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Predictive factors affecting students' performance in studying engineering mathematics in technical universities in Ghana

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ABSTRACT: *The study's major purpose was to investigate the factors that influence engineering mathematics performance in Ghanaian technical universities. Three hundred and fifteen (315) participants were surveyed using questionnaires and six (6) expert interviews. Descriptive variables were examined using cross-tabulation, univariate, and bivariate statistical methods. The logistic regression model and Pearson's chi-square test were used to examine the relationship between the dependent variable (engineering student performance) and the predictive variables respectively. The study's findings revealed that several factors influence students' performance in engineering mathematics, including age, terrible strain, and level of interest. It was revealed by an expert's interview that students from senior high school like engineering mathematics whiles those from technical senior high school do not like engineering mathematics because of their poor background in mathematics. To reinvigorate students' performance in this course area, pre-calculus classes for older students should be arranged to assist them to refresh their memory, according to the study, students should be encouraged to devote a significant amount of time to engineering mathematics coupled with tutorials.*

KEYWORDS: Age factor, engineering mathematics, interest factor, students' performance, technical universities, terrible strain factor.

INTRODUCTION

The study of mathematics has an impact on diverse aspects of human life at different levels. As posited by Eraikhuemen (2003), the taught and design of life can only be accomplished through the culture of mathematics due to its enormous applications in human relations. Mathematical knowledge has long been regarded as essential not only for educational purposes but also for daily intellectual engagement and logical

reasoning in all aspects of our lives (Carey et al., 2017). By learning mathematics, one will be able to develop precision, consistency, and mental discipline which are prerequisite skills and attitudes towards successful and responsible problem solving and decision making. Several areas in higher education, including technical fields, engineering, economics, finance, agriculture, pharmacy, and health sciences, have frequently highlighted mathematics as essential (Gradwohl et al., 2018; Nicholas et al., 2015). Since mathematical knowledge and expertise offers widespread application, other fields of study, such as social sciences, require students to take at least one mathematics course in university programs around the world. Their students acquire fundamental mathematical knowledge as well as the analytical and computational abilities required in their field of study.

However, the study of mathematics at a different level of the educational hierarchy remains one of the most challenging among most stu resulting in poor or mediocre performance in mathematics-related courses compared toon with the readable courses. According to Wahid et al. (2014), the performance of students in mathematics from the primary level of education to higher education is still a major concern. This proposition can be emphasized by the level of global recognition given to the importance of mathematical knowledge, coupled with the steady manifestation of underachievement in mathematical studies for many years (Eng et al., 2010). For example, the University of Cape Coast -Institute of Education Chief Examiner's 2013/14 academic year report highlighted, that 32.9 percent of the candidates who took the mathematics paper received D or D+ grades, and 20.9 percent failed their papers (Justice et al., 2015).

Nevertheless, mathematics in university courses is frequently identified as a primary obstacle to students' drop-out (Gradwohl et al., 2018). This problem is enormous among non-sciences disciplines, where the failure rate in mathematics can easily exceed thirty percent (Awaludin et al., 2015). Within the mathematical field, one of its sub concentrations - engineering mathematics is viewed by scholarships as the production of empirical and evidence-based data that is essential for facilitating innovativeness in the socio-economic growth and development of countries. This makes the application of theories in engineering mathematics very useful in practice and a contributing factor to the realization of evidence-based national development.

In Ghana, it is worrying that students in engineering mathematics are applauded for being well informed in all the theoretical explanatory powers in the field but are disadvantaged in the application of these theories to solve real-life and societal problems, hence, affecting the overall performance of the students. Since poor performance in engineering mathematics has an indirect impact on students' overall academic and professional performance, this study attempts to examine the factors that lead to the bad and good grades in engineering mathematics in technical universities in Ghana. This study is very significant because it will inform administrative decisions at the technical universities, as well as the lecturing body, parents, and other relevant stakeholders on the right interventions to reinvigorate the performance of technical students in engineering mathematics.

Research Question

1. What personal factors contribute to students' performance in engineering mathematics at Ghana's technical universities?

REVIEW OF RELATED STUDIES

A wide body of research has been conducted for several decades to determine the predictors of mathematics achievement among different groups of students. The authors expressed the dynamic and diverse existing factors and correlated them with mathematics success because education is a complex process with several variables interacting in a way that influences how much learning occurs. Some authors attempt to classify these predictors into different categories with related properties to provide a detailed and consistent image. In the work of Papanastasiou (2000), he highlighted the internal and external predictors of mathematics success. He furthered his explanatory powers on the internal predictors stating categorically that exams/test content, individual's environment such as his persona (students' attitudes toward mathematics), family's socioeconomic status, educational background, school climate, and language background. Papanastasiou's study only gave scholarly attention to socioeconomic and environmental factors that can affect the performance of a student in mathematical-related studies but did not look at the biological and psychological predictors which are very key in studies of this nature. This gap was filled in the studies conducted by Patterson et al., and Brezavšček et al. From the biological perspective, the studies of Patterson et al. (2003) made an interesting contribution to the literature by revealing, that there is a variation in the factors that influence mathematics performance due to the complexity of human brain functions to the social and environmental factors that influence a particular student. Also, from the psychological perspective, Brezavšček et al. (2020) found out that students with a lower level of mathematics anxiety perform better in this study area at the university.

Also, study findings from various levels of education (primary, secondary, and tertiary) cannot be correlated always due to the unique characteristics of the target population which can influence the study outcome. However, there have been numerous studies conducted on the poor performance in mathematics citing university education as the case study in many countries. A few references can be made to the case of Ghana (Enu & Nkum, 2015), Nigeria (Josiah & Olubunmi, 2014), and Iran (Kazeni & Ghoraishi, 2012). Other studies have also examined the economic and social predictors that influence the performance of students in mathematics. In these studies, the most popular method for determining socioeconomic status was to combine the educational level, occupational status, and household income (Jeynes, 2002). Surprisingly, one of the major predictive factors examined to have a massive influence on student academic performance was socioeconomic status (Graetz, 1995). This finding was further confirmed in the studies conducted by Considine & Zappala. In their research, it was revealed that families in which the parents are socially, educationally, and economically advantaged promote high levels of achievement/performance in their children (Considene & Zappala, 2002).

Furthermore, teachers, play a critical role in achieving the high expectations that are constantly stressed in classrooms and education systems around the world. Despite widespread agreement on the value of good teachers, scholars, educators, policymakers, and the public has been unable to reach a hypothetical consensus on what attributes and characteristics define a good teacher. With the constant manifestation of dynamism in society and the world at large, the teaching profession is becoming increasingly complex and technical which results in a very high and growing demand for teachers. Hanushek (1997) calculated that the gap in annual achievement growth between having a good teacher and having a poor teacher was greater than one-grade level equivalent. As a result, both pre-service and in-service training is critical for a teacher's professional development. A recommendation was made in a similar study conducted by Benson. His research highlighted that it is important for mathematics teachers to aspire for and maintain a positive attitude (that is delivery of quality teaching service) in mathematics to achieve excellent results in the upper grades (Benson, 1999).

Notwithstanding these, it is also very important to highlight the study conducted by the National Investigative Board (NIB). It was found in the NIB study that the effort students put into learning and practicing mathematical concepts and abilities is influenced by their attitude toward mathematics. Students' convictions about their abilities and desires for mathematics achievement have been directly linked to their levels of commitment, as well as their state of enthusiasm that advances their capacity to be academically fruitful (NIB, 2000 as cited in Akey, 2006) and mathematically knowledgeable. And finally, the study from John et al., cannot be overlooked when reviewing the literature on factors shaping the performance of students. They made an important contribution to research on academic performance and student motivation in general but were only limited to the secondary level of education. Though very important study, it is very crucial to highlight that the study of John et al. focused on the broader academic performance with no concentration on mathematical studies. Using the stratified sampling techniques, a student sample of four hundred and eighty-nine (489) was used to measure how their ages contribute to their respective academic performances. They applied statistical techniques such as Karl Pearson’s correlation approach and ANOVA. Their study revealed that there is a significant effect or relationship between the age of the student and his academic performance. This study indicated that there is a strong positive correlation between the age of a student and his/her academic performance, hence, age is said to be a major predictor of the shape of one’s performance in school (John et., 2015).

Researchers have expressed interest in learning about the variables that influence the efficacy of students' performance in mathematics. These variables, both within and outside the classroom, affect students' academic achievement in mathematical studies. Students' factors, family factors, school factors, and peer factors are examples of these variables (Crosnoe et al., 2004). Academic performance on the other hand; academic performance is a direct reflection of a student's knowledge. It can be influenced by factors such as demographic profile and attitudes toward the course. These are important factors to consider in any educational institution. They are crucial in

determining whether a student's academic life is a success or a failure. However, examining the predictive factors that influence students' performance in engineering mathematics dearth the scholarly attention, and it is the purpose of this study to make a scholarly contribution to such identified lacuna.

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METHODOLOGIES

The targeted population for this study was engineering mathematics students in the technical universities of Ghana. Within this targeted population, three hundred and fifteen (315) participants (105 of them from each technical university) were conveniently sampled from three randomly selected technical universities in Ghana namely Cape Coast Technical University (CCTU), Kumasi Technical University (KSTU), and Tamale Technical University (TATU). Also, six (6) expert interviews were conducted which lasted for 20 to 30 minutes each. With these, the informed consent of the participants was taken into consideration, participants were given the free will to be answerable and unanswerable to survey instruments/questions asked during data collection. Also, to ensure anonymity, the study participants were made aware that their data and responses given are solely for academic purposes and strictly confidential. These made the participants of the study give out their full participation in the study process.

Cross-tabulations, univariate, and bivariate statistical methods were used to examine all descriptive variables. A logistic regression model was used to examine the predictive factors that affect students' performance in engineering mathematics. Pearson's Chi-square test was used to examine the percentage distribution and the relationship between the dependent and independent variables.

The independent variables were run against the dependent variable (my first semester (2020/21) performance (grade) in engineering mathematics. The independent variables with the p-value ≤ 0.05 mean that those variables have a positive significant relationship with the students' performance. Factors that fundamentally influence students' performance in engineering mathematics were also broken down at the multivariate logistic regression model level to examine the magnitude respectively on the student's performance in engineering mathematics at the Chi-square test level. For all data analyses, the Statistical Package for Social Sciences software version 22.0 was used. In all tests, a p-value of 0.05 (2-sided) was considered crucial in all test study analysis easier, we divided the participant responses into two categories: those who Agreed and Strongly Agreed as "Agreed," and those who Strongly Disagreed, and Disagreed as "Disagreed." For the first semester's grades, we grouped them into two: C-C+, B-B+, and A-A+ as "Good," and below F, and D-D+ as "Bad."

RESULT

Three hundred and fifteen (315) students, ages ranging from 15 to 50 years, with socio-demographic features that include 302 male students (constituting 95.87% of the total sampled size) and 13 female students (constituting 4.13% of the total sampled size) and

six expert's interviews which comprise of 4 females' and 2 males. However, it is very important to establish the fact that the male majority in the participant selection is not a result of any form of selection bias but was mainly due to the male domination in the field of engineering mathematics, their readiness, motivation, and availability to participate in this research in comparison to the non-readiness, no/less motivation and non-availability of female to participate in this research due to their minimal numbers in engineering mathematics.

Since the goal is to discover personal factors that influence students' performance in engineering mathematics, we used the first semester's grades of the 2020/21 academic year as a dependent variable and other factors as the independent variables. Only three characteristics have a substantial relationship effect on first semester grades according to our findings including terrible training, and low interest in engineering mathematics. For the age factor (as an independent variable), we divided it into three categories: under 25 years old, 26 to 34 years old, and 35 years old and above. Other factors (I feel insecure when attempting engineering mathematics questions, I do not like engineering mathematics, my mind goes blank when working on engineering mathematics, engineering mathematics made me feel uncomfortable, and I am happy in engineering mathematics class than other subjects) were ignored due to their insignificant effect on the student performance associated with their first semester's grades. This made it easier to figure out students' feelings toward engineering mathematics. Table 1 and Tables 1.1 give the details of the participant's responses.

In Table 1, to obtain 100%, we add the percentages in vertical, and in Table 1.1 we add it in horizontal.

Table 1: age against performance in univariate

			Last semester's mark in Engineering Mathematics		
			Good	Bad	p- value†
Factors			n(%)	n(%)	
		Below 25	160(85.5)	86(67.2)	
Q2	Age	26 to 34	26(14.0)	37(28.9)	0.000
		Above 35	1(0.5)	5(3.9)	

***Note: %** = Percentage; **Q** = Question, **Q2**= Question number, the †Chi-square test was used. p-value at $p \leq 0.05$.*

Table 1.1 The relationship between the dependent and independent variables

Factors	Response	Last semester's mark in Engineering Mathematics Good N (%)	Bad N (%)	p-value
I am always under terrible strain in engineering mathematics class	D	50(39.1)	78(60.9)	0.030
	A	44(23.5)	143(76.5)	
I do not like engineering mathematics	D	41(32.0)	87(68.0)	0.055
	A	37(19.8)	150(80.2)	
My mind goes blank when working on mathematics	D	43(33.6)	85(66.4)	0.052
	A	33(17.6)	154(82.4)	
Engineering mathematics is interesting to me	A	43(33.6)	85(66.4)	0.000
	D	106(57.2)	80(42.8)	
I feel insecure when attempting engineering mathematics questions	A	79(61.7)	49(38.3)	0.060
	D	143(76.5)	44(23.5)	
Engineering mathematics makes me feel uncomfortable	A	37(19.8)	150(80.2)	0.075

	D	82(64.1)	46(35.9)	
I am happy in engineering mathematics class than in other subjects	A	31(24.2)	71(75.8)	0.066
	D	116(62.0)	71(38.0)	

Note: *% = percentage,* ***A*** *= Agreed and Strong Agreed,* ***D*** *= Strongly disagreed, and disagreed, the †Chi-square test was used. p-value at* $p \leq 0.05$

Table 2: Multivariable logistic regression by students.

Factors	**AOR**	**95% CI**	**p**
Age			
A	29.918	(1.043, 94.311)	0.046
D		Reference	
I am always under a terrible strain in engineering mathematics class	0.550	(0.310, 0.976)	0.041
A			
D		Reference	
Engineering mathematics is very interesting to me and I enjoyed it	2.281	(1.279, 4.067)	0.005
A			
D		Reference	

Note: *Not included at the multivariate level because of non-significance at the bivariate level.* ***AOR*** *= Adjusted Odd Ratio;* ***A*** *= Agreed,* ***D*** *= Disagreed,* ***CI*** *= Confidence Interval and* ***p*** *= p-value at* $p \leq 0.05$.

DISCUSSION

The elements that influence students' engineering mathematics performance were investigated in this study. This is the first time a comprehensive study of such a nature on technical university students in Ghana has been conducted. The findings revealed that independent variables such as age, terrible strain in engineering mathematics class, and interest in engineering mathematics are the major predictive factors that affect students' performance in engineering mathematics. Other factors such as I feel insecure when attempting engineering mathematics questions, engineering mathematics made me feel uncomfortable, I do not like engineering mathematics, and I am happy in engineering mathematics class than in other subjects which do not have a significant effect or relationship with the first semester grades were not considered as a result of

their poor background in mathematics from technical senior high school by the expert interview.

With the age category 25 years and below, 160 participants representing 85.5% had a good grade, and 86 participants representing 67.2% also had a poor grade in engineering mathematics. For those aged 26 to 34, 26 participants (14.0%) obtained a good grade while 37 of them (28.9%) had a poor grade. Also, in the age category 35 years and above, only 6 participants and only a percent had a good grade, and the rest had a poor grade. Considering the relation between the age group of the study participants and their performance in engineering mathematics, it is therefore noticed, that the above research findings correspond or concur with the empirical position of John et al. (2015), asserts that there is a significant relationship between age and academic achievement among students.

Also, one hundred and eighty-seven (187, representing 59.37%) of the study participants agreed that they feel terrible in engineering mathematics class and only forty-four (44, representing 23.5%) obtained good grades and 143(76.5%) had poor grades. The feeling of terror in students in engineering mathematics class promotes a sense of anxiety in such students. With this, it was realized in this study, that the higher the students' anxiety/ feel of terror-the lower the performance, and the lower the students' anxiety/feel of terror – the higher the performance. This research finding conforms with the psychological assertion of Brezavšček et al. (2020) which states that students with a lower level of mathematics anxiety produce better mathematics performance at the university level. However, it is also important to highlight those one hundred and thirty-six (136) participants disagreed that they feel terrible in engineering mathematics class. Among them, only fifty (50, representing 39.1%) had good grades, and eighty-six (86, representing 60.9%) had bad grades. This research finding agreed with the psychological assertion of Brezavšček et al. (2020) that a student's performance in engineering mathematics is minimally affected by his/her uncomfortable feeling in class. This means that other predictors are family-related, school factors, and peer factors (Crosnoe et al., 2004), biological (Patterson et al., 2003), socioeconomic (Considene & Zappala, 2002), and student's commitment to studies (NIB, 2000) may influence the engineering mathematics performance outcome of the students in the technical universities in Ghana.

Moreover, it's also worth noting that one hundred twenty-eight (128) individuals disagreed that they feel uncomfortable in engineering mathematics classes. Only eighty -two (82, representing 64.1%) of them earned good grades, and forty-six had bad grades (46, representing 35.9%). 187 participants agreed that they feel uncomfortable in engineering mathematics class. One hundred fifty (150 representing 80.2%) had a bad grade and thirty-seven (37 representing 19.8%) had a good grade which agrees with the expert opinion that students coming from technical senior high school do not do elective mathematics so mathematics at technical university is very difficult for them.

Furthermore, one hundred and twenty-eight (128) participants disagreed that they do not like engineering mathematics but only 32.0% of them got good grades and 68.0%

had a poor grade. Students liked engineering mathematics but still had poor grades (teacher quality issue). Also, one hundred and eighty-seven (187) participants agreed that they do not like engineering mathematics with thirty-seven (37, representing 19.8%) having good grades and one hundred and fifty (150, representing 80.2%) having poor grades. This is due to a low level of student interest in the course due to the difficulty of the course. Finally, 186 students agreed that engineering mathematics is something they enjoy. With this, one hundred and six (106, representing 57.2%) had good grades due to their commitment, motivation, and desire to study (Enu and Nkum, 2015; Benson 1999), and 80(42.8%) had a bad grades due to their complacency and underestimation of the course, hence, producing the bad or mediocre grades. One hundred and eighty-seven (187) participants do not enjoy engineering mathematics. Out of this, one hundred and fifty-four (154, representing 82.4%) had bad grades and 33(17.6%) had good grades which agrees with the expert interview that students from technical senior high schools have a poor background in mathematics that contributes to the difficulty in liking engineering mathematics, which also demotivates the participants from investing much time and effort into studying the course. This psychologically inculcates into the minds of students that engineering mathematics is a terrible course to study.

CONCLUSION AND RECOMMENDATIONS

The goal of the research was to find out the predictors of students' performance in engineering mathematics in technical universities. The data led to the conclusion that predictors such as age, terrible strain, and level of interest are personal factors that affect students' engineering mathematics performance. It was revealed by an expert's interview that students from senior high school like engineering mathematics whiles those from technical senior high school do not like engineering mathematics because of their poor background in mathematics. Students from Senior High School get the chance to do advanced mathematics whiles those from the Technical Senior High School do not get the chance to do advanced mathematics. As a result of the above findings, recommendations such as the organization of pre-calculus classes for students especially the older and those from technical senior high school help them catch up with their colleagues.

Finally, students should be encouraged consistently to invest much time and effort in learning engineering mathematics since complacency is not an option.

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