Modelling the Determinants of Students' Performance in Mathematics

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Abstract

Mathematics is a subject most students perceived to be difficult and have consequently developed a phobia towards. This study aimed to model the determinants of students' performance in core and elective mathematics and to unearth the various factors that make students perceive mathematics as a difficult subject. Self-administered questionnaires were used to collect primary data from a total of 170 students in five (5) selected senior high schools (SHS). Whereas convenience non-probabilistic sampling was used to select the SHS and elective mathematics students, simple random sampling was employed in selecting core mathematics students. Results from a multiple linear regression analysis indicated that characteristics of students such as students' fear of mathematics, parents' level of education, students' perception of the subject as being difficult, and students' residential type (boarding or day) were significant determinants of students' performance in mathematics. Results of a binary logistic regression showed younger students are about 4 times more likely to perceive mathematics to be a difficult subject compared to older students while students who generally fear the subject are about 19 times more likely to perceive the subject as difficult than those who have no mathematics anxiety or fear. Similarly, a student whose father had only basic education could perceive mathematics about 18 times difficult compared to those whose fathers went beyond basic education. The study recommends that in order to improve mathematics performance, students should be desensitized to misconceptions that the subject is for only top-notched students, more boarding facilities should be built, and students studying mathematics should be motivated by teachers and parents.

Keywords determinants of students' performance; students' perception of mathematics, fear of mathematics

Introduction

Mathematics is the basis of scientific and technological development and is crucial for the national and social-economic growth of nations. It is reasoned that mathematics is the basis of creation. Consequently, the subject is indispensable and compulsory at both the basic and secondary levels of education in most countries (Gafoor & Kurukkan, 2015). Core mathematics is among the prerequisite subjects for reading integral programs of national development at the tertiary level such as engineering, medicine, and architecture, among others.

Despite the crucial role mathematics play in society, performance and general interest in mathematics have been generally low. The subject is perceived by some students as one of the most difficult to understand, reserved for only top-notched students (Di Martino & Zan, 2013). Suleiman & Hammed (2019) have shown that students' negative attitude toward mathematics, anxiety, fear of the subject, inadequately well-trained teachers, poor teaching methods, inadequate teaching materials, and overcrowded classes were some of the causes of poor performance in mathematics.

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They also indicated that inadequate periods allotted for teaching mathematics resulted in low performance. This confirms the studies of Hill et al. (2005); Metzler & Woessmann (2012); and Tella (2017) who found that teacher self-efficacy and mathematical knowledge significantly affect student performance and consequently suggested employing well-trained teachers.

Insufficient teaching aids were found by Otieno (2010) and several other studies to cause a similar effect on students' performance (Bringula et al., 2018; Unodiaku, 2013). Muema et al., (2018) also confirmed that positive teaching methodologies are strongly correlated to higher mathematics achievement of students.

Amazigbo (2010) however uncovered that poor performance in mathematics may be attributed to heredity and environmental factors. These can be subdivided into students, home, teachers, and school factors. The work of Suan (2014) supports these findings and went further to categorize the determinants under three headings; teacher factors, student factors and environmental factors as key influences on mathematics performance. Many other works agree with these findings. For instance, it was found that poor and ill-managed teaching environments exert a bad influence on students' achievements in mathematics (Harinarayanan & Pazhanivelu, 2018; Michael, 2015). Dauda et al. (2016) attributed the challenge to the inadequate number of mathematics teachers and students' socioeconomic backgrounds as well as the overpopulation of students in the mathematics classroom. This confirms the studies of Agirdag et al. (2012), Osonwa et al. (2013), and Wang et al. (2014) who uncovered that students' socioeconomic status (SES) critically impacts their mathematics achievements. Important constituents of SES such as the level of education of parents and income level of parents significantly contribute to their general performance in the subject. Students from lower SES performed significantly lower than those from higher SES households (Osonwa et al., 2013).

Test anxiety is another major factor responsible for students' underachievement in mathematics examinations (Alemu & Feyssa, 2020; Mkpaoro & Nwagu, 2019). Other studies have also investigated the impact of family structure on student academic performance and found single parenthood to negatively affect student achievement academically (Akinleke, 2017; Nato, 2016; Ella et al., 2015). Regular class attendance played a significant role in the findings of Lukkarinen et al. (2016). They insisted that for students to uplift their performance in the subject, it is not enough to undertake self-studies but to regularly attend classes. Contrarywise, Von Stumm, et al. (2011) found personal effort and intellectual curiosity to be the most direct and important determinants of academic performance.

The Chief Examiner for Mathematics (Core) 2 and Mathematics (Elective) 2 of the West Africa Examination Council (WAEC) suggested the following as measures to uplift students' performance in exams: (i) students should be given adequate and effective teaching in concepts and skills necessary to help them overcome their weaknesses; (ii) quizzes and tests should be given periodically to review and reinforce the concepts taught; and (iii) teachers should guide students to work on problems they have observed students have weaknesses in understanding (waecgh.org).

These suggestions from the Chief Examiner came up as a result of the usual poor performance of students in the mathematics exams. Even though teachers do implement most of the Chief Examiner's suggestions, the question remains unanswered as to the real determinants of students' performance in the subject. This study seeks to model the determinants of performance of Senior High

School students in mathematics examinations and investigate the various factors influencing the perceived difficulties of students in mathematics. The study seeks to address the following research questions;

i. How do students' background characteristics contribute to their general performance in mathematics examinations?

ii. What are the various factors influencing the perceived difficulties of students in mathematics?

Methods

Population and sample size

The study population consisted of students in five senior high schools across the Greater Accra and Ashanti regions of Ghana who study only the Core Mathematics subject or both Core and Elective Mathematics. One of the researchers is a teacher in one of the schools selected while the others either lived within proximity to the schools or had some form of alliance in the schools thus necessitated using the convenience non-probabilistic sampling method for the selection of schools. A total of 170 students were sampled from these five (5) schools. The convenience sampling technique was used in selecting elective mathematics students while the simple random sampling method was employed in the selection of Core Mathematics students. Minimum sample size for an unknown population size was estimated using:

$$Sample\ Size\ (N) = \frac{Z^2\ x\ P(1-P)}{C^2}$$

Where: Z = z value probability (1.96)
P = Prevalence/Standard deviation (85% i.e., 0.85)
C = Level of precision (0.05)

A sample size of 196 was estimated which was calculated using the prevalence value of 85% adapted from (Cochran, 1977). Thus, the sample size N is $N = \frac{1.96^2\ x\ 0.85(1-0.85)}{0.05^2} = 195.9 \approx 196$. Though the sample size of 196 students were the selected for data collection, 170 of the students became the working sample size since they were those that filled and returned questionnaires.

Data collection procedure

Data was collected using a questionnaire adapted from Wang et al. (2014) and Mutodi, & Ngirande, (2014). The questionnaire consisting of 28 open and closed-ended questions was self-administered. The instrument elicited information on students' demographic characteristics, their perceptions on various factors influencing their academic performance as well as their performance in the previous end of semester or end of term examination score in elective and or core mathematics. Students' average performance in the subject was then calculated from these scores obtained in the previous end of term's core and elective mathematics exams in their various schools. Interview guides who were teachers in the schools were employed to gather information to help meet the aims of the study.

Results and discussions

Students' background characteristics

The age of the students ranged from 15 years to 20 years. The average age was 18 with a standard deviation of 0.704 years. The number of siblings of respondents ranges from 0 to as many as 9 with an average of 3 siblings. Table 1 presents the rest of the background characteristics of the students. Gender-wise, 98 were males representing 57.6% of the total sampled students while the remaining 72 (42.4%) were females.

As shown in Table 1, most of the students, 99 (58.2%), grew up in urban areas, 55

Table 1 Respondents' demographic information

	Variables	Count (N)	Percent (%)
Gender	Males	98	57.6
	Females	72	42.4
Siblings in or finished tertiary	Yes	68	40
	No	102	60
Home residential type	Urban	99	59.3
	Semi-urban	55	32.9
	Rural	13	7.8
Ethnicity	Akan	93	58.5
	Ewe	25	15.7
	Ga	31	19.5
	Guan	3	1.8
	Others	7	3.4
Father's highest education	None	11	6.6
	Basic	37	22.2
	Secondary	29	17.4
	Poly/College of Edu/Nursing	13	7.8
	University	77	46.1
Mother's highest education	None	6	3.6
	Basic	42	25.3
	Secondary	37	22.3
	Poly/College of Edu/Nursing	25	15.1
	University	56	33.7
Parents/guardian economic/income level	Low	11	6.6
	Middle	122	73.1
	High	25	20.4
Current parenting structure	Single parenting	31	18.2
	Both parent	131	77.1
	Guardianship	8	4.7
Father's employment type	Self-employed	56	33.9
	Private employment	58	35.2
	Government employment	51	30.9
Mother's employment type	Unemployed	3	1.8
	Self-employed	102	61.1
	Private employment	19	11.4
	Government employment	43	25.7

(32.4%) were from semi-urban areas while 13(7.6%) originated from rural areas. In terms of their family structure, 31 (18.2%) have single parents, while 131 (77.1%) are with both parents, whiles 8(4.7%) stay with guardians when not in school. Only 41 (24.1%) of respondents are day students, the remaining 129 (75.9%) are in boarding houses. It is also worthy to note that among the 170 respondents, 102(60.0%) of them have their siblings in and or have finished tertiary and other higher educational institutions while 68(40.0%) do not have siblings who have completed tertiary or other higher education. Moreover, many of the respondents, 108(63.5%) attended a private junior high school as against only 62(36.5%) who attended a government/public junior high school. Over 60% of all the respondents' parents, both father and mother have had at least a secondary school education. See table 1 for a summary of respondents' demographic information.

Students' background characteristics as a determinant to performance in mathematics

Characteristics such as home residential type, school residential type, ethnicity, parents' income level, parents' education level, and student's perception of mathematics among others, served as independent variables and their effect (or contribution) to students' overall average performance in mathematics were explored using the multiple linear regression model with its associated analysis of variance (ANOVA) test to determine whether or not the overall regression model is a good fit for the data. The results are presented in Tables 2, 3 and 4.

Table 2 Regression Statistics

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.661[a]	.437	.293	13.42228

It is observed from Table 2 that the correlation coefficient (R) of 0.661 indicates a good prediction level. The model summary also shows that about 43.7% of the variations in the average performance in mathematics is explained by the various independent variables.

Table 3 Analysis of Variance (ANOVA) Summary

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	16932.494	31	546.209	3.032	.000[b]
	Residual	21799.064	121	180.158		
	Total	38731.559	152			

In Table 3, the F-ratio in the ANOVA table, which is a test determining whether the overall regression model was a good fit for the data, indicates that the independent variables significantly predict the average performance in mathematics, $F(31, 121) = 3.032, p < .0005$. Thus, the model is a good regression model fit for the data.

Table 4 Estimation of Parameters for Average Performance Model

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	42.376	12.511		3.387	0.001
Students fear mathematics subjects	7.673	3.68	0.181	2.085	0.039
Low-income parents	5.305	5.556	0.078	0.955	0.342
High-income parents	1.869	3.056	0.047	0.611	0.542
Single parenting	2.063	3.336	0.049	0.618	0.537
Parenting by a guardian	2.82	6.683	0.034	0.422	0.674
Father had only basic education	17.792	5.57	0.46	3.195	0.002
Father had up to secondary education	17.419	5.471	0.405	3.184	0.002
Father had up to Poly/training colleges	13.204	6.656	0.223	1.984	0.05
Father had up to university education	12.005	5.362	0.377	2.239	0.027
Mother had only basic education	3.516	6.296	0.095	0.558	0.578
Mother had up to secondary education	12.768	6.281	0.33	2.033	0.044
Mother had up to poly/teacher training	6.398	6.873	0.144	0.931	0.354
Mother had a university education	10.6	6.701	0.314	1.582	0.116
Student perceives maths as very difficult	-15.346	6.781	-0.215	-2.263	0.025
Student perceives maths as difficult	-12.529	4.451	-0.34	-2.815	0.006
Student perceives maths as normal	-2.965	3.967	-0.092	-0.747	0.456
Invested ample time into studying maths	10.232	8.038	0.287	1.273	0.206
Invested average time into studying maths	7.291	7.936	0.227	0.919	0.36
Invested little time into studying maths	-3.186	8.245	-0.068	-0.386	0.7
Father is self-employed	2.336	3.578	0.07	0.653	0.515
Father is privately employed	-5.754	3.003	-0.172	-1.916	0.058
Mother is unemployed	19.47	8.927	0.17	2.181	0.031
Mother is self-employed	0.884	3.495	0.027	0.253	0.801
Mother is privately employed	2.444	4.04	0.051	0.605	0.546
Any siblings in or finished tertiary	1.141	2.511	0.035	0.454	0.65
School residential type	-6.842	3.231	-0.182	-2.118	0.036
Was forced to do programmed	9.411	4.856	0.146	1.938	0.055

From Table 4, the background characteristics, student fears of mathematics, (coded 0 = Yes and 1 = No), was observed to be a statistically significant determinant of performance in the subject with students who do not fear mathematics scoring a grade point that is 7.67 higher on the average than those who fear mathematics holding all other variables constant. This confirms the findings of Suleiman & Hammed (2019) who also pointed out that students' fear of mathematics adversely affects their performance in the subject. It is observed as well that a father who had his highest education as basic (coded as 1 = Yes and 0 = No), secondary (coded as 1 = Yes and 0 = No), training college (coded as 1 = Yes and 0 = No) or university education (coded as 1 = Yes and 0 = No) statistically significantly contribute positively to their children average performance in mathematics compared to a father who had no formal education at all. A similar finding was noted by Dauda et al. (2016); Agirdag et al. (2012); Osonwa et al. (2013); Wang et al. (2014) who found student's socioeconomic level especially parents' level of education significantly impacts their mathematics performance. Holding all other variables constant, a father who had only basic school education could contribute 17.79 average scores, a father with only secondary education could contribute an additional 17.42 average score, a father with only training college education contributes 13.20 and a father with only a university education could contribute an additional 12.00 average score to their children's average performance in mathematics compared to a father who had no formal education at all. Moreover, a mother who had up to secondary school education statistically significantly contributes positively to a child's average performance in mathematics by 12.77 average scores compared to a mother who had no formal education. It was also observed that the students' general perception of mathematics is a statistically significant determinant of their average performance in the subject. A student who perceives mathematics as a very difficult subject, (coded 0 = No and 1 = Yes), scores an average grade point of 15.35 lesser than those who perceived mathematics as an easy subject. Moreover, students who perceive maths subjects as difficult significantly had a grade point of 12.53 lesser compared with those who perceived mathematics as an easy subject. This current finding although supports the results of Mutodi & Ngirande (2014), is in contradiction with the finding of Hagan et al. (2020) who found mathematics difficulty perception of students to be weakly and negatively correlated to performance.

A mother's work type was observed to be a statistically significant determinant of a student's average performance in mathematics. An unemployed mother who is always at home and supervising the child's studies actually paid off positively on the child's average performance in mathematics. Such a student could score an average grade that is about 19.47 higher compared to a mother who is a government worker.

Finally, it was observed that students' residential type, coded as 0 = Boarder and 1 = Day student was a statistically significant determinant of average performance in mathematics. It was observed that holding all other variables constant, a student who is a day student could score 6.84 less in mathematics than one who is a boarder. Gerbi & Heyi (2021) found similar results where they found boarding students had excellent academic performance than their day counterparts. The significant determinants of students' average performance in mathematics can be predicted by the model in Box 1.

$$\begin{aligned}\mathrm{Average_{Perf}} = {} & 42.48 - 7.67\mathrm{Fear_{maths}} + 17.79\mathrm{father_{basic}} + 17.42\mathrm{father_{sec}} \\ & + 13.20\mathrm{father_{training}} + 12.00\mathrm{Father_{uni}} + 12.77\mathrm{mother_{sec}} \\ & - 15.35\mathrm{very_{difficult}} - 12.53\mathrm{difficult} + 19.47\mathrm{mother_{unemploy}} \\ & - 6.84\mathrm{day_{student}}\end{aligned}$$

Where:

$\mathrm{Average_{Perf}}$ = avarege performance in mathematics
$\mathrm{Fear_{maths}}$ = Student fear maths
$\mathrm{father_{basic}}$ = father had basic education
$\mathrm{father_{sec}}$ = father had up to secondary education
$father_{training} = father\ had\ up\ to\ training\ college\ education$
$\mathrm{Father_{uni}}$ = father had up to university education
$\mathrm{mother_{sec}}$ = mother had up to secondary school education
$\mathrm{very_{difficult}}$ = student perceive mathematics to be very difficult
difficult = student perceive mathematics to be difficult
$\mathrm{mother_{unemploy}}$ = mother unemployed
$\mathrm{day_{student}}$ = student residential type is day

Box 1

Factors influencing the perceived difficulties of students in mathematics

Binary logistic regression model was used to investigate the factors that lead to perceived difficulties of students for the mathematics subjects. Perception of student of the subject was coded as *0=not difficult (non-target group)* and *1=difficult (target group)* as displayed in Table 5

Table 5 Dependent Variable Encoding

Original Value	Internal Value
Not difficult	0
Difficult	1

The overall prediction power of perceived difficulty of mathematics as displayed in the classification table in Table 6 is 90.4% and 76.3% for predicted perceived difficulty. This is indicative of a strong prediction power of the model.

Table 6 Predictive power of perceived difficulty of mathematics model

		Predicted		
		How student perceives mathematics		
Observed		Not difficult	Difficult	Percentage
How student perceives mathematics	Not difficult	93	4	95.9
	Difficult	9	29	76.3
Overall Percentage				90.4

Omnibus Test of Model Coefficients tests the fit of the model. With a fit significance of $p < 0.0005$ as shown in Table 7 indicates a good model fit.

Table 7 Omnibus tests of model coefficients

		Chi-square	Df	Sig.
Step 1	Step	111.086	40	.000
	Block	111.086	40	.000
	Model	111.086	40	.000

Thus, there is a significant improvement in fit as compared to the null model of no-good fit.

In Table 8, the only statistically significant variables for perceived difficulty in mathematics are Age, with *Sig. = .049, Exp(B) = 0.192, father's education being basic, with Sig. = 0.038,* Exp(B)=18.099, Student fear mathematics subjects, Sig. = 0.032, Exp(B)=19.52, General performance in mathematics subjects, Sig. = 0.026.

Table 8 **Variables in the equation in a binary logistic regression predicting likelihood of students' demographic characteristics influencing their perceived difficulty of mathematics**

	B	S.E.	Wald	df	Sig.	Exp(B)
Gender (1)	2.214	1.573	1.981	1	0.159	9.153
Age	-1.651	0.838	3.883	1	0.049	0.192
Home residential type			0.016	2	0.992	
Home residential type (1)	0.189	1.918	0.01	1	0.922	1.208
Home residential type (2)	0.093	1.799	0.003	1	0.959	1.098
Ethnicity			0.15	7	1	
Type of basic school attended (1)	0.849	1.124	0.571	1	0.45	2.338
Father's educational level			6.041	4	0.196	
Father's educational level (1)	-20.187	11148.2	0	1	0.999	0
Father's educational level (2)	2.896	1.398	4.288	1	0.038	18.099
Father's educational level (3)	1.257	1.264	0.989	1	0.32	3.516
Father's educational level (4)	-3.124	2.99	1.092	1	0.296	0.044
Mother's educational level			5.115	4	0.276	
Mother's educational level (1)	3.018	2.268	1.771	1	0.183	20.447
Mother's educational level (2)	-1.257	1.407	0.798	1	0.372	0.284
Mother's educational level (3)	0.293	1.307	0.05	1	0.823	1.34
Mother's educational level (4)	2.002	1.81	1.224	1	0.269	7.405
Parents/guardian income level			2.94	2	0.23	
Parents/guardian income level (1)	-2.091	3.4	0.378	1	0.538	0.124
Parents/guardian income level (2)	1.772	1.354	1.713	1	0.191	5.885
Current family structure			0.85	2	0.654	
Current family structure (1)	-1.981	2.236	0.785	1	0.375	0.138
Current family structure (2)	-1.366	2.065	0.437	1	0.508	0.255
School residential type (1)	-0.783	1.203	0.424	1	0.515	0.457
Was forced to do programmed (1)	-0.568	5.434	0.011	1	0.917	0.567
Student study Elective Mathematics (1)	0.316	1.211	0.068	1	0.794	1.372
Average performance in mathematics	-0.041	0.029	1.941	1	0.164	0.96
Student fear mathematics subjects (1)	2.971	1.386	4.598	1	0.032	19.518
General performance in mathematics subjects			12.741	5	0.026	
Single sex schools perform better in Maths (1)	-0.447	1.446	0.095	1	0.757	0.64
Time invested in studying Maths subjects			0.215	3	0.975	
Time invested in studying Maths subjects (1)	-0.606	56841.2	0	1	1	0.545
Time invested in studying Maths subjects (2)	-0.43	56841.2	0	1	1	0.651
Time invested in studying Maths subjects (3)	0.345	56841.2	0	1	1	1.412
Constant	34.328	42902.8	0	1	0.999	8.101y*

*$y=10^{14}$

Various factors believed to influence students' perception of mathematics as either difficult or not difficult are displayed in Table 8. Results indicate that *age of student with Olds Ratio, Exp(B) = 0.192* is significant with *Sig. = 0.049.* In logistic regression, odds ratio less than one (*Exp(B) < 1*) as in this event, is indicative that the event does not fall within the target group, in this case students who perceive mathematics to be difficult. Thus, odds ratio of 0.049 means younger students are about 4 times more likely to perceive mathematics to be a difficult subject compared to older students. Therefore, increase in students age is indirectly related with student perceiving maths to be difficult. Thus, whereas younger students are more likely to see the subject to be difficult, older students being more matured are able to think deeper and analytically and so perceive mathematics not to be difficult. This coincides with the findings of Cobley et al. (2009) who reported in their study that relatively older students do better in secondary school mathematics compared to their younger counterparts indicating a positive age effect on the subject. However, Stipek (2002) and Bedard & Dhuey (2008) believe older students do better simply because they are older and more matured, nothing more.

The current study also found *father's education being basic, with Sig. = 0.038 and Odds Ratio, Exp(B)=18.099.* Odds ratio greater than one (*Exp(B) > 1*), indicates the probability of the specific event falling into the target group is greater than the probability of falling into the non-target group. Odds ratio of 18.099 indicates that students whose father has only some basic education is about 18 times likely to perceive mathematics as a difficult subject. This might be due to the lack of motivation from the father and a lack of existing example from the father breaking through with the subject. Thus, the event of a student's father having only basic education is highly likely to make him/her to perceive mathematics as an extremely difficult subject. With the exception of mothers' education which was not significant in this study, this finding partially matches the results of Vanbinst et al. (2020) who found children's mathematics fear or anxiety to be significantly related to their mothers' educational level as well as both mothers' and fathers' educational level. They also found mother's mathematics anxiety level as a borderline in considering mathematics anxiety as well as both parents educational level simultaneously.

Student's fear of mathematics subjects, scored an Odds Ratio, Exp(B) of 19.52, with Sig. = 0.032, implying that students who fear mathematics are about 19 times more liable to perceive mathematics subjects as difficult compared to those who do fear the subject. This is quite obvious because it the student fears mathematics, they will perceive math subjects to be difficult already. This fear could originate from the society, home or classroom (Vinson, 2001).

Conclusion and Recommendations

Education plays key role in the development of any nation and human resources in Science, Technology, and Mathematics (STEM) are aggressively being sought for because they served as the foundation of national transformation. This study sought to unearth some of the determinants of students' poor performance in mathematics examinations in Ghana. In retrospect of the results of this study contingent on the data collected, it is found that students' demographic characteristics namely, father's level of education, mother's educational level, student's perception of the mathematics subject as either very difficult or easy to understand, student's fear of mathematics as well as student's school residential type, either day or boarding, are statistically significant determinants of their overall performance in mathematics. Based on the findings of this study, the following recommendations are made:

i. Junior and Senior School students should be given adequate education in the prospect of studying mathematics which will enable them put in their best in studying the subject and will erase erroneous believe the mathematics is only for the few brilliant students.
ii. Government and school authorities should upgrade all senior high schools to a boarding status so that students can concentrate on their studies.
iii. Parents should get involved in the education of their children.
iv. Teachers should adequately prepare for their class and be patients with the students.

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