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EVALUATION OF DIFFERENTIAL ITEM FUNCTIONING (DIF) IN 2017 WEST AFRICAN EXAMINATIONS COUNCIL (WAEC) PHYSICS MULTIPLE CHOICE TEST IN OSUN STATE, NIGERIA

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Abstract
The study established if the 2017 WAEC Physics multiple-choice items satisfied of unidimensionality and local independence assumptions of Item Response Theory (IRT). It also identified Physics test items that functioned differentially for male and female testees as well as items that functioned differentially among urban and rural examinees. The study adopted the descriptive survey research design. A sample of 720 senior secondary school III Physics students was used for the study using the multi-stage sampling procedure in Osun State. The research instrument used for data collection was an adopted 2017 WAEC's Physics multiple choice questions. The instrument showed a reliability coefficient of 0.85. *Data collected were analysed using the IRT package of R language and environment for statistical computing and Yen Q3 statistic. Results showed that 2017 WAEC Physics multiple-choice items were essentially unidimensional (maximum DETECT value = -0.30 (< .20), ASSI = -0.154 (< 0.25), and RATIO = -0.206 (< 0.36). Furthermore, none of the items violated the assumption of item local independence of IRT since the residual correlation coefficients among pairs of items were less than or equal to 0.2 as the benchmark. Finally, results showed that 12 items functioned differentially among male and female examinees (p< 0.05) while 20 items functioned differentially among urban and rural examinees at (p< 0.05). The study concluded that* 2017 *WAEC's Physics multiple choice questions possessed items that functioned differentially concerning gender and school location. The study recommended that DIF analysis of test items should be done and that items identified to be functioning differently should be revised, modified, or eliminated from the test before final administration to the examinees.*
Keywords: Differential Item Functioning (DIF), Physics, West African Examinations Council, multiple-choice items

Introduction

Tests are instruments designed to evaluate latent traits such as skills and abilities. They are used to elicit information about the latent ability of an individual and provide evidence for taking educational decisions about the individual test-taker. One of the major reasons for testing examinees is to produce scores which are often used in making important decisions such as selection, promotion, diagnosis, and certification among others (Emaikwu, 2011). However, these scores have to be standardized to reduce the error component and increase reliability. These standardized test scores are then usually used to make decisions about programmes and individuals such as evaluating the education quality, promoting students to a higher grade, recruiting new staff, and for promotional purposes. Test scores should therefore reflect the most accurate estimates of examinees' abilities and skills. According to National Policy on Education a document of the Federal Republic of Nigeria (2014), national examinations should be valid and fair to measure the attributes that are sought from the students for who the test intends to evaluate. Therefore, the need for public examination bodies such as West African Examination Council (WAEC), National Examination Council (NECO), and Unified Tertiary Matriculation Examination (UTME), to develop test items that are not only reliable and valid but must also be fair to all across the sub-group of examinees. To ensure test validity and test fairness, all items are expected to function similarly across different groups of people. However, Differential Item Functioning (DIF) exists when individuals with equal trait levels but from different groups perform differently on the same test item. This may occur due to the presence of irrelevant, non-target constructs which are related to gender, ethnicity, race, linguistic background, socioeconomic status or handicapping conditions, differences in upbringing environment, culture (Flores, 2000), and daily life experiences.

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Differential item functioning DIF exists in a test item when, despite controls for overall test performance, examinees from different groups have a different probability of getting an item correct or when students from two sub-populations with the same ability level have different expected scores on the same item (Penfield & Camilli, 2007). DIF of an item can therefore be understood as a lack of conditional independence between an item response and group membership (often gender, location, or ethnicity) given the same latent ability or trait (Ajeigbe & Afolabi, 2014). However, Ogbegor (2012) has reiterated that testees or test takers of the same latent trait or ability should respond to test items correctly irrespective of their gender, school location, and school type. The idea of gender also refers to the preconceived notions people have about the traits, skills, and likely behavior of men and women (femininity and masculinity) as individuals. Gender describes the social relation between males and females and the way it is socially constructed by society. Other factors that it interacts with include class, ethnicity, and religion (Chukwudi, 2019). School location describes the community in which a school is established. A school can be established either in urban (a city or town) or rural areas (a village or hamlet) depending on the interest and vision of the owner. Pedrajita, (2009) in a study "used logistic regression method to detect test items that function differently in Chemistry achievement based on gender. Owoyeye, (2002) also observed that there is a significant difference in the performance of students from rural and urban schools. Similarly, Shogbesan et. al. (2021) investigated the extent to which moderating variables such as sex and school type affect the occurrence of differential item functioning for compromised and secured Economics test items. Accordingly, they found out that the sex and school type of examinees had a moderating effect on the occurrence of differential item functioning (DIF) for 34 (56.7%) and 42 (70%) compromised and secured item conditions. In addition, the effect of compromised and secured items contributed more to the occurrence of DIF based on sex and school type of the examinees.

The West African Examinations Council (WAEC) is one of the public examination bodies that administer tests/examination questions in all subjects taught in secondary school from year to year. Students are expected to sit for the Senior School Certificate Examination (SSCE) at the end of their six years in secondary school. Apart from Mathematics and English language which are compulsory subjects for every student to pass, one of the core science subjects also expected to be passed by all science students in the SSCE is Physics. The inconsistencies in the performance of students in secondary school Physics has brought concern to researchers, scholars, parents, and guardians according to the annual release of the West Africa Senior School Certificate Examination results since the student's outcomes do not match both the governmental and parental investment most especially in senior secondary schools (Akinsolu, 2010). Regardless of the extensive research on the improvement of item and test evaluation procedures, empirical evidence of the disparities in test performance across sub-group of examinees continues to exist and it is well documented in the literature. Also, the presence of Differential Item Functioning (DIF) items in the test may lead to test bias. Therefore, it is very important to avoid bias which may unfairly influence examinees' test scores. These factors among others have drawn the attention of researchers towards providing a dependable solution to students' poor performance in Physics as a result of differential item functioning most especially in public examinations. To actualize the aim of the researchers, the following research questions were raised:

i. Do the 2017 WAEC Physics multiple-choice items satisfy unidimensionality and local independence assumptions of Item Response Theory (IRT)?
ii. Which of the items in the 2017 WAEC Physics multiple choice test functioned differentially by male and female examinees?
iii. Which of the items in the 2017 WAEC Physics multiple choice test functioned differentially by urban and rural examinees?

Methodology

The study adopted the descriptive survey research design. The population for the study comprised all secondary school Physics students in Osun State. A sample of 720 senior secondary school III Physics students was used for the study using the multi-stage sampling procedure. From each of the three senatorial districts in Osun State, three Local Government Areas (LGAs) were selected using a simple random sampling technique. From each of the selected LGAs, four public secondary schools (two urban, two rural) were selected using a stratified random sampling technique. The respondents were also stratified into male and female and each

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group (male and female) was finally selected using a simple random sampling technique. In carrying out the study, an adopted WAEC/SSCE Physics paper 2 questions used for 2017 examinations was used for data collection. The reliability coefficient of the instrument yielded a value of 0.89 Cronbach's Alpha which was considered appropriate and reliable. Data were analysed using equate IRT package (Battauz, 2015) of R language and environment for statistical computing version 3.6.2 (R Core Team, 2019) for appropriate descriptive and inferential statistics. The student's responses to each of the items were dichotomously scored (1 for the right option while 0 for the wrong option). Research question 1 was answered using the Stout's test and Yen Q3 statistics while research questions 2 and 3 were answered using the Wald-type test for Differential Item Functioning detection.

Results

Research Question 1: Do the 2017 WAEC Physics multiple-choice items satisfy unidimensionality and local independence assumptions of Item Response Theory (IRT)? The response of examinees was subjected to Stout's test of essential unidimensionality.

Table 1: Unidimensionality Assessment of 2017 WAEC Physics Multiple Choice Items

	Unweighted	Weighted
DETECT	-0.328	-0.328
ASSI	-0.154	-0.154
RATIO	-0.206	-0.206

Table 1 showed that the 2017 WAEC Physics multiple-choice items were essentially unidimensional (maximum DETECT value = -0.30 (< .20), ASSI = -0.154 (< 0.25), and RATIO = -0.206 (< 0.36)). Therefore the assumption of unidimensionality was not violated based on the criteria of essential dimensionality of a test on the following basis (0.20< Detect < 1.00, ASS < 0.25, RATIO < 0.36) according to Jang and Roussos, (2007) and Zhang (2007). These implied that one dominant dimension accounted for the variation observed in students' responses to the Physics test items. To address the issue of local independence assumptions of Item Response Theory in the above question, item local independence of the 2017 WAEC Physics multiple-choice items was estimated using correlation residual with Yen Q3 statistics and used for assessing the local independence of the 2017 WAEC Physics multiple data. Table 2 presents (an abridged) Yen Q3 statistics for the test.

Table 2: Item Local Independence of 2017 WAEC Physics Multiple Choice Items

ITEM	IT1	IT2	IT3	IT4	IT5	IT6	IT7	IT8	IT9	IT10
IT1	1.00									
IT2	-0.01	1.00								
IT3	0.05	0.00	1.00							
IT4	-0.07	-0.14	0.11	1.00						
IT5	0.04	0.02	0.10	0.14	1.00					
IT6	-0.01	0.00	-0.02	-0.10	0.13	1.00				
IT7	0.07	0.16	0.19	0.01	0.08	-0.03	1.00			
IT8	-0.02	0.12	0.02	0.1	0.01	-0.16	-0.04	1.00		
IT9	-0.07	-0.05	0.05	0.02	-0.09	0.01	0.05	-0.12	1.00	
IT10	-0.10	-0.02	0.10	0.12	0.03	0.12	0.15	-0.08	0.11	1.00
+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+
IT49	-0.01	0.05	0.12	-0.04	-0.15	-0.04	0.13	0.04	0.03	0.02
IT50	0.12	-0.05	0.04	-0.06	-0.04	-0.07	0.04	0.05	-0.08	0.03
~~ITEM~~	~~IT11~~	~~IT12~~	~~IT13~~	~~IT14~~	~~IT15~~	~~IT16~~	~~IT17~~	~~IT18~~	~~IT19~~	~~IT20~~
~~IT11~~	~~1.00~~									
IT12	0.03	1.00								

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IT13		-0.16	-0.05	1.00							
IT14		0.16	0.04	-0.01	1.00						
IT15		-0.00	0.09	0.16	-0.11	1.00					
IT16		-0.09	-0.11	0.18	0.08	0.06	1.00				
IT17		0.03	0.15	0.13	0.01	-0.07	-0.12	1.00			
IT18		0.14	0.12	-0.10	0.05	0.05	-0.17	0.095	1.00		
IT19		0.14	0.05	-0.04	-0.15	-0.00	-0.03	-0.03	0.00	1.00	
IT20		0.13	-0.08	-0.06	-0.00	-0.06	-0.04	-0.03	-0.13	-0.05	1.00
+		+	+	+	+	+	+	+	+	+	+
+		+	+	+	+	+	+	+	+	+	+
IT49		0.14	0.07	-0.04	0.01	-0.09	0.02	0.13	-0.01	0.13	-0.08
IT50	-0.03	-0.08	0.16	-0.04	-0.08	0.09	-0.13	0.00	0.127	0.05	-0.10

ITEM	IT21	IT22	IT23	IT24	IT25	IT26	IT27	IT28	IT29	IT30
IT21	1.00									
IT22	0.09	1.00								
IT23	0.09	0.08	1.00							
IT24	0.04	0.07	0.09	1.00						
IT25	-0.07	-0.01	0.06	-0.11	1.00					
IT26	-0.10	0.09	0.08	-0.02	0.14	1.00				
IT27	0.11	0.14	0.10	0.18	-0.04	-0.005	1.00			
IT28	0.12	0.05	0.10	0.02	-0.00	-0.02	0.16	1.00		
IT29	0.13	-0.02	-0.03	-0.03	0.09	0.09	-0.13	0.09	1.00	
IT30	0.10	0.12	-0.05	0.03	-0.09	0.13	-0.00	-0.04	-000	1.00
+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+
IT49	0.12	0.03	-0.03	-0.12	0029	0.14	0.01	-0.05	0.12	0.07
IT50	0.17	0.04	0.05	-0.04	-0.06	-0.01	-0.02	-0.15	-0.01	-0.07

ITEM	IT31	IT32	IT33	IT34	IT35	IT36	IT37	IT38	IT39	IT40
IT31	1.00									
IT32	-0.04	1.00								
IT33	0.02	-0.09	1.00							
IT34	0.03	-0.02	0.02	1.00						
IT35	-0.15	0.06	0.00	0.01	1.00					
IT36	0.06	0.08	-0.08	0.00	0.17	1.00				
IT37	0.42	0.04	-0.07	0.07	0.061	0.06	1.00			
IT38	-0.16	0.08	-0.02	-0.11	-0.06	0.08	0.02	1.00		
IT39	0.10	0.04	-0.05	-0.01	-0.11	-0.03	0.02	0.06	1.00	
IT40	0.01	-0.02	-0.03	0.12	0.15	0.11	0.02	0.03	0.05	1.00
+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+
IT49	0.07	-0.06	0.14	0.14	0.08	-0.15	-0.09	-0.14	0.02	0.03
IT50	-0.07	-0.16	-0.06	-0.11	0.16	0.05	-0.18	0.05	-0.12	-0.06

ITEM	IT41	IT42	IT43	IT44	IT45	IT46	IT47	IT48	IT49	IT50
IT41	1.00									
IT42	-0.14	1.00								
IT43	0.04	0.06	1.00							
IT44	-0.08	-0.10	-0.11	1.00						
IT45	0.04	0.00	0.04	-0.04	1.00					
IT46	-0.09	0.02	0.03	-0.07	-0.05	1.00				
IT47	-0.12	0.11	-0.00	0.16	-0.05	0.05	1.00			
IT48	-0.11	-0.06	-0.11	0.044	-0.07	0.01	-0.13	1.00		
IT49	0.03	-0.08	0.13	-0.07	0.05	-0.06	0.04	-0.03	1.00	
IT50	-0.06	0.07	-0.10	-0.12	0.01	0.00	0.06	-0.12	-0.04	1.00

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Legend: IT = Item

Table 2 showed the correlation item residual of item local independence of the 2017 WAEC Physics multiple-choice items. The results showed that the residual correlation coefficients among pairs of items were less than or equal to 0.2. This implied that none of the items violated the assumption of item local independence of IRT.

Research Question 2: Which of the items in the 2017 WAEC Physics multiple choice test functioned differentially by male and female examinees?

To answer this research question, the responses of the examinees were subjected to differential item functioning as the sex of the candidates was used as the grouping variable. The DIF analysis adopted was the Wald-type test for Differential Item Functioning detection. The result was presented in Table 3.

Table 3: Differential item functioning of 2017 WAEC Physics multiple choice question based on male and female examinees

Item	Wald Statistic	p.value	Remark	Item	Wald Statistic	p.value	Remark
1	5.425	0.066	No DIF	26	1.215	0.545	No DIF
2	1.733	0.420	No DIF	27	18.154	0.000	DIF
3	1.454	0.483	No DIF	28	0.746	0.689	No.DIF
4	2.091	0.351	No DIF	29	1.362	0.506	No DIF
5	2.894	0.235	No DIF	30	8.519	0.014	DIF
6	1.124	0.570	DIF	31	2.917	0.233	No DIF
7	8.360	0.015	No DIF	32	12.742	0.002	DIF
8	2.521	0.284	No DIF	33	2.631	0.268	No DIF
9	0.797	0.671	No DIF	34	0.304	0.859	No DIF
10	0.693	0.707	No DIF	35	1.658	0.436	No DIF
11	3.073	0.215	No DIF	36	3.665	0.160	No DIF
12	6.720	0.035	DIF	37	1.966	0.374	No DIF
13	2.781	0.249	N o DIF	38	9.856	0.007	DIF
14	5.278	0.080	No DIF	39	2.647	0.266	No DIF
15	13.528	0.000	DIF	40	1.559	0.459	No DIF
16	6.623	0.036	DIF	41	7.829	0.020	DIF
17	7.160	0.028	DIF	42	2.112	0.348	No DIF
18	2.624	0.269	No DIF	43	2.683	0.261	No DIF
19	5.748	0.056	No DIF	44	6.107	0.047	DIF
20	2.499	0.287	No DIF	45	0.294	0.863	No DIF
21	3.502	0.174	No DIF	46	3.543	0.170	No DIF
22	0.778	0.678	No DIF	47	1.157	0.561	No DIF
23	5.429	0.066	No DIF	48	3.126	0.210	No DIF
24	7.592	0.022	DIF	49	2.022	0.364	No DIF
25	3.638	0.162	No DIF	50	1.137	0.566	No DIF

Table 3 showed the differential item functioning of the 2017 WAEC Physics question concerning the sex of the examinees. The Table showed that 12 items (items 7, 12, 15, 16, 17, 24, 27, 30, 32, 38, 41, and 44) functioned differentially among male and female examinees at ($p < 0.05$) as a benchmark. The result implied that the 12 items measured the Physics proficiency of the examinees differently among male and female examinees.

Research Question 3: Which of the items in the 2017 WAEC Physics multiple choice test functioned differentially by urban and rural examinees?

To answer this research question, the responses of the examinees were subjected to differential item functioning as the school location of the candidates was used as the grouping variable. The result was presented in Table 4.

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Table 4: Differential item functioning of 2017 WAEC Physics multiple choice question based on school location

Item	Wald Statistic	P.value	Remark	Item	Wald Statistic	p.value	Remark
1	12.425	0.002	DIF	26	7.880	0.089	No DIF
2	1.901	0.387	No DIF	27	14.384	0.001	DIF
3	0.875	0.646	No DIF	28	5.821	0.054	No.DIF
4	18.826	0.000	DIF	29	13.051	0.001	DIF
5	1.972	0.373	No DIF	30	12.805	0.002	DIF
6	1.589	0.452	No DIF	31	7.505	0.073	No DIF
7	4.757	0.093	No DIF	32	16.370	0.001	DIF
8	17.602	0.000	DIF	33	19.603	0.000	DIF
9	3.323	0.190	No DIF	34	6.819	0.080	No DIF
10	1.513	0.469	No DIF	35	5.103	0.078	No DIF
11	0.259	0.003	DIF	36	2.780	0.249	No DIF
12	1.952	0.878	No DIF	37	0.000	1.000	No DIF
13	4.503	0.105	No DIF	38	7.061	0.059	No DIF
14	0.297	0.862	No DIF	39	7.456	0.074	No DIF
15	48.025	0.000	DIF	40	3.760	0.153	No DIF
16	4.055	0.132	No DIF	41	15.421	0.000	DIF
17	20.160	0.000	DIF	42	5.674	0.059	No DIF
18	12.624	0.002	DIF	43	49.162	0.000	DIF
19	9.857	0.070	No DIF	44	2.899	0.235	No DIF
20	10.228	0.006	DIF	45	14.744	0.001	DIF
21	20.891	0.000	DIF	46	42.988	0.000	DIF
22	1.993	0.292	No DIF	47	0.106	0.949	No DIF
23	1.900	0.284	No DIF	48	0.000	1.000	No DIF
24	10.592	0.028	DIF	49	8.835	0.012	DIF
25	2.557	0.278	No DIF	50	6.246	0.064	No DIF

Table 4 showed the differential item functioning of the 2017 WAEC Physics question concerning the school location of the examinees. The Table showed that 20 items functioned differentially among urban and rural examinees. The items were: item 1 (Wald statistics = 12.425, p = 0.002 < 0.05); item 4 (Wald statistics = 18.826, p = 0.000 < 0.05) e.t.c These results showed that item 1, 4, 8, 11, 15, 17, 18, 20, 21, 24, 27, 29, 30, 32, 33, 41, 43, 45, 46 and 49 functioned differentially concerning school location of the examinees (at $p < 0.05$). The result implied that the 20 items measured the Physics proficiency of the examinees differently among examinees whose schools were located in rural and urban areas.

Discussion

The findings from the assessment of the assumption of dimensionality showed that the 2017 WAEC Physics multiple choice test was unidimensional; one dominant ability accounted for the variations observed in the performance of the sampled candidates who took the 2017 WAEC Physics multiple choice test. However, the findings contradicted the finding of Oguoma, Metibemu, and Okoye (2016) who assessed the dimensionality of the 2014 West African Secondary School Certificate Examination Mathematics objective test items and found that the test is multi-dimensional. Also, findings from the local independence assessment showed none of the items violated the assumption of item local independence of item response theory. The finding negates the study of Alade, Aletan, and Sokenu (2018) who found that some of the 2018 West African Secondary School Certificate Examination Mathematics multiple-choice tests violated the assumption of local independence. However, the result is on the contrary to that of Shogbesan et. al. (2020) which indicated that *given the secured and pre-known conditions of test items, 5 pairs of items comprising 6 pre-known items and 1 secured item exhibited local item dependence for the Form A of the Economics Achievement Test while only 1 pair of item comprising 1 pre-known and 1 secured item exhibited local item dependence for Form B. However, the 6 pre-known items in the Form A did not exhibit local item dependence when they were secured in the Form B. Hence, the item conditions may influence the occurrence of* local item dependence.

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Furthermore, findings showed that items functioned differentially concerning gender which implied that those items measured the Physics proficiency of the examinees differently among male and female examinees. The finding of this study agreed with the findings of Adedoyin (2010), who in his study investigated gender-biased items in public examinations, and found that out of 16 items that fitted the 3PL item response theory statistical analysis, 5 items were gender biased. The findings correlated with the results of Omorogiuwa and Iro-Aghedo (2016), who did a similar study on 2015 NABTEB multiple-choice Mathematics that seventeen items out of fifty multiple choices Mathematics items functioned differently by gender. The finding also agreed with that of Adebule (2013) that out of the 40 items examined for the first-factor programme structure in computer science, only seven items displayed DIF, comparing male and female examinees. This study also correlated with the findings of Madu (2012) who investigated differential item functioning (DIF) by gender in Mathematics examination conducted by the West African Examinations Council (WAEC) in 2011 in Nigeria. Using a sample of students and Scheuneuman Modified Chi-square Statistics (SSχ2), the results of the analysis indicated that items significantly function differentially for male and female examinees while 11 items did not exhibit DIF in that study. Also, the findings are in tandem with the findings obtained by Shogbesan et. al. (2021) which indicated that sex and school type of examinees had a moderating effect on the occurrence of differential item functioning (DIF) for both secured and compromised item conditions.

Finally, findings showed that items functioned differentially concerning the school location of the examinees. The result implied that those items measured the Physics proficiency of the examinees differently among examinees whose schools are located in rural and urban areas. The finding supported that of Uwhekadom (2014), who reported in a study that chemistry multiple choice questions used by WAEC, in 2009, 2010, and 2011 SSCE contains test items that significantly functions differentially for students of different gender, high, and low socio-economic status, urban and rural geographical location test takers. The findings imply that this DIF tendency is not specific to questions or items used by WAEC alone, since other public examinations contain test items with similar characteristics. The finding agreed with the result of Ogbebor and Onuka (2013), which showed that the National Examination Council (NECO) Economic questions for 2010 had 18 items that functioned differentially for examinees based on school type and school location. This further corroborates the finding of Oladele, Adegoke, and LongJohn (2020) that both WAEC and NECO mathematics tests item exhibited DIF concerning gender under CTT and IRT frameworks.

Conclusion

The study concluded that the 2017 WAEC Physics multiple choice test possessed items that functioned differentially concerning the sex and school location of examinees. However, this DIF tendency is not specific to questions or items used by WAEC alone, also other public examinations such as NECO and NABTEB had similar characteristics. The study, therefore, recommended that WAEC and other public examination bodies should make an effort to ensure that test items in standardized tests are free of DIF across factors such as rural-urban, gender, and ethnicity. Also, items identified to be functioning differently should be revised, modified, or eliminated from the test.

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