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Mathematics as Determinant of Students' HOTS Among HND Electrical and Electronic Engineering Students in Ghana

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ABSTRAK

Salah satu komponen penting dalam pendidikan adalah mengembangkan keterampilan berpikir tingkat tinggi (HOTS). Tujuan dari penelitian ini adalah untuk menganalisis matematika sebagai determinan HOTS siswa pada mahasiswa HND teknik elektro dan elektronik di Ghana. Alat format tes yang digunakan memiliki dua indikator yaitu berpikir kritis dan kreatif, dan subjek penelitiannya adalah 488 mahasiswa teknik elektro dan elektronika dari 4 Universitas Teknik di Ghana yang dipilih secara acak. Uji reliabilitas Cronbach Alpha dilakukan, dan uji Pearson digunakan untuk menilai validitas instrumen MAT. Data diolah dan dianalisis menggunakan software SPSS versi 26.0. Regresi berganda digunakan sebagai teknik estimasi, dan hasilnya menunjukkan korelasi positif tinggi antara HOTS dan probabilitas (0,757), dan korelasi positif sedang untuk aljabar (0,669), fungsi (0,633), trigonometri dan bilangan kompleks (0,604), dan kalkulus dan persamaan diferensial (0,572). Statistik ini menunjukkan bahwa tingkat pemahaman konsep matematika, khususnya probabilitas, dapat menentukan HOTS. Implikasi penelitian ini adalah bahwa pengembang kurikulum matematika teknik harus menekankan penerapan praktis matematika, khususnya probabilitas dalam kehidupan sehari-hari dan menawarkan kesempatan bagi siswa untuk menggunakan pengetahuan matematika mereka untuk memecahkan masalah dunia nyata guna mengembangkan HOTS.

ABSTRACT

One crucial component of education is developing higher-order thinking skills (HOTS). The aim of this study is to analyze mathematics as determinant of students' HOTS among HND electrical and electronic engineering student in Ghana. The test format tool used had two indicators, critical and creative thinking, and the subjects for the research were 488 electrical and electronic engineering students from 4 randomly selected Technical Universities in Ghana. The Cronbach Alpha reliability test was performed, and the Pearson test was used to assess the validity of the MAT instrument. Data were processed and analysed using SPSS version 26.0 software. Multiple regression was used as the estimation technique, and the results show a positive high correlation between HOTS and probability (0.757), and positive moderate correlations for algebra (0.669), functions (0.633), trigonometry and complex numbers (0.604), and calculus and differential equations (0.572). These statistics suggest that the level of understanding of mathematics concepts, particularly probability, can determine HOTS. The study's implication is that engineering mathematics curriculum developers should stress the practical applications of mathematics, especially probability in everyday life and offer opportunities for students to use their mathematical knowledge to solve real-world problems in order to develop HOTS.

1. INTRODUCTION

Technical University education is one important component of the educational system that contributes to the creation of the middle-class workforce required for a nation's economic and technological growth. The advancement of technical University education is of high significance at this time Ghana is recovering from an economic recession because it has the potential to be a tool for diversify economy through the development of entrepreneurship in order to minimize unemployment. The main goal of technical university education is to prepare students for technical and vocational careers so they can start their own businesses after graduation and employ others. As a result, National Diplomas, Higher National Diplomas, and Postgraduate Diplomas are awarded, which are crucial for a nation's needs and development. Today, a country's destiny is determined by its residents' educational achievement and quality. As a result, the most beneficial nations are those whose populations have received a good education in the mathematics, engineering, technology, and other subjects that define the 21st century

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skills. The problem is that, courses like engineering are tied to higher-order thinking skills (HOTS), and students' academic success in mathematics learning. How are students who major in engineering and take courses in mathematics graded on their HOTS? Analysis, problem-solving, imagery, and both creative and critical thinking are all included in the definition of HOTS (Nguyễn & Nguyễn, 2017; Sun et al., 2022). These skills include the capacity to categorize things, contrast and compare ideas and theories, write about topics, and find solutions to issues. Both critical-thinking skills and creative-thinking skills come together under the heading of HOTS that are grounded in lower-level thinking (Ferrer & Staley, 2016; Singh et al., 2020). Students have to know the basic facts, understand the concepts, and apply what they know so that they can pick the topic apart through analysis, make a judgement call or create something new based on the idea. One of the abilities and skills that incorporate the use of HOTS in the classroom is the ability to engage in complicated thought that goes beyond mere data recall. Students around the world have problems with mathematics, including failures in the classroom, poor performance, and weak competencies (Costa & Diniz, 2022; Lehtinen et al., 2017). Even individuals entering university education were found to be unprepared for advanced and difficult mathematical courses (Cloonan et al., 2020; Nortvedt & Siqveland, 2019). These problems revealed that students' mathematical cognition was weak and that their higher-order thinking abilities were in doubt. To fill the gaps in studies, this study used a test based on Bloom's Taxonomy to gauge the cognitive capacity of technical university students who were currently enrolled in engineering courses to learn how they approached and solved problems in general mathematics covering the areas of Algebra, Functions, Trigonometry and Complex Numbers, Calculus and Differential Equations, and Probability. The study's conclusions evaluated how mathematics subjects have prepared students for the engineering subjects.

Ghana, a sub-Saharan African country, has a population of 31 million and its educational system must adapt to ensure that students acquire relevant skills for the rapidly changing global economy. The younger generation's education should prioritize problem-solving, critical thinking, and higher-order thinking abilities to prepare them for the 21st century's innovations. Several studies highlight the need for education goals to focus on these skills (Liu et al., 2021; Vidergor, 2018). This approach will enable Ghana's youth to contribute to the country's future success. According to statistics from the 2011 Trends in International Mathematics and Science (TIMSS) study, thinking ability among Ghanaian students is rated as being below average. Students from Ghana can only practice on problems requiring minimal critical thinking skills (questions that only require skills such as knowing or recall) (Bonyah & Clark, 2022; Sasson et al., 2018). Even though Ghanaian teachers performed rather well across the majority of the teacher preparation categories examined by the TIMSS study, this did not translate into improved student achievement. It is advised that researchers give attention to studying their students' high-order thinking levels in light of this.

Researchers have discovered that learners can be taught how to foster and develop HOT over time. Students should participate in understanding and knowledge transformation, which are said to as the ultimate goal of learning, to accomplish HOT (Thuneberg et al., 2018). In this context, different communications have established standards for legitimate assignments that might support educators' HOT; nonetheless, the majority of the activities offered are not appropriate for courses related to mathematics. Therefore, educational institutions need to work hard to create activities and teaching resources that might encourage HOT among students.

It is possible to think of mathematics as the language of science, technology, and engineering. It is often said that science and engineering cannot exist without mathematics. The use of mathematics in the social, medical, and physical sciences has significantly increased in recent years, demonstrating its importance in all school curricula and driving up demand for university-level mathematical training (Ramírez-Montoya, 2017; Tseng et al., 2013). Students are consequently taught strategies for addressing diverse mathematical problems as part of both pre-tertiary and tertiary curricula, and depending on the level of competence attained, these strategies may fail during the assessment phase. In other words, if one is not put through the necessary training to gain the appropriate competency, mathematical thinking may fail to achieve the desired result.

It was argued that cognitive engagement was crucial to creating in-class activities that were linked to higher-order thinking abilities (Soysal, 2021). The classic Bloom's Taxonomy has undergone continuous revision by previous study who have created a cognitive domain with an extensive set of concepts that purports to include all facets of HOT (Anderson & Krathwohl, 2021). In other words, by utilizing the hierarchical nature of knowledge, including remembering, Understanding, Applying, Analyzing, Evaluating, and Creating, they developed a practical and beneficial method for employing objectives as instruments to encourage students with lower-level thinking into higher-level thinking. Higher-order mathematics thinking (HOMT) therefore involves the use of the acquired thinking skill to recognize and think through problems and translate them into mathematical models that can be readily solved in the context of applications, analysis, synthesis, and evaluation. This is actually in the context of Bloom's Taxonomy (Prakash & Litoriya, 2022; Sokolowski et al., 2011). HOTS as a concept of education reform, concerning mathematics is based on learning taxonomies like that of Bloom, which is based on the notion that some types of learning and problem-solving in mathematics require more cognitive processing than others but also have more generalized benefits. The type of learning and problem-solving that involves analysis, synthesis, and evaluation are classified as higher-order thinking (HOT), whereas the others that require less cognitive processing, involving knowledge, comprehension, and application, are classified as lower-odder thinking (LOT) (Jansen & Möller, 2022; Oktiningrum & Wardhani, 2020).

Mathematics is often promoted as endowing those who study it with transferable skills such as an ability to think logically and critically, or to have improved investigative skills, resourcefulness, and creativity in problem-solving (Cresswell & Speelman, 2020; Hilmi & Dewi, 2021; Muhali, 2019). The goal of mathematics instruction is to help students acquire various types of knowledge, understanding, attitudes, values, and abilities. The youngster must develop thinking skills to succeed in today's modern culture. Teachers must instruct students on how to think. Higher-order thinking skills have been therefore widely studied. Research was conducted to study whether HOTS were related to academic achievement in mathematics (Durachman & Cahyo, 2020; Laurens et al., 2017; Tanujaya et al., 2017). They found that there was a strong positive correlation between HOTS and grade point average in 41 university students who had completed 120 credits in mathematics education in the university of Papua. The study concluded that there is a significant relationship between HOTS and academic achievement. Many other researchers, *similarly* used realistic mathematics education (RME) *as a way to improve students' abilities especially in mathematics* (Ariati & Juandi, 2022; Farida et al., 2019). *The population in their study were students from various schools, mostly in Indonesia. And their results showed that the ability to think creatively and mathematical connections of students in their experimental class were better than students who obtained conventional mathematics learning. Other researchers also investigated and found that there effective problem-based learning (PBL) in mathematics positively affects HOTS (Minarni & Napitupulu, 2020; Saepuloh et al., 2021; Suparman et al., 2021).* However, all these research focus on general mathematics and HOTS, and none focuses explicitly on each mathematics topic and HOTS.

After reviewing the literature, it was revealed that HOTS was uncommon in Singaporean mathematics classrooms because of the subject's teacher-centered learning environment and pedagogical successes undoubtedly pertain to students who have a minimal grasp of precalculus' fundamental ideas, and even the best ones merely succeed at a procedural manner of thinking. However, it was discovered that conditions of HOTS can occur in university mathematics lectures (Andriani et al., 2018; Shu Mei & Yan, 2005). Meanwhile, it is clear in the literature that no other study has examined the assessment of students' HOTS among engineering students in relation to important mathematical areas (topics), except for an indirect study that looked at HOTS among engineering students through mathematical problem-solving tasks. This research seeks to fill that gap. To address the research gap, this study's primary objective is to investigate the effect of training the brain toward the understanding of mathematics concepts in specific areas such as algebra, functions, trigonometry and complex numbers, calculus and differential equation, and/or probability affect students' HOTS. The aforementioned topics are key to electrical and electronic engineering. The study seeks to determine how strongly the selected engineering mathematics topics influence the HOTS of the HND electrical and electronic engineering students. We would thus conclude that mathematics topics that strongly influence students' HOTS are those that give them the needed skill for problem-solving in the theory field of study (Ghasempour et al., 2012; Lu et al., 2021). This development research is anticipated to be applied and contributed to the field of education, particularly concerning the creation of engineering curricula. Also, Students, parents, instructors, policymakers, and the general public can gain some understanding of how students develop higher-order thinking skills and their current cognitive ability through this study.

2. METHODS

A Mathematics Achievement Test is the primary data gathering tool in this study, which takes a quantitative approach. The framework or strategy for an investigation, used as a direction to collect and analyse data, is known as research design (Abutabenjeh & Jaradat, 2018). A research challenge that requires the identification of factors that influence a result is being addressed by using the quantitative method. Thus the research design employed in this study is the correlational research design (Acheampong et al., 2023; Apuke, 2017). Without the researcher manipulating any of the variables, this will help in the investigation of the relationships between them. Correlation reflects the strength and direction of the relationship between students' HOTS and their knowledge of the five selected topics of mathematics. The objective is to forecast the value of the dependent variable using the values of the known independent variables and to describe how each independent variable affects the dependent variable. The population in this study was 2022 final year HND electrical and electronic engineering students in the ten technical universities (TUs) in Ghana who have already completed their engineering mathematics courses over their first four semesters and make up the research population of interest in this study. Four TUs were randomly selected from the ten Technical Universities. Second-year HND electrical and electronic students at Cape Coast Technical University (CCTU) who had just completed their fourth semester were selected for testing the MAT instrument. This is as a result of a common entry requirement and syllabus for the HND electrical and electronic engineering program. Within the TUs that were randomly sampled, a convenient sampling technique was used to get a sample total of n = 488 students. A convenient sampling procedure was adopted within the selected TUs. That is, those who turned up for the four MAT sittings. These are 281 students from ATU; 54 from CCTU; 123 from HTU, and 30 from WTU, making the total sample for the study. These samples were however found to be approximately proportional to the numbers in the institutions.

The Mathematics Achievement Test (MAT) used for this research were in two types: the subjective type (MAT I) and objective type (MAT II). Both MAT I and MAT II were both made up of five sections, A to E, covering the areas of Algebra, Functions, Trigonometry and Complex Numbers, Calculus and Differential Equations, and Probability, respectively. MAT, I consisted of test items in each section that measured students' HOTS (analysis, evaluation, and creativity). MAT II consisted of twenty (20) objective test items in each section, covering the course content for the study in the six levels of the cognitive domain according to the Bloom Taxonomy (Muhayimana et al., 2022). Test items were on knowledge, comprehension, applications, and higher-order thinking. Because of the volume of the test, MAT II was administered on three different occasions under standard examinations condition. The many items in the MAT ensure repeated measurements in the cognitive domain and thus reducing the effect of using multiple choices in the measurements. We were also motivated by the positive impact multiple-choice question authoring and regular participation have on students' learning (Riggs et al., 2020) The Cronbach Alpha reliability test was performed, and the Pearson test was used to assess the validity of the MAT instrument. The value of the Cronbach Alpha was 0.8. The statistical tool employed in in analysing the data was the multiple linear regression analysis. Data were processed and analysed using SPSS version 26.0 software. The study adopted the data collection procedure indicated in the chat as in the works by (Acheampong et al., 2023). **Figure 1** represents the data collection procedure.

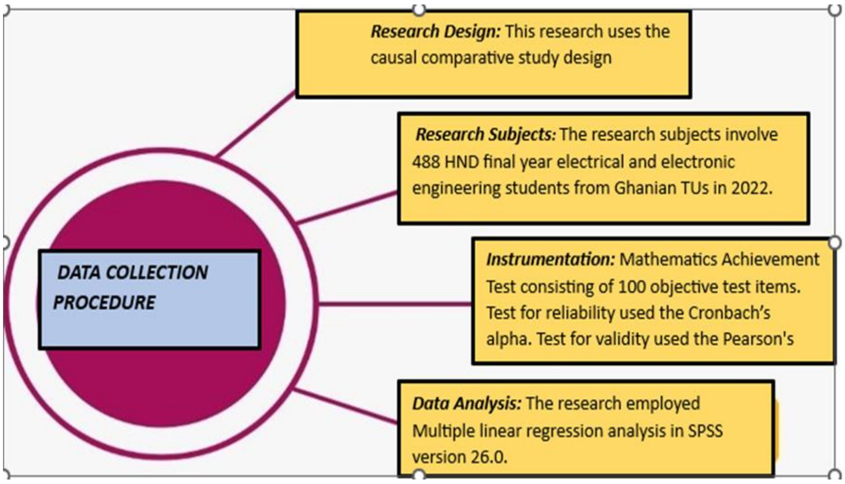


Figure 1. Data Collection Procedure

3. RESULT AND DISCUSSION

Results

This study begins the presentation of the results with a descriptive analysis of the data. The descriptive statistics will provide an overview of the student's performance in the MAT, and provide a knowledge base that will be a foundation and ground for our further quantitative analysis which will map the landscape for all the drawbacks in the students' MAT results. Table 1 consists of descriptive measures from the SPSS version 26.

Table 1. Descriptive Statistics for the Mathematics Topics Data

Variable	N	Minimum	Maximum	Mean	Std. Deviation
ALG	488	5	90	55.87	13.602
FUNC	488	20	95	58.14	12.045
TRIG	488	5	95	58.36	11.163
CALC	488	10	85	55.13	11.874
PROB	488	0	85	45.34	13.463
HOTS	488	0	92	42.60	15.896

Table 1 shows that the distribution of scores for the selected mathematics (Algebra, Functions, Trigonometry and Complex Numbers, Calculus and Differential Equation, and Probability) is from the lowest level (5, 20, 5, 10, and 0) to the highest level (90, 95, 95, 85 and 85). The HOTS data is also distributed from the lowest HOTS values of 0 to the highest of 92. In addition, the standard deviations (13.602, 12.945, 11.163, 11.874, 13.453, and 15.896), for all six variables are reasonably low indicating that there are good variabilities in each set of subject scores. The variation in the data is very important for analyzing data using the statistical procedure, and thus this data can be analyzed using correlation and regression analysis. Variability in the data is very important in estimating and testing the population parameters.

We then move on to assess the suitability of the data for the multiple correlation and regression analysis. The assumptions to check are (1) linearity (2) normality, (3) independence of errors, (4) homoskedasticity (5) independence of the independent variables (noncollinearity). To investigate the linear relationship between the independent variables: Algebra, Functions, Trigonometry and Complex Numbers, Calculus and Differential Equations, and Probability, and the dependent variable: HOTS, the multiple linear regression analysis was used. The multiple regression analysis is used to establish the correlations between these independent variables in other to predict the HOTS of the HND electrical and electronic engineering students. The multiple regressions helps to identify which of the mathematics topics have a significant impact on students' HOTS. We first investigate the assumptions for multiple regression analysis to have confidence in all our results. Figure 2 is an SPSS output for matrix scatterplots for all the variables under investigation.

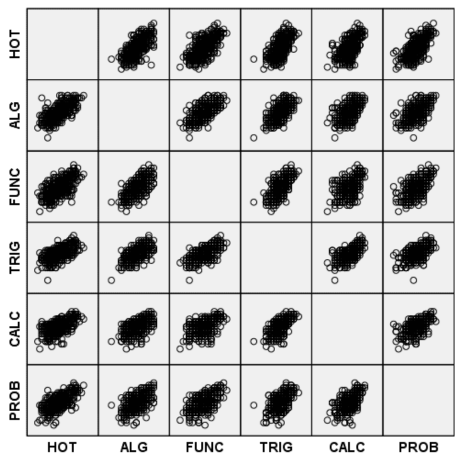
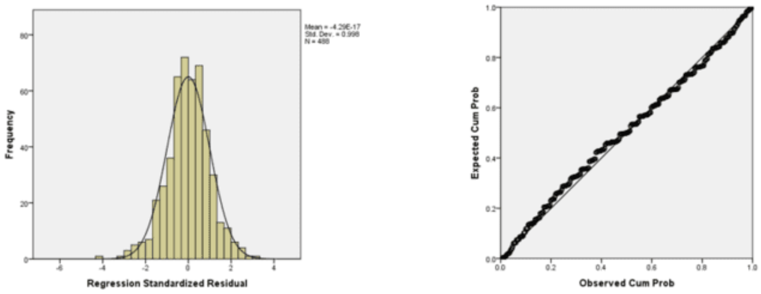


Figure 2. Matrix Scatterplots for Multiple Regression Variables

The first column or row of the matrix shows the scatterplots for HOTS on Algebra, HOTS on Functions, HOTS on Trigonometry and Complex Numbers, HOTS on Calculus and Differential Equations, and HOTS on Probability. We observe that in each case, the plots show some linear relationship between the variables. Thus, the linear relationship requirement (between the dependent and each independent variables) for multiple regression is satisfied.

The visual test for normality was used to determine the normality assumption of the independent variables. The benefit of statistical testing is that they can produce objective conclusions about the data. However, due to its disadvantage of being overly sensitive to large data and insensitive to small sample sizes, Graphical judgments about the data are sometimes preferred. Figure 4 is a display of the normality test from SPSS. Figure 3 is a check on the normality assumption for the regression model.



(a) (b)

Figure 3. Normal Plots of Regression Standardized Residual Variable: HOTS

From Figure 3, the histogram has the usual bell shape of the normal curve. Also, the plots in (b) tend to follow a straight line. This shows that the normality assumption for multiple regression analysis is satisfied. Standard residual on standard predicted values is show in Figure 4.

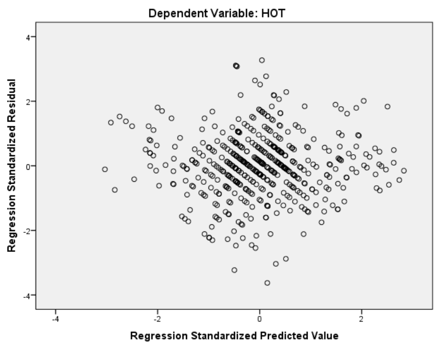


Figure 4. Standard Residual on Standard Predicted Values

Figure 4 is the visual representation of the standard residuals plotted on the standard predicted values. It is seen that the correlation is zero and the points roughly run in a square area of -3 to 3. This implies that there is no relationship between the HOTS and the residuals or the errors. Thus the assumption of independence of errors is also satisfied for the multiple regression analysis. If the errors are not independent, the estimate of the error standard deviation and thus regression results would be biased, potentially leading to improper inferences about students' HOTS. For the last two assumptions, we wanted to check our noncollinearity and homoskedasticity. The variance inflation factor (VIF) is a measure of the amount of multicollinearity in the set of multiple regression variables. If the VIF is more than 10, there is an indication of multicollinearity in the data. From the SPSS output for collinearity statistics shown in Table 2, all the VIFs are less than 10, and this indicates that our regression data does not suffer from multicollinearity.

Table 2. Collinearity Statistics for Regression Data

Variable	Collinearity Statistics	
	Tolerance	VIF
ALG	0.452	2.211
FUNC	0.448	2.231
TRIG	0.456	2.191
CALC	0.549	1.82
PROB	0.538	1.857

Homoskedasticity in regression analysis is important because it can reveal population differences. Any unequal variation in a population or sample will lead to skewed or biased results, which will invalidate the study. The Durbin Watson (DW) test was used to assess the assumption of equal or similar variances in different groups being compared. From the multiple regression model summary, the Durbin-Watson test for the regression model was 1.872. A DW of 1.872 indicates a very low positive heteroskedasticity which will not affect our regression estimate, given that all the other assumption are satisfied. At this point, we could go ahead to check the correlation between dependent and the independent variables.

Table 3. Correlation Between Variables: HOTS and Mathematics Topics

		HOTS	ALG	FUNC	TRIG	CALC	PROB
HOTS	Pearson Correlation	1	0.669	0.633	0.604	0.572	0.757
	Sig. (2-tailed)		0.000	0.000	0.000	0.000	0.000
	N	488	488	488	488	488	488

The summary of the correlation between the dependent variable, HOTS, and the independent variables, ALG, FUNC, TRIG, CALC, and PROB is shown in Table 3. The coefficient of correlation measures the degree of the relationship. The correlation table shows Pearson correlation coefficients, significance values, and the number of cases with no missing values. The range of a correlation coefficient is always from -1 to 1. Values of correlation coefficient near 0 indicate a very weak linear relationship. Values close to -1 indicate a very strong negative linear relationship between the dependent variable and independent variable, whereas those close to +1 show a very strong positive linear relationship between the two. Only when there is a perfect correlation between the dependent and independent variables can the correlation coefficients reach their extreme levels, $r = -1$ or $r = +1$. Table 3, shows a strong positive linear correlation between HOTS and probability scores ($r = 0.757$). This is followed by HOTS and Algebra which indicates a moderate positive linear relationship between the two variables ($r = 0.669$). The correlation between HOTS and Functions (0.633), HOTS and Trigonometry/Complex Numbers (0.604), and HOTS and Calculus are all showing a moderate positive linear relationship between the variables with an order of declining strengths. Furthermore, on the test p-values ($p<0.001$), they all show very strong evidence to suggest that the strengths of linear relationships mentioned above are all true. Multiple regression analysis produces an equation to describe the statistical relationship between two or more predictor variables and the response. SPSS generates two types of coefficients: standardized and unstandardized, which are used to construct a multiple regression equation. In multiple regressions where the explanatory variables were measured using various units, the standardized coefficients are used.

Table 4. Estimated Coefficients of Multiple Regression Model of HOTS on ALG, FUNC, TRIG, CALC, and PROB

Variable	I	II	III	IV
(Constant)	-21.130	2.691	-7.852	0.000
ALG	0.302	0.050	6.063	0.000
FUNC	0.217	0.056	3.845	0.000
TRIG	0.154	0.060	2.555	0.011
CALC	0.190	0.052	3.665	0.000
PROB	0.326	0.046	7.082	0.000

The rationale for this is to put all explanatory variables on the same scale, so that their coefficients can be compared. In the MAT data, we were able to convert all scores to percentages. Thus, unstandardized coefficients were used to estimate the multiple regression equation. From Table 4, the multiple regression equation for our investigations where HOTS is the dependent and Algebra, Functions, Trigonometry, Calculus, and Probability the independent variables is given by Also, the standard errors in Table 4 represent estimates of the variances of the unstandardized coefficients and can be applied to significance tests for the coefficients. Tests evaluating the value of the unstandardized coefficients include t-values and their accompanying significance values. From Table 4, we conclude that all the results are highly significant ($p<0.001$), and we therefore maintain that the coefficients in the multiple regression model cannot be zero. Also, Table 5 shows the Analysis of Variance (ANOVA) for the multiple regression model with an F-value of 147.438, and p=0.000.

Table 5. ANOVA of Multiple Regression of HOTS on ALG, FUNC, TRIG, CALC, and PROB

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	74407.241	5	14881.448	147.438	0.000
Residual	48650.037	482	100.934		
Total	123057.279	487			

Base on Table 5 the p-value of less than 0.05 implies that there is sufficient evidence to reject the null hypothesis and conclude that the regression coefficients (all coefficients and constant) are not zero. The feasibility of the regression model was also presented in the model summary in Table 6.

Table 6. Multiple Regression Model Summary

Model	R	R Square	Std. Error
1	0.778	0.605	10.047

Base on Table 6, the R-square value of 0.605 is a measure of the multiple regression model fit. This implies that 60.5% of the variation observed in students' HOTS data is explained by the independent variables, ALG, FUNC, TRIG, CALC, and PROB. This explanation is done with a standard error of 10.047%. The regression equations can be used for predicting students' HOTS with errors within the tolerance limits, for known values of ALG, FUNC, TRIG, CALC, and PROB.

Discussion

The multiple regression was used as the estimation technique, and the results showed a positive high correlation between HOTS and probability (0.757), and positive moderate correlations for algebra (0.669), functions (0.633), trigonometry and complex numbers (0.604), and calculus and differential equations (0.572). In general, the linear relationship resulted between HOTS and mathematics is in agreement with previous research's results, which concluded that there is a significant relationship between HOTS and academic achievement (Tanujaya et al., 2017). Also, the result supports those of researchers who used RME or PBL as a way to improve students' abilities especially in mathematics, and consequently their HOTS (Boldina & Beninger, 2016; Yu et al., 2015). The, research results have therefore shown that students' HOTS in mathematics can be developed through learning the concepts of various topics in mathematics and this also concurs with the findings that HOTS can occur in a mathematics lecture(Andriani et al., 2018; Chen et al., 2018; Olsen et al., 2020).

The model of the multiple regression analysis in Equation 1 revealed that for each percentage increase in the score of Algebra (with others kept fixed), students' HOTS was expected to increase by 0.302. Thus, if two students scored a difference of 10% in the Algebra section of the MAT, then they have a HOTS difference of 3.02% on our assessment scale. Similarly, 1% increase in the scores of Functions, Trigonometry and Complex Numbers, Calculus and Differential Equations, and Probability increased students' HOTS by 0.217%, 0.154%, 0.190%, and 0.326% respectively. From this observation, we can conclude that students' understanding of the concepts of Probability is likely to increase their HOTS in mathematics more than the other areas of mathematics selected for our investigation (Akoglu, 2018; Sarstedt et al., 2019). Mathematics is often promoted for equipping learners with transferable abilities, including enhanced logical and critical thinking skills, improved investigative and resourcefulness skills, and greater creativity in problem-solving (Cresswell & Speelman, 2020; Sharma & Kumar, 2017). Our study findings strongly support this idea that learning specific topics in mathematics, particularly Probability, enhances the ability to solve HOTS related problems through improved mathematical thinking. It was revealed in the literature that HOTS was uncommon in a certain Singaporean mathematics classrooms because of the subject's teacher-centered learning environment. The result of this research has however shown that appropriate pedagogical styles for mathematics have positive influence on students' HOTS in mathematics. Thus, supporting this research has discovered that conditions of HOTS can occur in university mathematics lectures (Andriani et al., 2018). Also, the novel assessment of students' high-order thinking skills among engineering students using important mathematical areas on engineering subjects has been made.

Previous study found that probability offers a suitable area for training students using the PBL approach, which has been extensively researched and demonstrated to improve students' critical and creative thinking abilities, both of which are closely connected to HOTS in mathematics, though at the primary level (Shu Mei & Yan, 2005). Our study aligns with other findings, supporting the idea that critical and creative thinking can indeed be fostered through the teaching and learning of Probability (Deeks et al., 2019). Literature suggests that mathematics teachers and lecturers should use the RME, PBL and other effective pedagogical approaches, as means to enhance students' HOTS in mathematics learning and we may therefore argue that these pedagogical styles in Probability learning in the early stages of the student life will best develop his or her HOTS (Al-Qahtani, 2015; Sarstedt et al., 2019; Schmidt & Finan, 2018). The strength of this research is the simultaneous assessment of the five areas of mathematics as determinants of HOTS, as was made possible by the multiple regression analysis. Researchers who conducted similar studies were able to assess the effect of one independent variable in a simple regression model

(Srinivasan et al., 2017; Tanujaya et al., 2017). However, a limitation of this study is seen in the area of possible environmental differences with respect to the four selected TUs (learning environment). Carrying this research in each TU separately might have yielded significantly different strength of the determinants of students' HOTS, for different learning environment

4. CONCLUSION

From the results and discussions, we can draw the conclusion that there is a linear, moderate positive linear relationship between HOTS and knowledge of Algebra, Functions, Trigonometry and Complex Numbers, Calculus and Differential Equations. Students that excel in comprehending all these mathematical concepts are expected to have HOTS. However, those who do well in Probability concepts are expected to have HOTS above their colleagues. The determinants: Algebra, Functions, Trigonometry and Complex Numbers, Calculus and Differential Equations, and Probability, collectively explains of the variation observed in students' HOTS in Ghanian TUs probability has positive linear relationship. Similar research may be carried out in each learning environment, to assess the strength of the relationship between each mathematics area and students' HOTS, as this is likely to necessitate different discussion on the results for each learning environment.

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