1: Item Difficulty Indices of 2023 WAEC Physics Multiple Choice Test Items

Item	Difficulty Indices	Item	Difficulty Indices	Item	Difficulty Indices	Item	Difficulty Indices
1	0.21	14	-0.46	27	3.46	40	0.89
2	-1.58	15	20.88	28	2.96	41	19.32
3	-0.90	16	0.32	29	1.90	42	2.92
4	18.84	17	1.43	30	0.26	43	1.32
5	1.88	18	0.10	31	1.43	44	5.97
6	2.50	19	22.84	32	19.07	45	0.90
7	24.09	20	2.30	33	4.56	46	1.41
8	2.94	21	5.93	34	-0.42	47	5.96
9	1.60	22	1.73	35	3.90	48	0.90
10	22.60	23	28.32	36	-0.21	49	2.38
11	5.88	24	1.30	37	1.92	50	-0.40
12	3.79	25	5.95	38	0.62		
13	1.72	26	1.47	39	3.00		

The result in Table 1 shows the item difficulty indices of the items of 2023 WAEC physics multiple choice test items. The result revealed that the item difficulty indices of the 2023 WAEC physics multiple choice test items range from -1.58 (item 2) to 28.32 (item 23). It shows that 33 items which constitute 66% of the items of 2023 WAEC physics multiple choice test items were within the acceptable range of item

difficulty index of +3 to -3 (Ayala, 2022) while 17 items (34%) of the items were above the acceptable range. Among the 17 items, 8 item (items 4, 7, 10, 15, 19, 23, 32, and 41 having 18.84, 24.09, 22.60, 20.88, 22.84, 28.32, 19.07 and 19.32 respectively) have extremely higher values than others showing that they are extremely difficult with respect to the students being examined.

Research Question Two: What are the discrimination indices of 2023 WAEC physics multiple choice test items?

Table 2: Discrimination Indices of 2023 WAEC Physics Multiple Choice Test Items

Item	Discrimination Index	Item	Discrimination Index	Item	Discrimination Index	Item	Discrimination Index
1	0.37	14	1.26	27	0.40	40	1.91
2	2.59	15	0.82	28	2.33	41	0.82
3	0.59	16	1.39	29	2.15	42	0.55
4	0.82	17	1.12	30	2.51	43	2.59
5	0.52	18	1.96	31	0.53	44	1.50
6	1.38	19	0.82	32	0.82	45	1.92
7	0.04	20	2.26	33	0.47	46	2.67
8	2.38	21	1.23	34	1.71	47	1.35
9	1.06	22	2.45	35	0.74	48	0.96
10	0.82	23	0.04	36	1.35	49	2.01
11	1.26	24	1.62	37	0.44	50	1.11
12	0.24	25	1.22	38	0.85		
13	1.67	26	1.89	39	0.74		

The result in Table 2 shows the discrimination indices of the items of the 2023 WAEC Physics multiple choice test items. The result revealed that the

item discrimination indices of the 2023 WAEC Physics multiple choice test items range from 0.040 to 2.59. 80% of the items were within the acceptable range of



item discrimination of 0 to 2 (Ali & Istiyono, 2022) and 20% (items 2, 8, 20, 22, 28, 29, 30, 43, 46 and 49) showed higher indices than others indicating they should be reviewed and modified. A greater number of

the items were able to differentiate between the high ability and low ability students which tells that the test has good quality.

Research Question Three: What are the guessing factor indices of 2023 WAEC physics multiple choice test items?

Table 3: Guessing Factor Indices of 2023 WAEC Physics Multiple Choice Test Items

Item	Guessing factor Indices	Items	Guessing factor Indices	Items	Guessing factor Indices	Items	Guessing factor Indices
1	0.19	14	0.06	27	0.14	40	0.50
2	0.09	15	0.24	28	0.29	41	0.28
3	0.09	16	0.17	29	0.32	42	0.07
4	0.19	17	0.25	30	0.26	43	0.20
5	0.16	18	0.50	31	0.09	44	0.22
6	0.22	19	0.22	32	0.23	45	0.30
7	0.25	20	0.23	33	0.16	46	0.32
8	0.21	21	0.12	34	0.05	47	0.22
9	0.05	22	0.15	35	0.14	48	0.15
10	0.26	23	0.26	36	0.10	49	0.25
11	0.15	24	0.21	37	0.22	50	0.14
12	0.19	25	0.24	38	0.11		
13	0.07	26	0.24	39	0.21		

The result in Table 3 shows the guessing factor indices of 2023 WAEC Physics multiple choice test items. The result revealed that all the items of the 2023 WAEC Physics multiple choice test items fall within the acceptable range of the guessing factor indices of 0 to 2 (Ayala, 2022). This implies that all the items (100%) of the 2023 WAEC physics multiple choice test items have good guessing factor indices, therefore the items are not susceptible to guessing.

Discussion

The findings revealed that most of the items were moderate items which were not too difficult nor too easy for students to respond to. 33 items which constitute 66% of the items of 2023 WAEC physics multiple choice test items were within the acceptable range of item difficulty index while 17 items (34%) of the items were above the acceptable range. This clearly implies that the difficulty level of 33 items out of 50 items were within the ability level of the examinees and 17 were above the ability level of the students. The range in item difficulty was in line with the findings of Ayala (2022) which asserts that item difficulty should range from -3 to +3, so that the items will not be too easy or too difficult for the intended test population. Also Baidoo-Anu (2025) agrees that a well-balanced test should contain items of varying difficulty levels to

assess both basic understanding and advanced knowledge. Furthermore, the finding is strengthened with that of Odukoya, Adekeye, Igbino and Afolabi (2018) that said that for most summative assessments such as those handled by the West African Examination Council, moderate difficulty indices are often preferred. The study is in line with the study of Ohiri (2023) where findings from the study showed that 38(76%) of the items in 2021 WAEC Mathematics multiple choice items satisfied the difficulty acceptable range and 12 items did not. (Chidozie & Orluwene, 2021) asserted that 7 out of 50 items in the WAEC Physics multiple choice items for 2018 was difficult. Most studies recorded a good number of high difficulty level of some items as in agreement with this study. This could be as a result of poor estimation of the difficulty levels of the item during test development or ambiguously worded items.

Also, the findings revealed that 40 (80%) of the items were within the acceptable range of item discrimination. This signifies that the items will be able to differentiate between the high ability and low ability students. This is consistent with the study of Gul, Shagufta, and Perveen (2022) which describes item discrimination as an essential technique for making the item analysis for selecting the appropriate items for intelligence tests. Maydeu-Olivares (2015) conducted a

study in line with the findings that stated that the ultimate purpose for designing a precise measure is to include items with high discrimination index in order to be able to map out individuals along the continuum of the latent trait. The result of the study is strengthened with the work of Baidoo-Anu (2025) who opined that a high discrimination index means the question is effective in distinguishing between different levels of students' ability and a low or negative discrimination suggests that an item may be flawed. There was no item among the 50 items of the 2023 that had a negative discrimination, implying that all the items did not go out of the context of what it was made for. This is in agreement with the study of Agu and Obidiebube (2021) that recorded good discrimination indices for 41 out of 50 of the items of 2017 WAEC physics multiple choice items. This is in contrast with the study of Chidozie and Orluwene (2021) where the 2017 WAEC Physics multiple choice items had item with negative discrimination. The discrepancies in the studies could be as a result of the test environment of the students who responded to the test items.

In terms of guessing parameter, the findings revealed that all the items have guessing factor indices that fall within the acceptable range for guessing factor parameter, indicating that the guessing parameters of all the items were good. This explains that all the items are not prone to guessing, thereby establishing the fact that the distracters were all plausible. The findings are in agreement with Teflpedia, (2024) which describes the guessing parameter as the probability of getting the correct response to an item by chance particularly for multiple choice items. Lower values of the guessing parameter as seen in the result of this present study implies that the items are more discriminative and less influenced by guess behavior. Huang and Cai (2023) argued that the guessing indices reflect the influence of random guessing on item response characteristics. This study was in contrast with the study of Cobbinah and Ntumi (2022) that found most of the WAEC mathematics items for year 2020 susceptible to guessing even though they had good difficulty and discrimination levels. The disparity in the studies could be as a result of the testing environment, poor time management and lack of preparation for the test by the examinees

Conclusion

From the findings of the study, the researchers concluded that 2023 Physics multiple choice questions

demonstrated good discrimination and guessing parameters. Thus, cause of students' poor performance in that particular examination is not from the nature of the test.

Educational Implications

The findings of this study show that majority of the items had acceptable difficulty levels indicating that they are of moderate difficulty. The implication of this is that the probability of high ability students getting the answers to those items correctly will be more than those with low ability levels. The difficulty of the other few items may have accounted for the poor performance of students in the 2023 WAEC Physics examination.

Another implication of the high difficulty indices of items as seen in the study is the inefficiency of the test to classify examinees based on their correct ability levels which may not provide reliable feedback to inform or modify instruction.

Recommendations

1. Thorough item analysis using the Item Response Theory should be done by assessment bodies to determine the validity indices of items before administering them to student in order to avoid having items that are extremely difficult or easy, as they help students with a fair and meaningful evaluation of their academic progress.
2. Assessment bodies should make use of only tests with acceptable reliability coefficients, as they measure accurately what they are intended to measure and produce consistent results over time. This will help to adequately make reliable decisions on the quality of the test and academic achievement of students.
3. Awareness should be created in schools by education stakeholders, to make use of feedbacks from assessment bodies that outlined problematic areas peculiar to students in various examinations so that instructors/teachers can adjust their teaching strategies and provide more effective instruction on difficult topics.

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