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ANALYSIS OF MULTIPLE-CHOICE ITEM FORMATS AND SECONDARY SCHOOL STUDENTS' ACHIEVEMENT IN MATHEMATICS IN AKWA IBOM STATE, NIGERIA

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Abstract

Although multiple-choice item formats are the most widely used test items by examination bodies, but have been observed to produce poor achievements especially in secondary school mathematics. In order to identify the multiple-choice item formats that could improve students' achievements, this study examined the three types of multiple-choice item formats and their effects on secondary school students' achievements in mathematics. The descriptive survey design was deployed for the study. The research instruments were the three types of multiple-choice test item formats namely, direct question type (DQT), incomplete statement type (IQT) and best answer type (BAT). Each of these formats comprised 50 multiple-choice mathematics achievement test items (MAT) based on the JSS2 mathematics syllabus. A total of 654 JS3 students comprising 332 males and 322 females using multi-stage sampling procedure from 30 secondary schools. Of the 30 secondary schools,19 were randomly selected from urban and 11 from rural areas of Akwa Ibom State. 22 students were selected from each school. Data obtained were analysed using one-way and two-way ANOVA. Hypotheses were tested at $p<0.05$ level of significance, and the results show that multiple-choice item formats significantly influenced secondary school students' achievement in mathematics. The study identified DQT as producing the utmost achievement compared to IQT and BAT irrespective of school location and students' gender. Hence, it was recommended that, DQT format should take preference when constructing multiple-choice mathematics tests for junior secondary school students.

Keywords: Multiple-choice, Item formats, Achievement, Mathematics, Students

Introduction

Mathematics is the science of reasoning and computations that deal with numbers, quantities and shapes. Mathematics expresses scientific facts using formulae, and shows the interdependence of variables in our environment. It helps to develop patterns that can modify events and situations in the ecosystem. Brown and Porter (2011), Khusna and Heryaningsih (2018) describe mathematics as the language that can be used to conceptualize relationships in the environment. Mathematics enables people to make the invisible to be visible and solve problems that are seemingly impossible. These link it with other subjects, particularly in science and technology. It develops flexibility in thinking that allows society to tackle contemporary issues such as turning human faeces into cooking energy and electricity (Evans, Umoh, James & Hilary, 2019).

In Nigeria, mathematics is a compulsory subject at the formative stages of primary and post-primary education. This is why the poor mathematical background at the formative stage has become a point of focus for researchers who are insistent on proffering solutions to the problem of poor students' achievement in mathematics. Haberman, (2011); Asim, Ekuri and Eni (2013); Tata (2013); Eduwem and Umoinyang (2014) identified the following as some of the factors influencing students' achievement in mathematics: motivation, class attendance, class size, subject matter, study time, teaching methods, external activities, test formats, student's interest toward mathematics, and the use of library materials. Various efforts have been made to reverse the persistent weak students' achievement in mathematics. Rutayuga and Amiri (2005); Lindberg, Hyde and Peterson (2010); Sa'ad, Adamu and Sadiq (2014); Eduwem and Umoinyang (2014); Evans (2014), Thawabieh, (2016) traced students' achievement in mathematics to their inability to understand the test items. Evans, Ekpofia and Thompson (2019) noted that students' primary school background is a significant influence.

Test formats for measuring students' achievements in a given subject such as mathematics range from recitation of memorised materials; giving oral answers to written questions, multiple-choice questions; matching of items; true/false; short answers to essay questions which require open-ended responses. E-based and computer-based tests adopt the multiple-choice item format for achievement tests (Bontis, Hardie & Serenko, 2009; Memon, Jough & Memon, 2010; Haberman, 2011; Mahta & Mokhasi, 2014). This has made multiple-choice test more popular than other test formats.

The persistently low achievement of students in secondary school mathematics motivated the researchers to examine test item formats as a possible explanation for the weak achievement in mathematics. It is believed that examinees' achievement will improve if they have a good understanding of test items. Therefore, identifying the multiple-choice item types easily understood by students could address the poor

achievement in mathematics. Test items are structured in different formats such as short answer questions, restricted essays, extended essays, matching items, completion, true or false and multiple-choice questions (Joshua, 2005;Memon, Jough & Memon, 2010; McAllister & Guidice, 2012). Asim et al. (2013) classified test formats as essay types and objective-test types. The essay types were further classified into restricted and extended response types; whereas, objective test format was grouped into selection test type and the completion test type. The completion test type consists of filling the gap and giving short answers, while the selection test type comprises true/false test items, matching test items and multiple-choice test types. Asim et al. (2013) further grouped multiple-choice test formats into direct question type (DQT), indirect question type (IQT) and best answer type (BAT).These multiple-choice test types are combined when testing students' achievement while the dominating formats would influence the overall achievement (Higgins & Tatham, 2003; Hendra, 2014;Schladitz, Groß-Ophoff & Wirtz, 2017).Literature has given little attention to candidates' achievement using the three multiple-choice test formats: DQT, IQT and BAT *(*Furnharm, Christopher, Garwood & Martin, 2008; Anikweze, 2010; Asim, *et al.,* 2013).The structural pattern of multiple-choice test types may probably have a way of influencing candidates' achievement either positively or negatively.

The following illustrates the three types of multiple-choice item formats:

Example	Direct Question Type	Incomplete Statement Type	Best Answer Type
1.	What is the inverse operation of add 8?	The inverse operation of add 8 is ……	One of the following currently shows the inverse operation of add 8.
2.	What is the place value of 4 in 7835.04?	The place value of 4 in 7835.04 is …….	Which of these is the accurate place value of 4 in 7835.04?

The role of sex in mathematics achievement test has been reported in a variety of studies. Boli, Allen & Payne (1985) explored sex differences and undergraduate students' achievement in mathematics and discovered that, male students' performed better than the females. Hudson (2012) combined multiple-choice item formats and short answer items to investigate the relationship between sex, question type and question content. The study used 192 SS 3 students from four secondary schools in Australia. The result showed that male students significantly outperformed their female counterparts.

Ajai and Imoko (2015) assessed sex differences in mathematics achievement and retention using problem-based learning (PBL). The pre-post-test quasi-experimental design was used for the study, which 261 male and 167 female students were selected using multistage sampling procedure. All the students were taught algebra and tested using PBL. The study revealed that, male and female students did not differ significantly

in academic achievement and retention. From the foregoing, gender and achievement in mathematics is contentious as some results indicate male candidates outperforming their female colleagues and vice versa. Some studies report no gender disparity in mathematics achievement. It is, therefore, of interest to investigate the effects of gender on students' achievement in the three multiple-choice item formats.

School location denotes the geographical area, urban or rural, in which a school is situated. While urban schools may be exposed to modern learning techniques, they tend to be faced with the challenge of large students' population, overcrowding and environmental pollution. Rural schools may not be exposed to modern learning techniques, but they operate in a near natural environment which tends to encourage leaning. School location should have a way of influencing students' achievement. Ezewu (cited in Ovat, 2009); Gajjar, Sharma, Kumar and Rana (2014); Martin and Itter (2014) discovered that children from rural settlements were not able to write and speak English like those from urban areas. This is in contrast with their counterparts who were brought up in literate homes and were able to speak English before going to school. It appears one cannot expect the academic performance of the two sets of children to be the same in a standard examination. The present study investigates students' achievement in mathematics across the three types of multiple-choice question formats using 50 mathematics test items for each of the multiple-choice types. Location of school and students' gender are important variables considered in the study because of their observed impact on students' academic performance (Owoeye 2011; Akubuiro 2002; Evans, 2014; Mukherjee & Lahiri, 2015).

The constantly changing technology has greatly influenced the ease of assessing large numbers of learners. This has made the multiple-choice test format the most favoured of available test formats. However, its increasing use by most examination bodies tends to synchronize with increasing poor students' achievement in mathematics. Since there are three types of multiple-choice test formats, it is necessary to assess students' achievement in the various multiple-choice test types in order to identify the one that could improve students' achievement in mathematics irrespective of gender and the location of the schools.

Research Hypotheses

1. Students' achievement in multiple-choice mathematics tests is not significantly influenced by item formats (DQT, IQT and BAT).
2. Male and female students do not differ significantly in achievement in the different multiple-choice mathematics test item formats.
3. Students' achievement in mathematics does not differ significantly among urban and rural schools based on the different multiple-choice test item formats.

Methods

The descriptive survey design was adopted for the study. The focus population was the Junior Secondary III students comprising male and female from urban and rural schools in Akwa Ibom State. The study adopted stratified random sampling to select secondary schools from the three senatorial districts of the state. The senatorial districts were considered as the bases for stratification. This gives three major strata with a total of 385 public and government accredited private secondary schools in the state. This was followed with the proportionate sampling technique which was deployed to determine the number of representative schools from each senatorial district.

Schools in the study area (Akwa Ibom State) were stratified based on the three senatorial districts. The researchers decided to use 30 schools for the study. Within each senatorial district, the proportionate sampling was deployed to select the number of participating schools as shown below:

Uyo: $\frac{153}{385}$ x 30 = 12

Eket: $\frac{97}{385}$ x 30 =8

Ikot-Ekpene: $\frac{135}{385}$ x 30 =10

Schools in each senatorial district were stratified into rural and urban, such that a total of 19 urban schools and 11 rural schools were selected. 22 students in each selected school were chosen through systematic random sampling technique. The study adopted stratified sampling as the basis for selecting participating students based on gender such that 332 male and 322 female students were selected. A total of 660 students were randomly selected from 30 secondary schools to form the sample size. The statistical basis for using the above sample size is in accordance with Krejcie and Morgan (1970); Ukwujie and Opera (2012) and Idaka (2015) who provided scientific means of computing the minimum sample size (n) to justify the precision of any study of a known population as:

$$n = \frac{x^2 NP(1-P)}{d^2(N-1) + x^2 P(1-P)}$$

Where $x^2$is the table value of Chi-Square at 1degree of freedom for the desired confidence level (0.05), N is the population size, P is population proportion (assumed to be 0.50) and d is degree of accuracy (expressed as a proportion (0.05). According to the researchers, for a population of 15,000, the minimum sample size of 375 is enough to produce valid results.

The instruments for data collection in the study were three 50-item multiple-choice Mathematics Achievement Tests (MAT) designed in the DQT, IQT and BAT formats respectively using the JSS2 mathematics syllabus. Every item has four options for the students to make their independent choices. It was necessary to use the JSS2 syllabus because of the assumption that every JSS3 student must have adequately covered the JSS2 syllabus. The following topics were randomly selected to cover one-tenth of the entire JSS2 mathematics syllabus: whole numbers, indices and standard form, plane figures and shapes, angles, inverse and identity, algebraic expression, home and office transactions, fraction, proportion, ratio, rate, and equations. The number of questions on each topic was determined using a table of specification. The research instrument was validated by experts for face and content validity. Each item had one correct option (key) and three distractors. The correct option was scored 1 mark, while every distractor was scored zero. The responses from a total of 654 JSS2 students selected across the study area were analysed and interpreted using one-way ANOVA and 2-way ANOVA to achieve the aim of the study.

Results

The results are presented in the order of the stated hypotheses as follows:

Hypothesis 1:

Students' achievement in multiple-choice mathematics tests is not significantly influenced by the item formats (DQT, IQT and BAT).

The distribution of students' achievement at the three multiple-choice mathematics item formats is shown on Table 1. The influence of item formats on students' mathematics achievement in the direct question type (DQT), incomplete statement type (IQT) and best answer type (BAT) was determined by a one-way analysis of variance (ANOVA). Table1 shows different group sizes, means, standard deviations, minimum and maximum scores for each of the item formats. The table also shows that the F- ratio of the ANOVA, F-ratio = 25.17, is significant at alpha < 0.05. This was interpreted to mean that students' achievement in multiple-choice mathematics test is significantly influenced by the multiple-choice mathematics item format used (DQT, IQT or BAT). A comparison of the mean scores for multiple-choice item formats shows that 221 students wrote the test

with the DQT mathematics item format and made a mean score of 48.19; 218 students wrote the test with the IQT mathematics item format and attained a mean score of 40.59, while 215 students responded to the BAT mathematics item format and got a mean score of 38.50. This shows that the students had their highest achievement in DQT item format, followed by the IQT and the BAT format in that order. Figure 1 gives a quick interpretation of students' achievement in the three multiple-choice item formats. The frequency distribution of students' achievement in each multiple-choice test type is presented in Figure 2in which DQT tends to be normally distributed, while IQT and BAT tend to be positively skewed. This showed that most of the respondents performed below average in IQT and BAT.

Table 1: One-way ANOVA of the influence of item formats on st udents' mathematics achievement

Item Format	N	Mean	Std. Deviation	Std. Error	Lower Bound	Minimum	Maximum
DQT	221	48.19	16.00625	1.07670	46.0681	20.00	86.00
IQT	218	40.7248	14.96686	1.01368	38.7268	18.00	80.00
BAT	215	38.5023	13.80162	0.94126	36.6470	18.00	70.00
Total	654	42.5168	15.50652	0.60635	41.3262	18.00	86.00

Sources of variation	SS	Df	MS	F-ratio	Sig.
Between Groups	11388.337	2	5694.169	25.17*	0.000
Within Groups	147276.611	651	226.231		
Total	158664.948	653			

P < 0.05

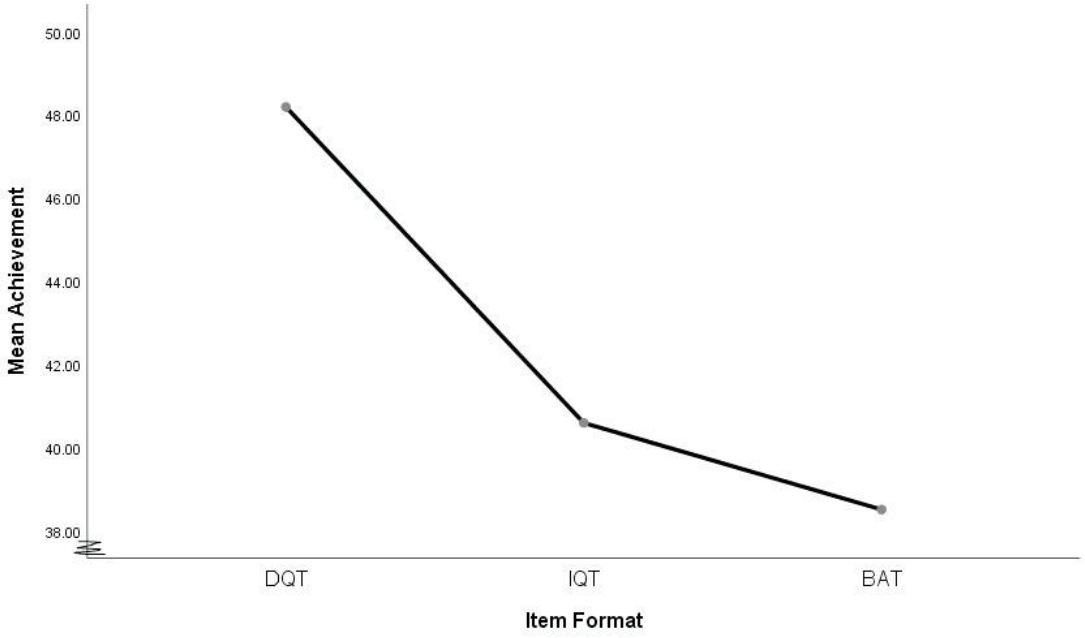

Figure 1: A plot of students' mean achievement in multiple-choice mathematics item formats

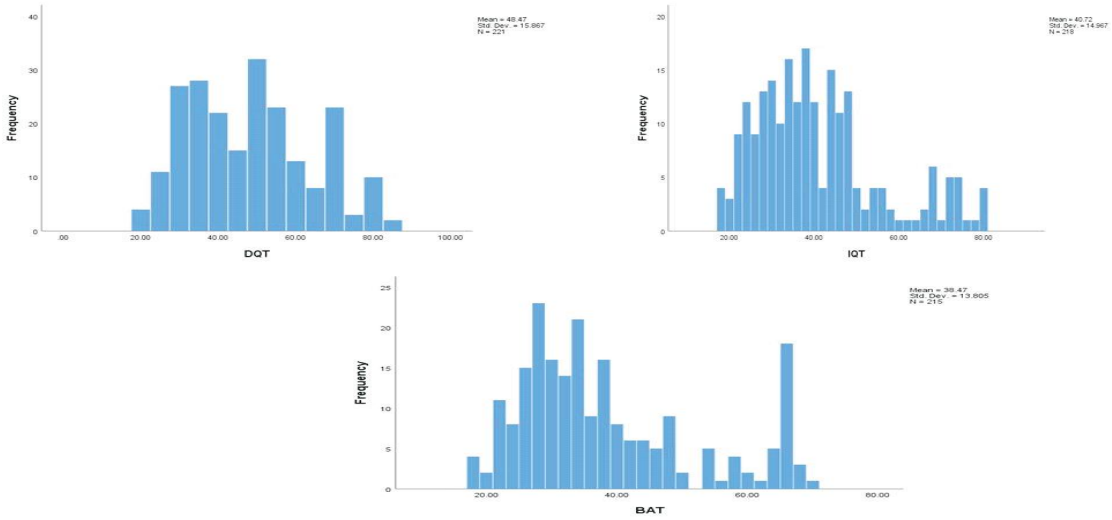

Figure 2: Students' Achievement in the three multiple-choice mathematics item tests

Based on the observed significant difference in achievement among the three multiple-choice item formats, a post hoc multiple comparison analysis was conducted. The result is presented in Table 2.

Table 2: Scheffe's post hoc pair comparison analysis of the influence of multiple-choice mathematics item formats on students' achievement

Dependent variable	Item format	Mean Difference	Std Error	Sig
DQT	IQT	7.47*	1.43	.000
	BAT	9.69*	1.43	.000
IQT	DQT	-7.47*	1.28	.000
	BAT	2.22	1.44	.123
BAT	DQT	-9.69*	1.43	.000
	IQT	-2.22	1.44	.123

*The mean difference is significant at 0.05 level.

Hypothesis 2:

Male and female students do not differ significantly in achievement across the different multiple-choice mathematics test item formats.

The result for the influence of gender on achievement across the three multiple-choice item formats is contained in Table 3.

Table 3: Two -way ANOVA of the influence of gender on achievement in multiple-choice mathematics test

Item Format	Gender	N	Mean	Std. Deviation
DQT	Male	121	52.5455	15.65886
	Female	100	42.92	14.86211
	Total	221	48.19	16.00625
IQT	Male	105	43.5619	16.5738
	Female	113	37.823	13.2922
	Total	218	40.5872	15.202
BAT	Male	106	42.1604	15.03972
	Female	109	34.945	11.47286
	Total	215	38.5023	13.80162
Total	Male	332	46.3886	16.40342
	Female	322	38.4317	13.58635
	Total	654	42.4709	15.58777

Source of Variation	SS	Df	MS	F-ratio	Sig.	Partial Eta Squared
Item Format	10043.158	2	5021.579	23.646*	0.000	0.068
Sex	9228.636	1	9228.636	43.456*	0.000	0.063
Item Format * Sex	420.329	2	210.165	0.99	0.372	0.003
Error	137613.611	648	212.367			
Total	1338338	654				

$P < 0.05$; df=1,2 and 648

This result shows a significant difference between male and female students' achievement in the three formats of multiple-choice mathematics items. It indicates that the F-ratio for the 2-way interaction of item formats and sex is not significant at 0.05 levels, while the two factors (sex and item format), taken separately, are significant at 0.05 levels. Further description of the variation of students' achievement at the various types of multiple-choice tests with students' sex is shown in Figure 3.

Hypothesis 3:

Students' achievement in mathematics does not differ significantly in urban and rural schools based on the constructed multiple-choice test item formats.

The result of the influence of school location on students' achievement in the three multiple-choice mathematics item formats presented in Table 4shows that the geographical location of schools has influence on students' achievement in the three types of multiple-choice tests .The result reveals that students from urban schools achieve more than those from rural schools in the three types of multiple-choice test formats. Figure 4 is a graphical representation of variation of students' achievement based on school location. The mean achievements for students of urban and rural schools at the various multiple-choice item types are shown on the graph.

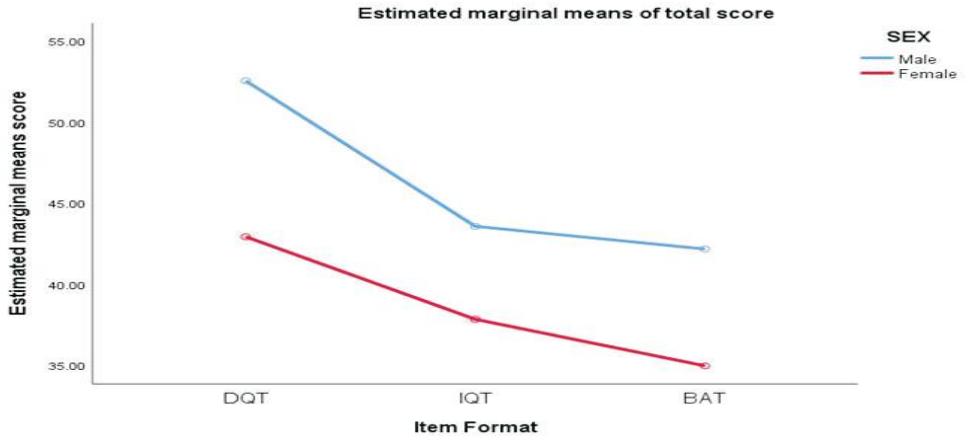

Figure 3: A plot of mean achievement against test item formats by students' sex interaction

Table 4: Two -Way ANOVA of school location and students' achievement in multiple - choice item formats in mathematics

Item Format	School Location	N	Mean	Std. Deviation
DQT	Urban	156	51.7179	15.51099
	Rural	65	39.7231	13.95921
	Total	221	48.19	16.00625
IQT	Urban	123	43.6585	15.78692
	Rural	95	36.6105	13.47993
	Total	218	40.5872	15.202
BAT	Urban	133	40.6466	14.99454
	Rural	82	35.0244	10.81948
	Total	215	38.5023	13.80162
Total	Urban	412	45.7379	16.13007
	Rural	242	36.9091	12.85863
	Total	654	42.4709	15.58777

Source of variation	SS	Df	MS	F	Sig.	Partial Eta Squared
Item Format	6279.604	2	3139.802	14.915*	0.000	0.044
School Location	10111.621	1	10111.621	48.034*	0.000	0.069
Item Format * School Location	1066.703	2	533.351	2.534	0.08	0.008
Error	136409.195	648	210.508			
Total	1338338	654				

P < 0.05;df= 1,2 and 648

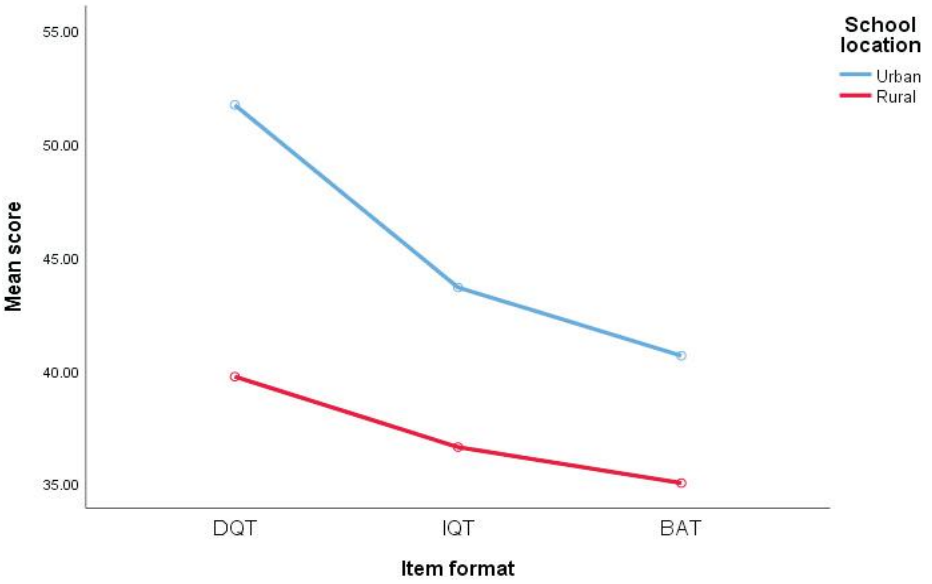

Figure 4: A plot of mean achievement against test item formats by school location

Discussion

The results make it apparent that students' achievement in mathematics is significantly influenced by the multiple-choice test types. The study shows that, students achieved better with the DQT item format followed by IQT and least with the BAT item format. Majority of the students achieved averagely at the DQT, while majority achieved below average at IQT and BAT. The reason could be that, DQT is much easier to construct and interpret and is frequently used by class teachers since it is the easiest of the multiple-choice item formats to construct when compared with IQT and BAT (Asim *et al.,* 2013).The students might have been more exposed to the DQT format than the IQT and BAT item formats. Obviously, the choice of an option from a list in a multiple-choice item test is influenced by the level of understanding and subsequent interpretations of the items. Going by this finding, one could say the more IQT and BAT formats in a mathematics test, the higher the likelihood of poor achievement by examinees. However, students' average achievement in the three multiple-choice test formats was below 50%.

The study also reveals that, students' achievement in the three multiple-choice formats was gender selective with the male students outperforming the female counterparts in all the three types of multiple-choice formats. This is a pointer to the fact that, on the average, female students are not as good as male students in mathematics; this might even translate to other subjects involving the application of mathematics. This result agrees with DiBattista and Kurzawa (2011); Buclcherr, Gurber and Bruhioler, (2011); Hudson (2011); Caldwell & Pate (2013) and Bassey, Joshua and Asim, (2014) who observed significant differences in male and female students achievement in mathematics. However, Ajai and Imoko (2015) discovered no significant difference in mathematics achievement based on the gender of students.

The result on the school location and achievement in the various types of multiple-choice tests indicates that students in urban schools achieved higher than students from rural schools in the three formats of multiple-choice items. The difference is so significant that the minimum achievement by urban schools is greater than the maximum scores by the rural schools. The female students were more negatively affected. It could be the presence government attention in urban schools through the provision of more learning infrastructures in urban schools than rural school that could influence the achievement. This is in agreement with Okon (2002); Akubuiro (2002); Joseph (2007); Caldwell & Pate (2013) and Omede (2015).

Conclusion and Recommendations

Students' achievement in multiple-choice mathematics items varies with the item formats. The maximum achievement was obtained with the DQT, while the least

achievement was obtained with BAT format. It was observed that male students achieved higher than female students in the three formats of multiple-choice items format. Students in urban schools achieved better than their counterparts in rural schools. Based on findings from this study, classroom teachersand educational authorities involved in students' testing using the multiple-choice format are advised to give preference to DQT to achieve desirable results. However, IQT and BAT should gradually be introduced to secondary school students especially during formative evaluation. This could provide students with the understanding of these types of multiple-choice item formats and enhance teachers' competency.

For the fact that mathematics is rooted in varies activities of man, imperative to use the DQT for testing students in irrespective of the location of the schools and students' sex. This is based on the relatively better achievement recorded with DQT. This recommendation does not undermine the gradual introduction of few IQT and BAT into test instrument by teachers. It is also important that government ministries and agencies with the oversight function of examining students should regularly vet teacher-made questions to ensure that multiple-choice test items are dominated by DQT items.

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