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Logistic Regression in Analyzing the Determinants of University Students' Mathematics Performance

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ABSTRACT

Mathematics provides an effective way of building mental discipline, encourages logical reasoning, and plays a crucial role in understanding the contents of other subjects. Mathematics performance is affected by several factors, including grade, social economic status, background and many more. The aim of this study is to investigate the factors which are related to students' mathematics performance and to identify the significant factors which affect the students' mathematics performance of MAT133 course. This study was conducted in UiTM Negeri Sembilan, Kuala Pilah campus. 480 students were selected from various programs who had registered Pre-Calculus course (MAT133). This study employed Logistic regression analysis to test the relationship between predictor variables and the dichotomous outcome variable which is categorized as low or high achiever in the MAT133 course. About 55.7% of the students are high achievers who achieved higher than 70% marks in MAT133. The research findings reveal that students' intake in July (OR = 2.941), male students (OR = 0.315), students who scored A+, A and A- in Modern Mathematics in SPM exam (OR = 0.340), students who had B+ and B- in Additional Mathematics in SPM (OR = 0.512) and assessment marks for MAT133 were found to have a significantly higher possibility to be high-achiever in MAT133. Acquiring strong mathematical background is a priority as a fundamental preparation for students to learn mathematics in higher institution.

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1. Introduction

Mathematics is essential as a key subject in higher education. Mathematical skills are required for most programs at university level and hence serve as a gatekeeper to various future careers domain such as science, engineering or technology[1]. The current fourth industrial revolution era sees a higher demand on the need to develop mathematical thinking among students particularly those in the science fields. Students learn and acquire skills on measuring, sorting, building, noticing patterns as well as making comparisons in mathematic courses. These components help students to learn more by focusing on problem solving rather than rote learning or just getting the right answer.

Despite of its advantages, the level of cognitive ability in mathematics among school students is still unremarkable[2]. In addition, many undergraduate students express lack of interest and restless in learning mathematics courses as they perceived high risks of failure and obtain bad performance assessments which can trigger anxiety and stress[3]. Many science students who enrolled in higher institutions have low to moderate achievement in mathematics during their secondary education. They might have good grades in some other subjects but their actual performance in mathematics does not reflect the expected mathematics capabilities. This situation can be related to the high failure rate of Pre-calculus course, MAT133 for year 2014 to 2018 in UiTM Kuala Pilah campus. The problem further leads to negative impacts on the students and lecturers as well.

Students' low mathematics achievements in many areas are always a great concern to all academics and government institutions. Therefore, revisiting the students` achievement in mathematics need to be conducted as a continuous effort since learning and teaching is a dynamic process. Inspired by this notion, this study was conducted to investigate the significant factors which contribute to mathematics performance among students in the category of low and high achievers.

2. Literature Review

2.1 Gender

Every year a considerable number of studies to determine relationships between gender and mathematics performance have been conducted in various countries. Findings from [4] confirmed that there was no significant difference between gender (male and female). Based on Bayesian analyses on gender differences in mathematic performance on three to ten year-old children, there were significant gender similarities in their neural functioning to indicate that both genders engaged the same neural system during mathematics learning[5]. However, there is a significant difference when gender traits are taken into account. The results from [6] confirm that girls tended to exhibit less positive attitudes about mathematics in particular low motivation and anxiety on mathematics, hence have a negative impact on their results. Similarly, higher mathematics achievement has been represented by male students, which explained by less positive attitudes towards mathematics such as lower self-efficacy by the female students[7]. Researchers in [8] reported that boys students were more positive than girls about their mathematics ability that contributed to their success in learning of mathematics. Based on 32 countries, researchers in [9] concluded that gender differences in mathematics achievement were significant in most countries, that indicated boys were better than girls as early as in fourth grade. This is supported by Asante [10] who claimed that high school males in his study in Ghana showed better mathematics achievement than females. According to the national data of 2011-2012 in India, Das and Singhal [11] found that there is a significant gender gap in mathematics performance in which the rural male students performed better than females. The level of interest in mathematics among male students was higher than females students[12] but by improving the learning strategy can be beneficial to attract the self-efficacy of female students as well as to support gender equity in the learning of mathematics[13].

However, findings in [14] reported that girls in Malta performed significantly better than boys in mathematics and in self-regulated learning (SRL). Tang, Voon and Nor Hazizah [15] discovered that female students in public university in Sarawak tend to perform better than male students in all underachieved mathematics courses. Based on student achievement in public examination from 2008 until 2014, Malaysian girls performed better than Malaysian boys[16]. This finding is consistent with the finding of researchers in [17].

2.2 Prior Mathematical Knowledge

Prior mathematical knowledge measures the acquired mathematics ability and knowledge of the students during their study at school level. The grades of Mathematics and Additional Mathematics obtained in the Malaysian Certificate of Education commonly known as SPM is always considered as a reliable measure of prior mathematics knowledge. Tang, Voon and Nor Hazizah [18] in their research paper found that there was a significant positive correlation between students' course marks and SPM Mathematics grades across all underachieved mathematics courses. These courses comprised of pre-calculus and calculus courses offered in most science and technology-based programs. In addition, the study also reported that there was a significant correlation between students' course marks and SPM Additional mathematics grades. A study done by Murray [19] revealed that students with high grades in mathematic subject of Caribbean Secondary Education Certificate Mathematics (CSEC) also obtained high grades in an Algebra course (MTH111). Hence, undoubtedly prior mathematics knowledge is a significant variable to measure students' current mathematics performance.

2.3 Class size

Class size is a factor which has been studied and debated among researchers. Classroom organization and management including the size of class determination have shown a direct association to the student performance[20]. Tang, Voon and Nor Hazizah [18] found that class size has a significant influence on MAT 133 (Pre-calculus course) but not for other high failure rate mathematic courses offered at higher level of study. MAT 133 is the first mathematics course encountered upon entering tertiary education at university level (UiTM) for science-based students. Smaller class size can help students adapt faster with the new learning and teaching environment. It is undeniable that smaller class size can lead to better facilitation of lecturer-student interaction and enhance the effectiveness of teaching and learning. Larger class size means a greater number of students which might require educators to adopt varied teaching pedagogy to match with varied learning styles of the students especially students whose major is non mathematics. Hence, effective learning is usually thought has significant correlation with small class size.

2.4 Intake (first or second)

In a year, UiTM has two student intakes known as July and December intakes to the admission of any diploma study. It is a common belief among UiTM academicians that there is a difference in terms of students' academic performance between the two intakes. Researchers in [21] reported the failure rate of UiTM Pahang students in April examination was higher than October examination for three consecutive years (2004-2007) in mathematic courses. However, they found that there was no significant difference in students' mathematics performance between both students' intake. In UiTM Kuala Pilah campus, the failure rate of MAT133 according to both intakes are illustrated as follows:

Table 1: Percentages of Failure of MAT133

	April Examination (December Intake)	**October examination (July intake)**
2011	35.56%	9.41%
2012	26.95%	18.45%
2013	17.2%	13.3%
2014	23.1%	16.76%
2015	14.89%	11.1%

Based on the results, it is obvious that the failure rates of April examination are higher than the October examination for the year 2011-2015.

3. Methodology

3.1 Data source

The data that are being used in this study are secondary data which were taken from 476 full-time students from UiTM Negeri Sembilan, Kuala Pilah campus. The data of the respondents were taken for two consecutive years (2016-2017) from various programs who had registered in Pre-Calculus (MAT133) course. Students who enrolled MAT 133 course must underwent mathematics

diagnostic test which compulsory before they started learning. It was an early intervention conducted by the mathematics lecturers to assess the students' prior mathematics knowledge. Before answering the questions, students need to provide particulars such as gender, SPM Mathematics grade, SPM Additional Mathematics grade, SPM English grade, description of former school category. After each session of the diagnostic test, total scores were calculated. Meanwhile, information such as students' final examination marks, assessment marks, students' intake and the class size were extracted from the report of final examination analysis. Students categorized as first, or second intake were students whose first enrollment was in July or December respectively.

3.2 Theoretical Framework

This study consists of one dichotomous dependent variable which is the students' mathematics performance category whether low-achiever or high-achiever and eight predictor variables. The predictor variables included are diagnostic marks, assessment marks, gender, SPM Mathematics grade, SPM Additional Mathematics grade, SPM English grade, class size and semester's intake. The SPM results were grouped into four different categories based on the grade obtained which are excellent, moderate, weak and fail. Those who scored A+, A and A- were grouped as excellent, for B+, B and B- were grouped as moderate, C+ and C were identified as weak and those who obtained below than C were grouped as fail. The theoretical framework of this study is shown below.

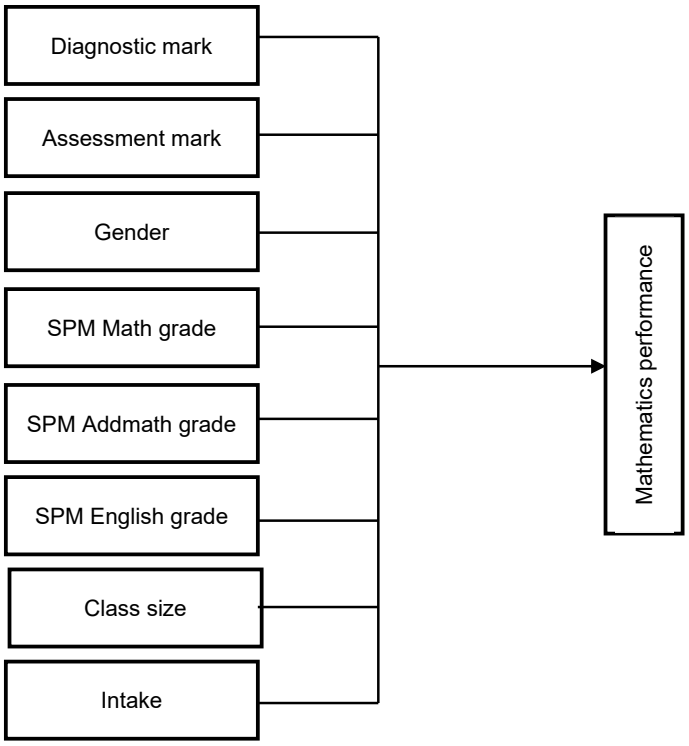

Figure 1. Determinants of Students' mathematics performance

This study categorized the students' performance based on the final exam score of MAT 133. Students who obtained 70% and below are considered to be in the low achiever category [17]. The cut-off seventy percent is predetermined due to the fact that students need to have strong foundation in introductory mathematics subject to move comfortably to the next level of calculus courses. Furthermore, in UiTM, a 'high-failure rate' course is a course with the passing percentage of less than 70 [15].

Additionally, in the Outcome Based Education (OBE) implemented in UiTM, the course grade point average (GPA) is used to measure the outcome attainment of overall students' final grade in a particular course. GPA score of 3.0 is attainable if 80% of students scored at least 65 marks.

Justification needs to be produced if GPA score is below 3.0. Hence, the choice of 70% as a cut-off mark is seen to be plausible.

3.2 Logistic Regression

Logistic regression analysis was used to identify the factors that affect the mathematical performance of students who took MAT 133 course. Logistic regression model is a model predict binary outcome based on a set of predictor variables. The probability of the dependent variable in logistic regression will be 1 as probability of high achiever students or 0 as probability of low achiever students. The general model of logistic regression is given by Equation (1).

$$logit(p) = log\left[\frac{p(x)}{1-p(x)}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k + \varepsilon \quad (1)$$

Then, in order to simplify the above model, the following formula in Equation (2) was used to calculate the value of p which is another rearrangement of the above formula.

$$p = \frac{exp(\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots.\beta_k X_k+\varepsilon)}{1+exp(\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots+\beta_k X_k+\varepsilon)} \quad (2)$$

where
p = The probability of success of successes of dependent variable
β_0 = The constant of the equation
β_k = The coefficient of the independent variables
X_k = The independent or predictor variables

There are four requirements to assess the logistic regression model which is firstly omnibus test of model coefficient. This test evaluates the information from predictor variables whether they give better prediction to the students' mathematical performance. The second requirement is Hosmer and Lemeshow test for the goodness-of-fit of this model. This requirement next followed by predicting the efficiency of the model by using by classification table. The classification table compares the predicted value for the dependent variable based on the logistic regression model with the actual observed value in the data set. Finally, the Cox and Snell R^2 and Nagelkerke R^2 were used to provide an indication of the amount of variation in the response variable explained by the model. The value of this R^2 must be positive and less than 1. All p-values, statistical tests and confidence interval were performed at significance level 0.05.

4. Results and Discussion

4.1 Respondents' Profile

In this research, a total number of samples were 476 which all of them enrolled MAT 133 course. Of this sample, there were 265 students fall into high achiever group which those who scored more than 70% in the final exam. While 211 students belong to the low achiever group. Table 2 presents the frequency and percentage of students for program, semester intake, gender, and SPM results across the performance category, low and high achievement.

Table 2. Summary profile on sample of (n=476) students

Variables	High Achiever	Low Achiever
	n (%)	n (%)
Students' Intake		
First (July)	205(70)	88(30)
Second (December)	60(32.8)	123(67.2)
Gender		
Male	35(41.2)	50(58.8)
Female	230(58.8)	161(41.2)
Students' Program		
Microbiology (AS114)	98(51)	94(49)
Food Technology (AS116)	138(62.4)	83(37.6)
Textile Technology (AS118)	29(46)	34(54)
SPM Modern Maths Grade		
Excellent (A+, A, A-)	258(65.2)	138(34.8)
Moderate (B+, B)	5(8.1)	57(91.9)
Weak (C+, C)	2(11.1)	16(88.9)
SPM Additional Maths Grade		
Excellent (A+, A, A-)	36(94.7)	2(5.3)
Moderate (B+, B)	104(87.4)	15(12.6)
Weak (C+, C)	93(56)	73(44)
Fail	32(20.9)	12.1(79.1)
SPM English Grade		
Excellent (A+, A, A-)	132(65.7)	69(34.3)
Moderate (B+, B)	91(50.6)	89(49.4)
Weak (C+, C)	40(47.6)	44(52.4)
Fail	2(18.2)	9(81.8)

Students' high achievement were highly associated with July intake (70%) as compared to students from second intake (32.8%). High achiever was more among female students (58.8%) than the male students (41.2). Most of the students from AS114 and AS116 program did well in MAT133 with 51% and 62.4% respectively except for students AS118 with only 46%. However, it is observed that the percentage of the low-achiever students from AS118 is around 50% which is considerably high. About 65.2% of high achiever students were excellent as the grade obtained for SPM Modern Mathematics exam are A+, A and A-, this also similar with those who had obtained excellent result in English subject (65.7%).

4.2 Factors Associated with Students' Mathematical Performance

Based on the methodology described, eight variables were selected to model the students' mathematical performance. The coefficient, standard error, Wald statistics, p-value and odd ratio for each variable are shown in Table 3.

Table 3. Model Coefficient

Variable	Estimate Coefficient	Standard Error	Wald Statistic	p value	Odds Ratio
Intake	1.079	0.522	4.265	0.039	2.941
Class size	0.001	0.061	0.000	0.984	1.001
Gender	-1.156	0.539	4.607	0.032	0.315
Diagnostic marks	0.004	0.018	0.051	0.820	1.004
Assessment marks	-0.688	0.076	81.219	0.000	0.503
SPM Mathematics Grade					
Excellent (A+, A, A-)	-1.078	1.175	0.842	0.035	0.340
Moderate (B+, B)	0.645	1.262	0.262	0.609	1.907
SPM Additional Mathematics Grade					
Excellent (A+, A, A-)	-0.420	1.080	0.151	0.697	0.657
Moderate (B+, B)	-0.669	0.651	1.055	0.024	0.512
Weak (C+, C)	-0.041	0.456	0.008	0.929	0.960
SPM English Grade					
Excellent (A+, A, A-)	0.979	1.136	0.742	0.389	2.661
Moderate (B+, B)	0.818	1.109	0.545	0.460	2.267
Weak (C+, C)	0.392	1.176	0.111	0.739	1.480
Constant	19.332	2.859	45.722	0.000	248786327.226

Outcome of Table 3 showed that semester intake, gender, assessment marks, SPM Mathematics Grade (Excellent) and SPM Additional Mathematics Grade (Moderate) are statistically significant since the p-value of these variables is lower than the significance value, 0.05. This indicates that semester intake, gender, assessment marks, SPM Mathematics Grade (Excellent) and SPM Additional Mathematics Grade (Moderate) are affecting the students' mathematics performance of MAT 133. The estimated logit model for full model is as follows:

Logit (Y=1) = 19.332 + 1.079 Intake + 0.001 Class size - 1.156 Gender + 0.004 Diagnostic marks - 0.688 Assessment marks - 1.078 SPM Mathematics (Excellent) + 0.645 SPM Mathematics (Moderate) - 0.420 SPM Additional Mathematics (Excellent) - 0.669 SPM Additional Mathematics (Moderate) - 0.041 SPM Additional Mathematics (Weak) + 0.979 SPM English (Excellent) + 0.818 SPM English (Moderate) + 0.392 SPM English (Weak)

Furthermore, the omnibus test showed that the overall model is statistically significant (p-value = 0.000 < 0.05). It indicates that the variables significantly contribute to the predictive ability of the model. Additionally, the value of the Hosmer-Lemeshow goodness-of-fit test which yielded, p-value = 0.87 > 0.05 which indicates that the tested model fits the data well.

Table 4. Predictive Efficiency Model for Students' Mathematics Performance

Observed		Predicted Performance		Percentage correct
		High	Low	
Performance	High	245	20	92.5
	Low	30	181	85.8
Overall percentage				89.5

Sensitivity measures the models' ability to predict positive outcome correctly. As shown in Table 4, the results demonstrate the model could predict the high achievement category correctly with a percentage of 92.5%. Contrarily, specification measure the models' ability to predict negative outcome correctly whereby it could predict the low achievement category with a percentage of 85.8%. Meanwhile, the proportion of the total number of correct predictions measures the accuracy of the model. Overall, the results provide an indication that the model is efficiently predicts positive outcome (high achiever) with an overall accuracy 89.5%.

Therefore, from the Odds ratio statistic in Table 3 showed that the first intake students which enrolled in July has about 2.941 times more chance of obtaining at least 70% in MAT 133 compared to those who enrolled in December (reference category). While the male students have 0.315 chance to be predicted as high achiever compared to female students as reference category. Those who scored A+, A and A- in SPM for subject Modern Mathematics were more likely to be a high-achiever compared to those who fail in this subject. The last significant variable which is students who scored B+ and B in SPM for subject Additional Mathematics have chances to perform well in MAT 133 compared to the failed students.

The Cox & Snell R^2 and Nagelkerke R^2 value is the alternative way to explain the results by determining the amount of the variation in the independent variable.

Table 5. Summary of Cox & Snell R^2 and Nagelkerke R^2

Category	Value
Cox & Snell R2	0.599
Nagelkerke R2	0.803

Both R^2 values above indicate that the total variation of the students' mathematics performance is about 59.9% and 80.3% explained by all the independent variables included in the model.

5. Conclusion

This research complemented some of the previous studies which investigated the factors which are related to mathematics performance measured by the results of MAT133 course. There are 211 students classified as low-performer and 265 students as high-performer in MAT 133 course as the cut-off point is 70%. The logistics regression analysis was done to identify the significant factors that contribute towards students' MAT133 performance (low or high achiever). Results showed that five factors were associated significantly with low or high mathematical performance: semester intake, gender, assessment marks, SPM Mathematics Grade and SPM Additional Mathematics Grade. Semester intake plays significant role in determining the mathematical performance where students from first intake have better performance by almost three times compared to those in the second intake. This result indicates that lecturers should put more effort and make early interventions to help students particularly from the second intake to strive successfully in the subject. Early intervention such as utilizing a valid diagnostic test instrument to measure the students' numerical skill and basic mathematical knowledge can be conducted.

Gender had significant influence on Mathematical performance. In contrary with the correlation analysis finding, male students' performance was better than the performance of female students in terms of low or high achievement. This finding is consistent with many of the research which had been documented [4,5,6,7].

Acquiring strong mathematical background is a priority as a fundamental preparation for students to learn mathematics in higher institution. This finding is consistent with Tang, Voon & Nor Hazizah [18] and Murray [19]. Students should at least obtain A- for Mathematics and B for Additional Mathematics in SPM in order to achieve high performance in mathematics.

This study indicates that Mathematics and Additional Mathematics at SPM level have high impact on the low and high performance in the MAT133 subject. Therefore, a plausible consideration on the students' achievement of SPM mathematics as an admission requirement into science programs should always be revisited so that relevant and futuristic programs can be designed and developed.

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Kelulusan daripada pihak tuan dalam perkara ini amat dihargai.

Sekian, terima kasih.

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