Influence of Gender and Environmental Factors on Students' Conceptions of Selected Mathematical Concepts in the Senior Secondary School Mathematics Curriculum

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Abstract: The study employed the survey design to assess secondary school students' conceptions of some basic mathematical concepts. The design consisted of four independent variables: gender (male and female), school location (urban and rural), school type (public and private), and school mode (boys, girls, and co-educational schools). The dependent variable was the students' right conceptions scores. The stratified random sampling technique was used to select 4332 students that adequately represented all the specific groups in the population. The reliability of the two-tier diagnostic multiple-choice instrument was established through the Kuder-Richardson Formular-20 and a coefficient of 0.85 was obtained. The t-test statistic, one-way analysis of variance (ANOVA), and the univariate analysis of variance were used to test the two null hypotheses at the 0.05 level of significance. The results showed low students' conceptions of mathematics, no significant gender influence on students' conceptions of mathematics and significant environmental factors influence on students' conception of mathematics. To improve students' understanding and achievement in mathematics, it is necessary to develop strategies for conceptual change instruction in mathematics

Keywords: Gender, Environmental Factors, Conceptions, Conceptual Change Instruction, Mathematics

1. INTRODUCTION

The study of student conceptions in learning mathematics and of assessment of their academic outcomes in mathematics is relatively new in Nigeria. Few researchers have investigated and identified a number of ways to probe and understand the conceptions held by teachers and students of mathematics (Harbor-Peters, 2001; Obodo, 2004; Nurudeen, 2007). Many factors have been identified as determinants of students' achievement in mathematics: such factors include gender, location, school type, and school mode. These are environmental factors that interact with each other and other school and teacher/student characteristics to predict students' achievement in mathematics. Towards this end, Walberg (1981) has proposed a theoretical model to explain the linkages existing among learning variables and student academic outcomes. To Walberg, the key variables that affect student academic outcomes are characteristics of the students (ability/prior achievement, motivation, age/developmental level); quantity and quality of instruction; and psychological environment (classroom climate, home environment, peer group, and exposure to media). These psychological, instructional, and home environment characteristics have a more significant impact on achievement than variables such as state, district, or school level policy. The model was later modified by Waldrip and Giddings (1994) to include a fourth set of cultural variables namely gender, race and customs.

Mazana, Montero and Casmir (2020) employed Walberg's theory of productivity to understand factors related to students' learning of mathematics in Tanzania by utilizing the primary, secondary and tertiary students' performance data during the period 2008 to 2016. The findings revealed that factors associated with students' poor performance in mathematics are in line with Walberg's productivity model but for Tanzania, policy environment and culture also play important role. Acharya's (2017) study on the causes of learning difficulties in mathematics by Nepalese public-school students, found that students related factors (mathematics anxiety and lack of practice), home environment (parents support and economic status), teachers related and school

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environment factors (management system infrastructure and regular assessment) influence students learning of mathematics. Also, Anigbo (2016) found that students, teachers, and government's factors, infrastructure, instructional strategy, class size and mathematics anxiety correlated positively in predicting Nigeria's secondary school students' interest in learning mathematics. Omemu (2018) examined the impact of school climate (physical appearance of buildings, teachers' availability, classroom facilities and school security) on students' academic achievement in public secondary schools in Edo State, Nigeria. The study revealed a significant positive relationship between school climate and academic achievement of students in Edo state public secondary schools. Moving beyond students' achievement, for this study, these factors are summarized and examined as gender and environmental (school location, school type and school mode) as they influenced Nigerian secondary school students' conceptions of mathematics concepts.

On gender, the Programme of International Student Assessment (PISA) reported that in the organization for economic cooperation and development (OECD) countries boys out-performed girls in mathematics by 12 score points (OECD, 2010). Oloja and Adeniji (2019) investigated the effect of concept mapping teaching strategy on senior secondary school male and female students' achievement in Geometry in Okitipupa Local Government Area of Ondo State, Nigeria. The study revealed a significant main effect of gender on students' achievement in geometry in favour of male students. Ayeobasan (2019) investigated the relative efficacy of one training method (concept mapping) on Test Anxiety and achievement in mathematics among secondary school students in Lagos Island, Nigeria. The study found that male students (mean=56.8) performed significantly better than female students (mean=42.5). Oribhabor (2019) surveyed the influence of gender on academic achievement in mathematics among 1754 Senior secondary school students from 12 public school schools in Bayelsa State, Nigeria. The result of the analysis revealed that there was a significant difference in the mathematics achievement of male and female students in favour of the males. Olajumoke and Olajumoke (2018) investigated gender disparity and academic performance of senior secondary school students in English Language and Mathematics in twelve schools in Ogun State, Nigeria. Although the analysis revealed no significant gender disparity in the performance of students in English Language, but there was a marked difference between male and female students' performance in Mathematics in favour of the males. Nannyonjo's (2007) study on grade six pupils indicated that in mathematics boys significantly scored 4 points higher than girls in Uganda National Examination Board National Assessment of Progress in Education. Contrarily, Mazana, Montero and Casmir

(2020) analysed students' performance data in mathematics between 2008 and 2016 in Tanzanian schools. The analysis revealed that in the Upper secondary school, girls outperformed boys in many occasions. In 2008 the failure rate of boys stood at 59.5 percent while that for girls was 55.4 percent, and in 2016 the failure rate dropped to 53.9 percent and 49.0 percent for boys and girls respectively. Also, Jayanthi and Srinivasan (2015) studied the influence of the achievement of 1007 Standard 10 students in Chennai and Thiruvallur district, India, in mathematics. With the examination of knowledge, understanding, application, and skills as factors of achievement in mathematics, the study revealed a significant difference between the mean scores of male and female students' achievement in mathematics in favour of the females. However, Ebisine (2010) found that gender seemed not to be a relevant factor associated with school mathematics achievement among some Nigerian students.

On school location, Babatunde's (2015) ex-post facto research study on 1060 students in Kaduna state, Nigeria, found that students in urban schools performed better than those in rural schools. This result is supported by Xu (2009) and Ellah and Ita (2017) that students in urban schools performed better than rural school students in China and Nigeria respectively. Omemu (2018) on the impact of school climate on students' academic achievement in Edo State, Nigeria, public secondary schools, found that students in urban schools (mean=54) were better than those from rural schools (mean= 48) in academic performance. Contrarily, Ntibi, and Edoho (2017) study revealed that school location does not influence Nigeria students' performance in Mathematics and Basic Science.

For several decades, it has been a common belief that private schools do a better job of educating the nation's children than public schools (Crane, 2010). However, Crane in her study found that public elementary school pupils are making greater gains on mathematics assessment in some American schools than their Catholic (private) school peers, particularly in the early 1ˢᵗ and 3ʳᵈ grades. Also, Newhouse and Beegle (2005) found that Indonesian students that attend public junior secondary schools have higher test scores upon completion than private school students. On the other hand, the PISA (OECD, 2016) Report revealed that generally there are more low performers in public than in private schools. Similarly, Okon and Archibong (2015) study revealed that private school students performed better in Social Studies than those in public schools in Junior Secondary Certificate Examination in Akwa Ibom State, Nigeria. However, Yusuf and Adigin (2010), and Agbaje and Awodun (2014) studies found that gender, school location, and school type have no significant influence on Senior Secondary School Certificate Examination (SSCE) in

Ekiti State, Nigeria. This is supported by Harry (2016) who reported no meaningful difference in academic achievement between students in public and private schools in Trinidad

Furthermore, on school mode (i.e. schools attended exclusively by members of the same sex or both sexes), most studies reported positive effects for single-sex schools on all subject areas over and above co-educational or mixed schools among American schools (U.S. Department of Education, 2005). This result is supported by Woodward, Fergusson, and Horwood (1997) who found that New Zealand children attending single-sex schools perform better than their co-educated peers across several educational outcomes including school certificate attainment, longer school retention and less exposure to unemployment. Contrarily, Omemu reported that in Nigeria, Edo State students from single sex schools (mean= 55) do not perform better than those from mixed schools (mean = 63) in academic performance.

Summarily, from the available studies reviewed, gender, school location, school type, and school mode are personal and environmental variables that could influence student achievement in mathematics. However, these studies did not examine the reasons for the students' success or failure in the mathematics tests or examinations by assessing the conceptions of students in Mathematics. In conception measures, the answer(s) given to a question and the corresponding reason(s) that support the answer (s) are examined. This is the gap this study seeks to fill.

2. STATEMENT OF PROBLEM

One of the challenges facing Mathematics education in Nigeria is the persistent low performance of students in General Mathematics in the West African Senior School Certificate Examination (WASSCE). The Test Development Division of the West African Examination Council (WAEC), Lagos, Report from 2006 - 2016 (as cited in Oloja and Adeniji, 2019) showed that the percentage of Nigeria students who scored at least credit pass in Mathematics stood between 15.56 and 49.0. For the years 2016 to 2018, generally, on average students' performance at credit level in at least five subjects including mathematics and English Language was a little above 50 percent (National Bureau of Statistics, 2019). In Nigeria, the assessment of students understanding of mathematics as a subject in the school curriculum has often and primarily be based on achievement tests. These achievement tests measure what the students have learned to do as they are made to solve mathematics problems to get at the answers. The tests measure for right or wrong answers without probing into the underlying reasons for the right or wrong answers. However, recent research efforts have been centered on finding out students' conceptions in science and mathematics. The purposes of such researches are to help to develop curriculum

materials that will enable students to learn effectively and to develop methods that are in line with the two major pathways of learning – the continuous and discontinuous pathways (Duit & Treagust, 1998). When the conceptions of students of different gender, location, and school type and school mode are identified, efforts are made either to guide the learning of the student with the existing conceptions or to discontinue the pathway if it is in contradiction with the existing conceptions.

According to Brown and Hirshfeld (2000), conception is a "mental construct or representation of reality communicated in a language or metaphor containing beliefs, meaning, preferences, and attitude, and which explains complex and difficult categories of experiences". That is, mathematics knowledge conceptions are the beliefs, meanings, and attitude formed and provided by student or teacher which count as explanation or support for mathematics ideas or concepts. Hence, students' conception of mathematics would impact the way they approach and learn mathematics which in turn influences their performance in the subject. It is therefore important that the Nigerian students' conceptions of some basic mathematical concepts be investigated.

3. PURPOSE

The purpose of the study was to develop a two-tier multi-choice diagnostic instrument to investigate how factors of gender, school location, school type, and school mode explained the conceptions of mathematics held by secondary school students in the Edo State of Nigeria.

4. RESEARCH QUESTIONS

The following research questions guided the investigation:

1. What is the difference between the mean scores of students' right conceptions of mathematics by gender, location, school type, and school mode?
2. What are the interaction effects of gender, location, school type, and school mode in the right conceptions of mathematics?

5. HYPOTHESIS

The following hypotheses were formulated from the research questions and tested at the 0.05 level of significance:

1. **H_{01}:** There is no significant difference in the mean conception scores of different gender, location, school type, and school mode in students' right conceptions of mathematics.
2. **H_{02}:** There is no significant interaction effects of gender, location, school type, and school mode in students' right conceptions of mathematics.

6. METHODOLOGY

A. Design

The study assessed senior secondary school students' conceptions of some thirty basic mathematics concepts selected from five themes (Number and Numeration, Algebra, Measurement, Geometry, and Statistics) (Idehen, 2011) from the 9-year Basic Education Mathematics Curriculum (Federal Ministry of Education, 2007a) and the Senior Secondary Mathematics Curriculum (Federal Ministry of Education, 1979, 2007b) for Nigeria schools. Six concepts each were assessed under the five mathematics themes or content areas. The design of the study was a sample survey of the conceptions of some 30 basic mathematical concepts held by a total of 4332 students selected from across the sub-groups from 114 schools in the 18 local government areas of Edo State senior secondary schools. The multistage stratified random sampling techniques were used to select students across school location (urban and rural), school type (public and private), and school mode (Boys, Girls, and Co-educational).

B. Instrument

A two-tier multiple-choice diagnostic instrument (Treagust, 1995, as cited in Tan, Taber, Goh & Chia, 2005) was developed and used to elicit students' conceptions of the thirty basic mathematical concepts. The instrument consisted of two sections, A and B. Section A sought background information on students' sex, school location, school type, and school mode. Section B contains items with 3 sub-scale designed to elicit students' conceptions in the five mathematics areas under study. Section B has thirty items with two parts. The first part of each item consisted of a multiple-choice content question that relates to propositional statements which have three choi**ces.** One of the choices is the correct answer. The seco,nd part of each item contained a set of three possible reasons for the answers to the first part. The set of reasons includes the correct mathematical reasoning and possible misconceptions held by students.

C. Data Analysis

The study adopted the survey design using a test of difference of means, analysis of variance, and univariate analysis of variance to analyze data and test the hypotheses. A correct response was scored 1 if the respondent gave the right answer and the corresponding right reason for an item. A response was scored 0 if the respondent gave the right answer and a wrong reason, gave a wrong answer and the right reason, or gave a wrong answer and the wrong reason. All the points were added to give a total score which ranged from 0–30. A right answer and right reason mean a right conception, while wrong response combinations mean a misconception of the

concepts by the students. Higher scores indicate greater understanding and higher conceptions, and hence fewer misunderstanding or misconceptions.

7. RESULT

A. Hypothesis 1

H_0: There is no significant difference in the mean conception scores of different genders, location, school type, and school mode in students' right conceptions of mathematics. To test this hypothesis right conceptions scores for the different subgroups are presented in Table 1.

Table 1. Descriptive Statistics of Mean Conception Scores for Gender, Location, School Type, and School Mode in Mathematics.

Variables		N	Mean	Std deviation
Gender:	*A. Male*	2109	12.96	5.292
	B. Female	2223	12.95	5.534
Location:	**Urban**	2335	14.30	5.065
	Rural	1997	11.37	5.389
School type:	*C. Public*	2824	11.92	5.075
	D. Private	1508	14.89	5.506
School Mode:	**Boys**	407	13.74	5.371
	1) Girls	763	14.27	5.135
	Co-educational	3162	12.54	5.429

To test for significant differences in means, the t-test statistic was employed for gender, location and school type, and analysis of variance (ANOVA) and Scheffe's Post-hoc test statistics were used for differences between mean scores of boys' and girls' school students, Boys and co-educational school students, and Girls and co-educational students. Tables 2, 3, and 4 present summaries of the results of the data analysis

Table 2. t-test of Mean Conception Scores for Mathematics of Different Gender, School Location, and School Type of Male and Female Students.

Description	Mean difference	Df	t	P-value	Decision H0
Gender	0.01	4330	0.027	0.978	NS
Location	2.93	4330	18.429	0.0005	S
School type	-2.97	4330	-17.811	0.0005	S

Gender and environmental factors' influence on mathematics conception is generally low (less than 50%). From Table 2, for gender, t-value = 0.027, and p-value = 0.978 which is greater than the alpha value of 0.05. This

shows that there was no significant difference between male and female students' right conceptions of mathematics. Therefore, the null hypothesis was accepted. It was concluded that there was no difference in the right conception scores of male and female students. That is, gender does not significantly influence students' right conceptions of mathematics. However, Table 2 further shows that there were significant differences in the right conception scores of mathematics of urban and rural school students ($t = 18.429$ and $P = 0.0005 < 0.05$) and public and private school students ($t = -17.811$ and $P = 0.0005 < 0.05$). Thus, location and school type influence students' right conceptions of mathematics, and in favor of urban and private school students over rural and public-school students, respectively.

Table 3.   ANOVA on Mathematics Conceptions of Boys, Girls, and Co-educational School Students.

Sources	Sum of squares	Df	Mean squares	F	P-value	Decision H0
Between groups	2130.021	2	1065.010			
Within groups	124953.84	4329	28.864	36.897	0.000	S
Total	127083.86	4331				

Significant at P<0.05

Table 3 indicates that there was a significant difference among the boys, girls, and co-educational school students in their right conceptions of mathematics [$F(2,4331) = 36.897$, $\alpha = 0.05$]. To determine where the difference lies between the groups, the Scheffe's Post-hoc tests were computed as shown in Table 4.

Table 4. Scheffe's Post-hoc Tests on Mathematics of Boys, Girls, and Co-educational School Students.

School mode		Mean difference (I-J)	P-value	Decision
I	J			
Boys only	Girls only	-0.53	0.273	NS
	Co-educational	1.20*	0.000	S
Girls only	Co-educational	0.53	0.273	NS
	Boys only	1.74*	0.000	S
Co-educational	Co-educational Boys only Girls only	-1.20*	0.000	S
		-1.74*	0.000	S

Significant at P<0.05

From Table 4, at the 0.05 level of significance, the difference between the means of boys and girls school students was not statistically significant ($P = 0.273 > 0.05$). However, the differences between the means of boys and co-educational school students as well as girls and co-educational school students were statistically significant ($P = 0.000 < 0.05$). In conclusion, the mean right conception scores in mathematics for boys and girls school students were the same, while single-sex school students had more right conceptions than co-educational school students did in mathematics.

B. Hypothesis 2

H0₂: There are no significant interaction effects of gender, location, school type, and school mode in students' right conceptions of mathematics.

There were observed differences in the comparison of students' scores for the different groups as shown in Table 1. Therefore, the univariate analysis of variance statistic was employed to analyze the data to test for significant interaction effects of gender (G), location (L), school type (T), and school mode (M) for the different groups as shown in Table 5.

Table 5.   Univariate ANOVA on Mathematics Conceptions by Gender, Location, School Type, and School Mode.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	21575.894	15	1438.393	58.840	.000	S
Intercept	286833.142	1	286833.142	11733.444	.000	S
G	180.926	1	180.926	7.401	.007	S
L	3592.846	1	3592.846	146.972	.000	S
T	5814.102	1	5814.102	237.837	.000	S
M	1895.338	2	947.669	38.766	.000	S
2-way interaction						
G * L	27.013	1	27.013	1.105	.293	NS
G * T	95.956	1	95.956	3.925	.048	S
L * T	512.163	1	512.163	20.951	.000	S
G * M	.000	0	.	.	.	
L * M	136.342	2	68.171	2.789	.062	NS
T * M	481.749	2	240.874	9.853	.000	S

3-way interaction						
G* L* T	142.578	1	142.578	5.832	.016	S
G* L * M	.000	0	.	.	.	
G* T * M	.000	0	.	.	.	
L * T * M	5.785	2	2.893	.118	.888	NS
Error	105507.965	4316	24.446			
Total	854027.000	4332				
Corrected Total	127083.858	4331				

Significant at P<0.05

At the 0.05 level of significance, the two-way interaction effects showed that there were no significant interaction effects of gender and school location $[(F(1,4331) = 1.105, \propto = 0.05)]$; and of school location and school mode $[F(1,4331) = 2.789, \propto = 0.05)]$. The two-way interaction effects further showed that there were significant interaction effects of gender and school type $[(F(1,4331) = 3.925; \propto = 0.05)]$; of school type and location $[(F(1,4331) = 20.951; \propto = 0.05)]$; and of school type and school mode $[(F (2,4331) = 9.853 \propto = 0.05)]$. However, the 3-way interaction effects results showed that gender, location and school type are significant $[(F(1,4331) = 5.832; \propto = 0.05)]$, and not significant for location, school type and school mode $[(F(2,4331) = 2.893; \propto = 0.05)]$. Therefore, the null hypothesis of no significant interaction effects is rejected for gender, location and school type but accepted for location, school type and school mode. Hence, environmental factors influence male and female students' conceptions of mathematics. The conceptions of male and female students vary across urban and rural schools, and across public and private schools.

8.   DISCUSSION

The results from this study revealed that there was no significant difference between male and female students' conceptions of mathematics. This finding is consistent with that of Ebisine (2010) that both male and female students experienced the same level of difficulty in understanding non-technical words (concepts) in mathematics. Also, the finding is corroborated by Yusuf and Adigun (2010) that gender does not influence school achievement in Mathematics. However, the finding is contradicted by those of Ayeobasan (2019), Oloja and Adeniyi (2019), Oribhabor (2019), Olajumoke and Olajumoke (2018), PISA (OECD, 2010) and Nannyonjo (2007) that gender differences exist while learning mathematics in favor of males. Also, that gender differences exist in students' performance in Mathematics in favour of the females as reported by Mazana, Montero and Casmir (2020) and Jayanthi and Srinivasan (2015).

The study further showed that environmental factors influenced students' conceptions of mathematics. Urban and private school students performed better than rural and public school students respectively. Also, single-sex school students performed better than their co-educational school counterparts. These findings are supported by

Umemu (2018), Ellah and Ita (2017), Babatunde (2015), and Xu (2009) that urban school students perform better than rural school students. However, Ntibi and Edoho (2017) found that school location has no influence on students' achievement in mathematics. OECD (2016) and Okon and Achibong (2015) studies support the finding that private school students perform better than public school students. Contrarily, Newhouse, and Beegle (2005) and Crane (2010) studies revealed that public school students performed better than their private school counterparts. However, Yusuf and Adigun (2010), Agbaje and Awodun (2014), and Harry's (2016) studies revealed that school type does not influence students' achievement in Mathematics. On school mode, Woodward, Ferguson, and Horwood (1997) and the U. S. Department of Education (2005) works support the finding of this study that single-sex school students perform better than coeducational school students in Mathematics. Contrarily, Omemu (2018) reported that coeducational school students had better performance than single-sex schools in Edo State, Nigeria.

The 3-way interaction effects results showed that gender, location, and school type influenced students' conceptions of mathematics. These findings are consistent with that of the Universal Basic Education (2001) on school achievement in Nigeria. However, these differences are not due to the sex of the students but to the environmental factors associated with attitudinal, psychological, and socio-cultural factors on boys and girls and teaching approaches and school environments (Acharya, 2017; Anigbo, 2016; Walberg, 1981). Therefore, differences in students' conceptions are specific to the context of the settings in which schools are established and how students are taught. These differences may have resulted from the inequitable distribution and management of the educational, human and materials resources among urban and rural schools, public and private schools, and single-sex and co-educational schools. Hence, gender and environmental factors guide the conceptions of mathematics held by students

9.   CONCLUSION

This study reveals that students' conceptions of basic mathematical concepts are generally low. Students having low conceptions of mathematics means that minority has the right conceptions and majority have misconceptions.

Low conceptions imply that that student solve to get the right answer to a given mathematics problem does not always mean that they have a clear understanding of the underlying concepts. Low conceptions affect students' understanding of mathematics and consequently mathematics achievement. This study further reveals that: there is no significant difference in male and female students' conceptions of mathematics concepts; urban school students perform better than rural school students in their conceptions of mathematics; private school students perform better than public school students in their conceptions of mathematics and single-sex school students perform better than co-educational school students in their conceptions of mathematics. Environmental factors, therefore, influence male and female students' understanding of mathematics and guide the conceptions of mathematical concepts held by them. Hence, the records of poor achievement of Nigerian students' in mathematics could have resulted from students' low conceptions of mathematical concepts.

10. RECOMMENDATION

Based on the findings, definite measures should be taken by mathematics teachers and educators to help students improve on their achievement, and, to help students to replace their misconceptions and develop them into more acceptable mathematics knowledge through conceptual change instructional strategies. The key assumption of conceptual change approaches is that learning has to start from certain already existing conceptions and learning pathways (continuous or discontinuous) have to be designed so that they lead students from these pre-conceptions towards the mathematics conceptions to be learned. As different environmental factors affect students' conceptions of mathematics in varying achievement levels, educational administrators and planners should set standards and encourage equitable distribution of human and material resources, and equal access of students to educational facilities among urban and rural schools, public and private schools, and, single-sex and co-educational schools.

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