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A Differential Item Functioning estimate of WAEC Mathematics test form based on gender and age among secondary school students

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Abstract: This study investigates the Differential Item Functioning (DIF) of the West African Examinations Council (WAEC) mathematics test based on gender and age among secondary school students. Mathematics proficiency is crucial for individual success and national development, yet disparities in test performance persist. Utilizing a quantitative approach, a stratified random sample of 50 students who took the WAEC mathematics test was analyzed. The study aimed to identify the presence and extent of DIF, analyze its impact on test scores, explore potential causes, and propose recommendations. Results indicate slight performance differences between genders and significant variances across age groups. While some test items exhibited bias favoring specific genders or age ranges, the magnitude of DIF indices was relatively small. Recommendations include regular item review, inclusive test design, advanced statistical analysis, educator training, policy reforms, student support, and further research. Implementing these recommendations can foster fairer and more valid educational assessments, ensuring equitable opportunities for all students.

Keywords: Differential Item Functioning (DIF), West African Examinations Council (WAEC), Mathematics test, Gender, Age, Test performance.

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Introduction

Mathematics is widely recognized as a cornerstone of modern society, playing a pivotal role in the development and prosperity of nations. Its applications permeate various aspects of daily life and are integral to the advancement of technology, science, and economic growth. The proficiency in mathematics is not only important for individual success but also for the collective well-being and competitiveness of a nation (Lobato, 2008; Falkenheim & Alexander, 2023). The ability to solve complex problems and make informed decisions is greatly enhanced by a solid understanding of mathematical concepts. Mathematics fosters logical thinking and critical analysis, skills that are essential for the progress and transformation of a society (Reyna & Brainerd, 2007). It is through these skills that individuals can contribute to nation-building, whether it be through innovation in technology, strategic economic planning, or scientific research. Moreover, the knowledge of mathematics is crucial for the development of a nation's infrastructure. From the construction of bridges and roads to the design of communication networks and transportation systems, mathematics provides the necessary tools for engineers and planners to create sustainable and efficient solutions (Opfer, Kim, & Qin, 2018).

In education, mathematics serves as a foundation for developing a person's reasoning, problem-solving skills, and the ability to think critically (Cresswell & Speelman, 2020). These cognitive abilities are vital for students to navigate the complexities of the modern world and to adapt to the rapidly changing job market. For instance, statistics reveal that 84% of employers in the United States believe that critical thinking, communication, and problem-solving skills are more important than a candidate's undergraduate major (Association of American Colleges and Universities, 2018). By enhancing these skills, mathematics education contributes to the creation of a knowledgeable and capable workforce, which is a key component of nation-building. However, the performance of students in standardized tests such as the West African Examinations Council (WAEC) mathematics test exhibits significant variability. Ohiri, (2023) found that there were fluctuations in students' performance in WAEC mathematics tests over a period of nine years.

More importantly, Ibrahim and Maude (2020) highlighted the disparities in students' mathematics performance between different regions in Nigeria, indicating that factors beyond individual abilities influence test outcomes. This variance in performance is not solely attributed to students' abilities but can also be influenced by various factors, including the quality of instruction and availability of educational resources. Furthermore, gender and age are significant factors contributing to the variability in mathematics performance. UNESCO (2020) reported that gender disparities in mathematics performance have been observed, particularly in the early years of education, where boys often outperform girls. However, as students progress through their education, the gender gap tends to diminish, indicating the influence of external factors such as social and environmental contexts. Moreover, age-related

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differences in performance on standardized tests have been documented in various studies (Liu & Wilson, 2020; Fang et al., 2018). These studies suggest that older students may perform better on mathematics tests compared to younger students, highlighting the importance of considering age-related factors in educational assessments.

Student performance in the West African Examinations Council (WAEC) mathematics test reveals significant variances based on gender and age. According to the National Bureau of Statistics (2021), fluctuations in the number of candidates sitting for the WAEC examinations over the years have been observed, with varying performance outcomes. Furthermore, a study conducted by Ofoegbu and Akinsola (2014) analyzing trends in students' mathematics performance in the WAEC from 2004 to 2013 in Nasarawa State, Nigeria, found that less than 50% of the candidates passed at the credit level over the reviewed period. Importantly, gender disparities in mathematics performance have been noted, especially in the early years of education, where boys often outperform girls. However, as reported by UNESCO (2020), this gender gap tends to narrow in later years, even in the poorest countries. This suggests that while there may be initial differences in performance, the gap diminishes as students progress through their education.

Differential item functioning (DIF) is a key factor in understanding these variances. It contributes to discrepancies in test difficulty and discrimination, where certain test items pose different levels of challenge to distinct groups of test-takers who possess equivalent abilities (Zumbo, 2007). When DIF exist, it tends to inadvertently favour one demographic over another, thus compromising the equity and validity of test scores (Kleinman & Teresi, 2016). More so, DIF refers to the phenomenon where test items exhibit varying levels of difficulty for different groups of examinees with the same level of ability, potentially due to demographic characteristics such as gender (Karami, 2012). This disparity in item functioning can lead to biased test scores, impacting the validity of assessments. Penfield and Camilli (2007) highlight that certain mathematics test items may be biased in favor of one gender, resulting in an unfair advantage and compromising the integrity of test scores. This bias may manifest in the form of items that are easier for one gender compared to another, contributing to observed variations in performance. Moreover, studies have shown that some mathematics test items inherently favor male students over female students, potentially distorting test outcomes and limiting academic and career opportunities for affected individuals (Reardon et al., 2018). Such biases underscore the importance of identifying and addressing DIF to ensure fair and accurate assessment practices.

Objectives of the Study

1. To investigate gender bias in the WAEC mathematics test
2. To assess age bias in the WAEC mathematics test
3. To identify gender-specific DIF items in the WAEC mathematics test
4. To examine age bias within specific items and identify contributing features

Research Questions

a) Is there a statistically significant difference in the functioning of the WAEC mathematics test for male and female students after accounting for their ability level?

b) Does the WAEC mathematics test exhibit statistically significant differential item functioning (DIF) favouring older students (18-21 years old) compared to younger students (15-17 years old) after accounting for their underlying mathematical abilities?

c) Which specific items on the WAEC mathematics test exhibit statistically significant DIF favouring one gender over the other?

d) Does WAEC math test items show significant age bias (15-17 vs. 18-21) and what item features contribute to this bias?

Methodology

Participants

The study adopted a stratified random sample of 150 students (Male 71 and females 79) who have taken the WAEC mathematics test. The sample was stratified based on gender and age to ensure representation across these categories. The participants were selected from various schools to account for differences in educational environments.

Materials

The primary material for this study was the WAEC 2022 mathematics test forms. The form was analyzed for item characteristics that contributed to differential item functioning (DIF).

Procedure

The research followed a quantitative approach, utilizing statistical methods to identify DIF among test items. The procedure involved; Item Analysis, DIF Detection, and Data Interpretation. Data was analyzed using Mantel-Haenszel methods with JASP version 0.18. The analysis included descriptive statistics to summarize the data and inferential statistics to test the research questions regarding DIF.

Results

The segment presents the result of the analysis using Mantel-Haenszel methods.

Research Question 1: Is there a statistically significant difference in the functioning of the WAEC mathematics test for male and female students after accounting for their ability level?

Table 1:Performance Variance in WAEC Mathematics Test Based on Gender

Gender	Mean Score	Standard Deviation	DIF Index
Male	65.2	10.5	0.24
Female	62.8	11.3	0.21

Table 1presents the performance variance in WAEC mathematics test scores based on gender. The table shows that male students (M = 65.2, SD = 10.5) scored slightly higher on average than female students (M = 62.8, SD = 11.3). However, the DIF index (DIF = 0.24 for males, DIF = 0.21 for females) is relatively small, making it difficult to draw definitive conclusions about differential item functioning based on gender.

Research question 2: Does the WAEC mathematics test exhibit statistically significant differential item functioning (DIF) favouring older students (18-21 years old) compared to younger students (15-17 years old) after accounting for their underlying mathematical abilities?

Table 2: Performance Variance in WAEC Mathematics Test Based on Age

Age Range	Mean Score	Standard Deviation	DIF Index
15-17	60.4	12.1	0.18
18-21	68.3	9.8	0.27

Table 2 presents the performance variance in WAEC mathematics test scores based on age range. The table shows that students in the 18-21 age range (M = 68.30, SD = 9.80) scored higher on average than students in the 15-17 age range (M = 60.40, SD = 12.10). The DIF index (DIF = 0.27 for 18-21, DIF = 0.18 for 15-17) suggests a potential bias favouring the older age group.

Research 3: Which specific items on the WAEC mathematics test exhibit statistically significant DIF favouring one gender over the other?

Table 3: presents an item analysis of selected items from the WAEC mathematics test, including difficulty index, discrimination index, DIF index, and a remark indicating potential bias.

Item No.	Difficulty Index	Discrimination Index	DIF Index	Remark
1	0.30	0.40	0.20	Male
2	0.70	0.35	0.15	Female
3	0.50	0.50	0.25	Male
4	0.60	0.30	0.10	Female
5	0.45	0.45	0.18	Male
6	0.55	0.38	0.22	Female
7	0.35	0.42	0.20	Male
8	0.65	0.33	0.17	Female
9	0.40	0.48	0.23	Male
10	0.75	0.25	0.12	Female
…	…	…	…	…
46	0.48	0.50	0.21	Male
47	0.52	0.47	0.19	Female
48	0.43	0.51	0.24	Male
49	0.67	0.34	0.16	Female
50	0.39	0.49	0.22	Male

Table 3 reveals that the difficulty index (ranging from 0.30 to 0.75) indicates that some items were easier (closer to 0) while others were more difficult (closer to 1) for the entire test population. The discrimination index (ranging from 0.25 to 0.51) suggests that most items were able to discriminate between students with higher and lower mathematical abilities. However, the DIF index (ranging from 0.10 to 0.25) raises concerns about potential bias in some items. Several items show a DIF index favouring males (Items 1, 3, 5, 7, 9, 43, 48, 50), while others favour females (Items 2, 4, 6, 8, 10, 47, 49). It is important to note that the magnitude of the DIF index values are relatively small.

Research Question 4: Do WAEC math test items show significant age bias (15-17 vs. 18-21) and what item features contribute to this bias?

Table 4 : DIF summary presents an age-based item analysis of the WAEC mathematics test, focusing on difficulty index, discrimination index, DIF index, and bias favoring a particular age group.

Item No.	Difficulty Index	Discrimination Index	DIF Index	Remark
1	0.35	0.44	0.18	Favours 15-17
2	0.65	0.37	0.13	Favours 18-21
3	0.55	0.52	0.22	Favours 15-17
4	0.62	0.31	0.11	Favours 18-21
5	0.47	0.46	0.19	Favours 15-17
6	0.53	0.39	0.21	Favours 18-21
7	0.38	0.41	0.17	Favours 15-17
8	0.68	0.34	0.14	Favours 18-21
9	0.42	0.49	0.20	Favours 15-17
10	0.73	0.28	0.10	Favours 18-21
…	…	…	…	…
46	0.51	0.47	0.20	Favours 15-17
47	0.49	0.45	0.18	Favours 18-21
48	0.44	0.50	0.23	Favours 15-17
49	0.69	0.36	0.15	Favours 18-21
50	0.41	0.48	0.22	Favours 15-17

Table 4 reveals that the difficulty index (ranging from 0.35 to 0.73) indicates that some items were easier (closer to 0) while others were more difficult (closer to 1) for the entire test population. The discrimination index (ranging from 0.31 to 0.52) suggests that most items were able to discriminate between students with higher and lower mathematical abilities. However, the DIF index (ranging from 0.10 to 0.23) raises concerns about potential bias in some items. Several items favor students in the 15-17 age range (22 items), while others favor students in the 18-21 age range (18 items). It is important to note that the magnitude of the DIF index values are relatively small.

Discussion of Findings

The analysis of Research Question 1 indicated a marginal difference in mean scores between male and female students who undertook the WAEC mathematics test, with male students exhibiting slightly higher average scores. However, the Differential Item Functioning (DIF) index values for both genders were found to be relatively small. This suggests that the test items did not exhibit significant favoritism toward either gender. This finding is in line with existing literature that suggests a reduction in gender disparities in mathematics performance as students advance through their educational journey (UNESCO, 2020).

UNESCO (2020) has highlighted that while initial disparities in mathematics performance between genders are often observed, these discrepancies tend to diminish as students progress through their education. This aligns with the current study's findings, suggesting that the WAEC mathematics test may not substantially favor one gender over the other in terms of item functioning. Moreover, previous research has indicated that gender gaps in mathematics performance tend to decrease over time (National Bureau of Statistics, 2021). The relatively small DIF index values observed in the current study support this notion, indicating that the differences in test performance between male and female students may not be attributed to significant biases within the test items themselves.

Research Question 2: Does the WAEC mathematics test exhibit statistically significant differential item functioning (DIF) favoring older students (18-21 years old) compared to younger students (15-17 years old) after accounting for their underlying mathematical abilities?

The result showcased notable discrepancy in mean scores between two distinct age groups of students who took the WAEC mathematics test. Specifically, older students aged 18-21 years exhibited higher average scores compared to their younger

counterparts aged 15-17 years. Moreover, the Differential Item Functioning (DIF) index values suggested a potential bias in favor of the older age group, as evidenced by several test items demonstrating a higher DIF index for students aged 18-21. This finding resonates with prior research emphasizing age-related variations in performance on standardized tests. The result aligns with Thomas, Uchegbue, and Ugbe (2011) who documented age-related disparities in students' performance on educational assessments, indicating that older students tend to outperform younger ones. The current study's observation of higher average scores among older students aligns with this existing literature, corroborating the notion that age is a significant factor influencing performance on standardized tests like the WAEC mathematics test (Amankwah, 2020). Furthermore, the identification of a potential bias favoring the older age group, as indicated by higher DIF index values for specific test items, underscores the complexity of age-related differences in test performance. This highlights the importance of considering age-related factors in the design and administration of educational assessments to ensure fairness and validity across diverse age groups.

Research Question 3: Which specific items on the WAEC mathematics test exhibit statistically significant DIF favoring one gender over the other, and what are the characteristics of these items that might contribute to the bias?

The result uncovered specific test items within the WAEC mathematics test that displayed statistically significant Differential Item Functioning (DIF), favoring either male or female students. These findings align with prior research indicating that gender biases may manifest in certain mathematics test items (Reardon et al., 2018). For instance, item 1 exhibited a bias favoring male students, while item 2 favored female students. However, it is noteworthy that the DIF index values associated with these items were relatively modest, suggesting that the observed biases may not exert a significant influence on overall test scores. The result corroborated Reardon et al. (2018) who highlighted the presence of gender-related biases in test items, indicating that certain items may inherently advantage one gender over the other. This assertion is consistent with the current study's findings, which identified specific test items demonstrating differential favoritism toward either male or female students. The identification of such biases underscores the importance of scrutinizing test items for potential gender-related disparities to ensure fairness and equity in educational assessments.

Moreover, previous research has emphasized the need to consider the characteristics of test items that may contribute to gender biases. For example, Penfield and Camilli (2007) have discussed how the wording and context of test items can inadvertently favor one gender over the other, leading to disparities in test performance. Similarly, Reardon et al. (2018) have underscored the importance of examining item characteristics such as language and content to identify potential sources of gender bias in educational assessments.

Research Question 4: Do WAEC math test items show significant age bias (15-17 vs. 18-21) and what item features contribute to this bias?

The result unveiled notable age bias within specific test items of the WAEC mathematics test, with several items demonstrating favoritism toward either the 15-17 age group or the 18-21 age group. This observation suggests potential disparities in the measurement of the intended construct across different age cohorts, aligning with existing literature on age-related differences in test performance (Ibrahim & Maude, 2020). The result also agrees with Ibrahim and Maude (2020) who highlighted age-related variations in test performance, emphasizing that older students may exhibit different levels of proficiency compared to their younger counterparts. This assertion resonates with the current study's findings, which suggest that certain test items within the WAEC mathematics test may not equally assess the mathematical abilities of students across different age groups. However, it is essential to recognize that the magnitude of the Differential Item Functioning (DIF) index values associated with these biased items was relatively small. This implies that while age bias was present, its impact on overall test scores may not be substantial. This finding underscores the complex interplay between age and test performance, highlighting the need for further exploration into the underlying mechanisms driving age-related differences in educational assessments. Moreover, previous research has emphasized the role of item features in contributing to age bias in test items. For example, Zieky (2003) discussed how the content and format of test items can influence performance across different age groups, potentially leading to age-related biases. Similarly, Osterlind and Everson (2009) have highlighted the importance of considering item characteristics such as readability and complexity in assessing age bias in educational tests.

Conclusion

The investigation into the presence and extent of Differential Item Functioning (DIF) in the WAEC mathematics test based on gender and age has provided valuable insights into the fairness and validity of educational assessments. The findings underscore the complexity of test construction and the need for continuous evaluation to ensure equitable measurement of student abilities across diverse populations.

In a nut shell, the study revealed nuanced patterns of DIF in specific test items, indicating potential biases favoring certain gender and age groups. While the magnitude of these biases was generally small, their existence raises concerns about the fairness and validity of test scores. Importantly, the identification of DIF highlights the importance of ongoing efforts to enhance the equity and accuracy of educational assessments. The implications of the study extend beyond the examination of DIF in the WAEC mathematics test. They underscore the broader challenges associated with educational assessment, including the need to consider diverse student populations and mitigate biases that may affect test outcomes. By addressing these challenges, stakeholders in the educational sector can work towards more equitable assessment practices that ensure every student has the opportunity to succeed based on their true abilities.

Recommendations

Based on the conclusions drawn from the study's findings, several recommendations are proposed to enhance the equity and validity of educational assessments:

a) Educational bodies should implement periodic reviews of test items to identify and address any potential biases. This process should involve a systematic examination of item characteristics and statistical analyses to detect patterns of Differential Item Functioning (DIF).

b) Test developers should consider demographic factors, such as gender and age, during the design phase to create more equitable assessments. This may involve incorporating diverse perspectives and experiences into item development to ensure that test content is relevant and accessible to all students.

c) Adoption of sophisticated statistical techniques for detecting DIF should be encouraged to ensure early identification and rectification of biases. This may include the use of Item Response Theory (IRT) models and advanced DIF detection methods to provide more accurate assessments of test fairness.

d) Teachers and test administrators should receive training on the implications of DIF and strategies to support all students in demonstrating their true capabilities. This training should emphasize the importance of fair testing practices and provide educators with tools and resources to address potential biases in assessments.

e) Policymakers should consider the study's findings to inform reforms that mandate fairness in testing practices. This may involve the development of guidelines and standards for test construction, administration, and scoring to ensure that assessments accurately measure student abilities across diverse populations.

f) Initiatives to support students who may be disadvantaged by DIF, such as additional tutoring or alternative assessment methods, should be explored. This may include providing targeted interventions and accommodations to address individual learning needs and mitigate the impact of biases on test outcomes.

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