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The Influence of Prior Knowledge and Mathematics Anxiety on University-Level Mathematics Performance in Engineering Technology Students: A Case Study

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RESEARCH ARTICLE

Abstract

This study investigates the influence of prior knowledge and mathematics anxiety on the mathematics performance of university students enrolled in an engineering technology programme. Students' prior knowledge is assessed using *Sijil Pelajaran Malaysia* (SPM) grades in Mathematics and Additional Mathematics, while mathematics anxiety was measured using an adapted version of the Brief Math Anxiety Scale (BMAS). The sample comprises 46 students registered in the *Mathematics for Engineering Technology 2* course at Universiti Tun Hussein Onn Malaysia (UTHM). The regression used the 43 students with both SPM results. A multiple linear regression model was employed to examine the associations between the dependent variable (final scores in *Mathematics for Engineering Technology 2*) and the independent variables (SPM Mathematics, SPM Additional Mathematics, and mathematics anxiety). The results indicate that mathematics anxiety is a significant negative predictor of mathematics performance, with a coefficient of -8.7369. SPM Additional Mathematics is a significant positive predictor (4.0109), whereas SPM Mathematics (0.9589) is not significant, underscoring the need to address mathematics anxiety in order to enhance the academic performance of engineering technology students. This highlights the importance of mitigating anxiety as a means of improving outcomes. The study fills a gap in understanding how the integration of prior knowledge and mathematics anxiety influences mathematics performance among students in the Malaysia Technical University Network (MTUN), offering a unique perspective by combining cognitive and emotional factors in a technical education context. As the findings are drawn from a small, voluntary sample within one institution, they are specific to this case and are not generalisable to the wider population of engineering technology students. Nevertheless, they provide useful insights for educators and policymakers seeking to design targeted interventions and support systems aimed at improving the academic outcomes of engineering technology students.

Keywords: Mathematics Anxiety, Prior Mathematics Knowledge, Multiple Linear Regression, TVET Education, Mathematics for Engineering Technology.

1. Introduction

The Sijil Pelajaran Malaysia (SPM) examination in Malaysia is an important benchmark for measuring the preparedness of secondary school students for credit accreditation for higher learning and careers, especially in technical education. The SPM results for 2022 have caused concern due to the poor performance of many students in mathematics (Zanariah Abd Mutalib, 2023). About one in four students failed Mathematics, while 29% obtained grades D or E. It is a phenomenon referred to as 'buta matematik' or mathematical illiteracy. This trend shows that these students are deficient in basic mathematical skills that could affect their performance in mathematics-intensive university courses and consequently Science, Engineering, Technology and Mathematics (STEM) careers (Abdullah, 2023). Furthermore, the shift to online learning during the COVID-19 pandemic has led to increased levels of mathematics anxiety among secondary school (Zakaria et al., 2021) and university students (Li et al., 2023; Mendoza et al., 2021). Students with higher levels of mathematics anxiety tend to forget the mathematical processes, demonstrate procrastination, use less effort, may even avoid mathematical jobs in the future (Moustafa et al., 2021). A shortage of proficient STEM professionals might force Malaysia to rely on foreign expertise, hindering progress towards self-sufficiency in critical sectors.

Many university programs heavily rely on mathematics knowledge for disciplines such as engineering and technology-related fields. Nonetheless, students frequently encounter difficulties when trying to grasp principles within the STEM fields. The pandemic disruption during Corona virus disease (COVID-19) has further contributed to disparities in performance (Velazco et al., 2021).Two important factors that contribute to these difficulties are possessing prior knowledge, a background in mathematics that build the necessary knowledge for learning (Derr et al., 2018; Hailikari et al., 2008; Jaafar et al., 2021; Salim et al., 2017; Sapazhanov et al., 2020), and managing mathematics anxiety. Accordingly, it shows students' emotional reactions toward solving mathematics problems (Al-Shannaq & Leppavirta, 2020; Arevee & Vintere, 2023; Levere & Kahlon, 2019; Prahmana et al., 2019).

Understanding the interaction between these factors is essential for improving student outcomes. Thus, the aim of this study is to investigate the relationship between prior knowledge, using SPM results in mathematics and additional mathematics, and mathematics anxiety, assessed via an adapted version of the Brief Math Anxiety Scale (BMAS) (Núñez-Peña & Guilera, 2023), on university-level mathematics performance in engineering technology courses.

Mathematics anxiety was evaluated using a modified version of the BMAS, which is derived from the comprehensive Mathematics Anxiety Rating Scale (MARS). Richardson & Suinn (1972) aimed at measuring the stress and anxiety experienced by undergraduate engineering technology students during mathematical examinations or problem-solving tasks. In the Multiple Linear Regression (MLR) model, university students' mathematics performance will be the dependent variable, with prior knowledge and mathematics anxiety level as the independent variables. The findings of this study will provide valuable insights for educators and policymakers to develop targeted interventions and support systems to improve academic outcomes of engineering technology’s students.

2. Methodology

Forty-six undergraduate students, from Semester 2 of the 2023/2024 academic session, voluntarily consented to participate in this study. The regression analysis was based on the 43 students who had both SPM Mathematics and Additional Mathematics results. The recommended sample size for multiple regression with three predictors is approximately 35 participants (20 + 5k) (Khamis & Kepler, 2010). Accordingly, the 43 students included in the regression are considered sufficient for model stability, although the results are not intended to be generalised. These students, with an average age between 19 and 22 years, were enrolled in the first-year Mathematics for Engineering Technology 2 course at

UTHM. The course covers an introduction to differential equations, first-order differential equations, second-order linear differential equations with constant coefficients, Laplace transforms and numerical solutions of differential equations. The students were from various educational backgrounds, such as polytechnic diplomas (10.9%), Institute of Higher Learning diplomas (34.8%), matriculation (50%), and Sijil Tinggi Pelajaran Malaysia (STPM) (4.3%).

Students' prior knowledge was assessed using their SPM mathematics and additional mathematics scores, obtained from official university records with participants' consent. These scores, graded on a scale where A+ is the highest grade, followed by A, A-, and so forth with E as the lowest. For quantitative analysis, these grades were converted into numerical values based on an established scoring system, with higher values assigned to higher grades. The scale used was A+ = 10, A = 9, A- = 8, B+ = 7, B = 6, C+ = 5, C = 4, D = 3, E = 2 and G = 1.

Mathematics anxiety levels were measured using the adapted BMAS, completed by all the students. At the end of the 15-weeks semester, students sat for a final examination which served as the dependent variable in the analysis. Multiple linear regression (MLR) was employed to analyze the relationship between students' prior knowledge (SPM scores) and mathematics anxiety with their final examination performance. MLR was chosen for its ability to provide coefficients for each predictor, indicating both the direction and magnitude of their effects on the dependent variable. This approach allowed for a comparison of the relative impact of mathematics anxiety and prior knowledge, offering valuable insights for designing targeted educational interventions.

2.1 Mathematics Anxiety Rating Scale

Mathematics anxiety in this study was measured using an adapted rating scale, based on the BMAS (Núñez-Peña & Guilera, 2023), designed to assess students' emotional responses to various mathematical tasks and scenarios. Responses were rated on a Likert scale from 1 to 5, where: 1 = not at all anxious, 2 = mildly anxious, 3 = moderately anxious, 4 = very anxious, 5 = extremely anxious. The ten items are as follows:

1. Taking a final exam in a mathematics course.
2. Walking into a mathematics class.
3. Being asked to explain a mathematics problem in class.
4. Working on mathematics homework alone.
5. Listening to a mathematics lecture.
6. Starting a new chapter in a mathematics book.
7. Being given a surprise mathematics quiz.
8. Solving a mathematics problem in front of your peers.
9. Studying for a mathematics test.
10. Working on mathematics homework alone without a calculator.

These questions are appropriate for assessing mathematics anxiety in undergraduate engineering technology students because it represents real-life that these students are likely to encounter in their academic journey. This approach ensures that the scale captures both general and specific aspects of mathematics anxiety relevant to this population. .The internal consistency of the ten items in this sample was high (Cronbach's alpha = 0.92).

2.2 Multiple Linear Regression

Multiple linear regression (MLR) extends the simple linear regression model by predicting the value of a dependent variable, Y based on two or more independent variables X. This approach has been widely applied in educational research (Adnan et al., 2021; Khasawneh et al., 2021; Mohd et al., 2024). The general form of the model is as follows:

$$Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \varepsilon \quad (1)$$

where Y represents the final mathematics performance, x_1 represents the SPM mathematics results, x_2 represents the SPM additional mathematics results, and x_3 represents the mathematics anxiety score as shown in Equation (1). Meanwhile, β_0 is the intercept; β_1, β_2 and β_3 are the regression coefficients, and $\varepsilon \sim i.i.d\ N\left(\mu, \sigma^2\right)$ represents the error term that is independent identically distributed. The Ordinary Least Squares (OLS) method calculates the coefficients in a MLR model by minimising the sum of squared residuals (the differences between the observed and predicted values (Angelini, 2018). The formula to compute the regression coefficient is given by:

$$\hat{\beta} = \left(X^T X\right)^{-1} X^T Y \quad (2)$$

where X is the design matrix and Y is vector of dependent variable values. The OLS in Equation (2) method was chosen for this study due to its effectiveness in providing unbiased and efficient estimators, assuming the residuals are normally distributed and exhibit homoscedasticity. This approach allows the study to assess the relative influence of prior knowledge (SPM mathematics and additional mathematics) and mathematics anxiety on students' final mathematics performance.

2.3 Coefficient of Determination

The coefficient of determination r^2 in Equation (3) measures the variation of university students' mathematics performance that is explained by the regression line and the independent variables (SPM mathematics score, SPM additional mathematics score and mathematics anxiety score). The formula is given by

$$r^2 = 1 - \frac{SSE}{S_{yy}} \quad (3)$$

where SSE is a sum of squared error and $S_{yy} = \sum\left(y_i - \bar{y}\right)^2$, y_i is the dependent variable and $\bar{y}$ is the average of dependent variable y.

3. Results

Data were analysed to explore the descriptive statistics for SPM mathematics and additional mathematics scores.

Table 1. SPM Mathematics and Additional Mathematics Result

SPM result	Mathematics	Additional mathematics
Mean	8.76(A)	4.47 (C)
Variance	1.65	5.30
Standard deviation	1.29	2.30
n	46	43

The average student enrolled in the Mathematics for Engineering Technology 2 class has an average performance of A in SPM mathematics and a C in SPM additional mathematics, as shown in Table 1. The additional mathematics statistics are based on the 43 students who took the subject. The variance and standard deviation for additional mathematics scores are notably higher than those for mathematics, indicating greater variability in students' proficiency in this subject. Engineering technology programmes often emphasise practical applications and technical abilities over extensive theoretical mathematics. Consequently, the current SPM mathematics syllabus may adequately fulfil the fundamental calculation and analytical requirements in this discipline.

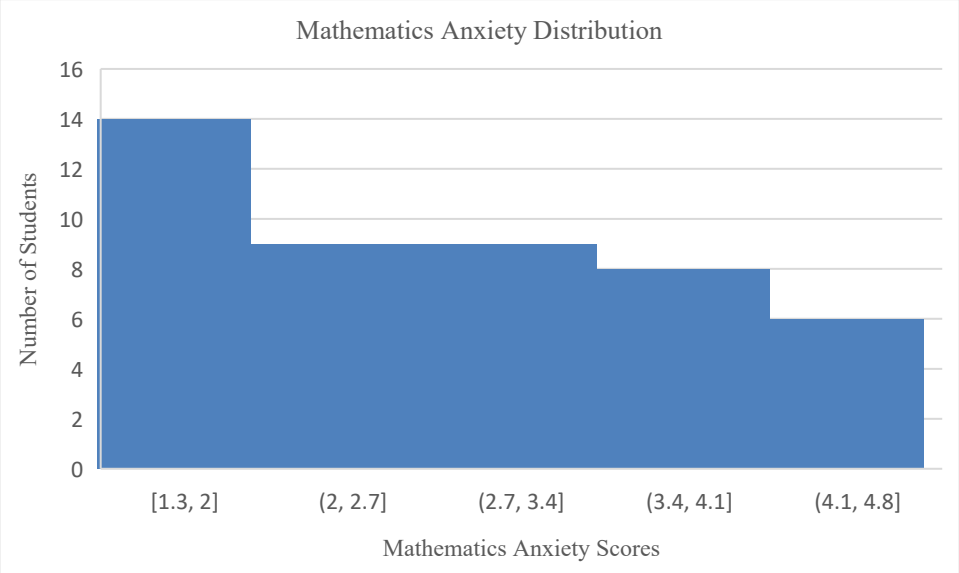

Figure 1. The Distibution of Mathematics Anxiety Scores

The distribution of mathematics anxiety scores in Figure 1 shows that most students experienced little to moderate anxiety [1.32 -3.4] in learning mathematics. Fewer students reported higher anxiety, with 8 students in the range (3.4, 4.1], while 6 students fell into the very high anxiety group (4.1, 4.8]. This pattern highlights that the majority of students experienced mathematics anxiety at the lower to moderate levels, with a minority exhibiting severe anxiety symptoms.

Table 2. Mathematics Anxiety Mean Score for Each Question

No	Mathematics Anxiety Questions	Value
1	Taking a final exam in a mathematics course.	3.57
2	Walking into a mathematics class	1.96
3	Being asked to explain a mathematics problem in class	3.09
4	Working on mathematics homework alone	2.26
5	Listening to a mathematics lecture	1.72
6	Starting a new chapter in a math book	2.04
7	Being given a surprise math quiz	3.61
8	Solving a math problem in front of your peers	3.39
9	Studying for a math test	2.78
10	Working on math homework alone without a calculator	3.52

The item with the highest average anxiety score is "Being given a surprise math quiz," with a score of 3.61, indicating that this scenario induces the greatest anxiety among engineering technology students on average, as indicated in Table 2. Conversely, the item with the lowest mean anxiety score is "Listening to a math lecture," with a value of 1.72. This suggests that students feel most at ease in passive learning environments, likely due to their reduced need for active participation or direct problem-solving during lectures. Interestingly, students reported feeling between moderately to very anxious (mean score of 3.52) when they are unable to use a calculator, even for basic calculations. This finding highlights the strong reliance on technological tools among engineering technology students and underscores the need to build their confidence in manual problem-solving skills.

Table 3. Mathematics Anxiety Score

Mathematics anxiety score	Value
Mean	2.79
Variance	0.89
Standard deviation	0.94
Median	2.80

The overall mean anxiety score of 2.79, falling between mildly and moderately anxious. This indicates that most students in the class experienced moderate levels of anxiety when engaging with mathematics-related tasks, as shown in Table 3. The variance of 0.89 and standard deviation of 0.94 indicate moderate variability in anxiety scores, which ranged from 1.3 to 4.6. These differences may stem from the students' diverse academic and educational backgrounds. Additionally, the median anxiety score of 2.80 is very close to the mean of 2.79, suggesting an approximately symmetric distribution.

Table 4. Mathematics Anxiety Score According to Previous Qualifications

Mathematics anxiety score	Range value	Mean
STPM	1.6 – 2.0	1.80
Matriculation	1.3 - 4.2	2.74
Institute of Higher Learning Diplomas	1.5 - 4.2	2.70
Polytechnic Diplomas	2.9 - 4.6	3.72

Table 4 indicates that STPM students generally exhibited low anxiety, while Matriculation and Institute of Higher Learning Diploma students displayed a mix of low to high anxiety levels. Polytechnic Diploma students, on the other hand, tend to experience higher anxiety levels. The difference in anxiety level is likely due to STPM students are exposed to rigorous curriculum and resilience to academic pressure. Matriculation and Institute of Higher Learning Diploma students are experiencing mixed anxiety owing to differences in their mathematical preparation. Meanwhile, Polytechnic Diploma students often experience higher anxiety due to their programs emphasizing practical skills over advanced math, leaving them less confident in theoretical concepts.

Table 5. Multiple Linear Regression Coefficient Values

Coefficient	Value	P-value
Intercept, β_0	43.99	0.25
SPM Mathematics, β_1	0.96	0.83
SPM Additional Mathematics, β_2	4.01	0.03
Mathematics Anxiety, β_3	-8.74	0.02

The MLR equation for the final mathematics score is presented in Equation (4).

$$\hat{Y} = 43.9934 + 0.9589x_1 + 4.0109x_2 - 8.7369x_3 \quad (4)$$

The regression coefficient of β_1 is 0.9589, indicating that for each one-unit increase in SPM mathematics grades, final exam scores are expected to increase by approximately 0.96 points as shown in Equation (4). Surprisingly, SPM mathematics grades do not significantly predict final marks with a *p*-value of 0.83, which is not statistically significant, as presented in Table 5. Meanwhile, the regression coefficient β_2 for SPM additional mathematics is 4.01 with a *p*-value of 0.03, suggesting that for each one-unit increase in SPM additional mathematics grade, final exam scores are expected to rise by approximately 4.01 points. This shows a significant positive relationship between advanced prior knowledge and mathematics final exam performance.

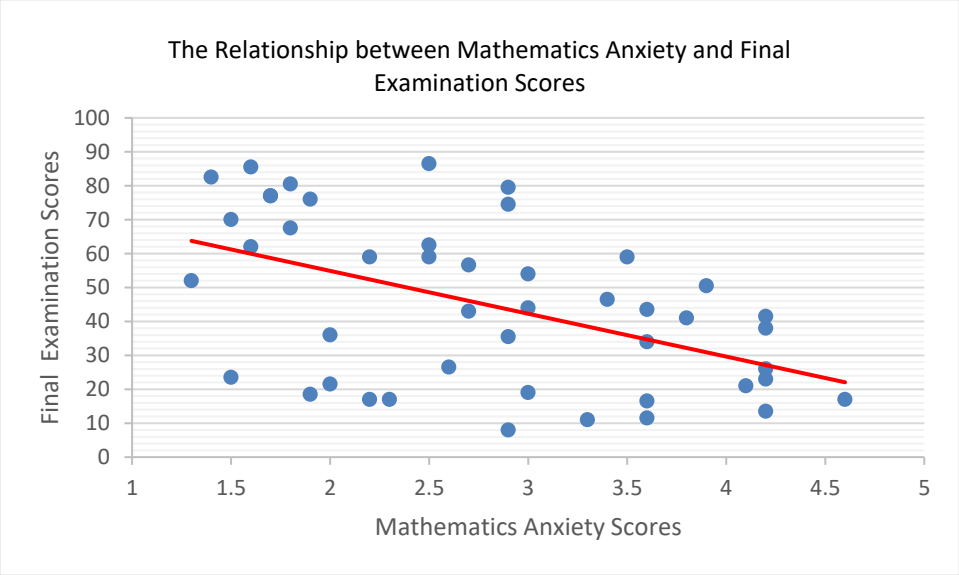

Figure 2. The Relationship between Mathematics Anxiety and Final Examination Scores in Mathematics for Engineering Technology 2

Furthermore, the regression coefficient β_3 for mathematics anxiety is -8.74, indicating that for each one-unit reduction in the mathematics anxiety score, final exam scores are expected to increase by approximately 8.74 points as shown in Figure 2. Figure 2 shows the unadjusted relationship for all 46 students; the coefficient of -8.74 is estimated with SPM mathematics and SPM additional mathematics held constant. The *p*-value is less than 0.05, indicating that this relationship is statistically significant. This demonstrates a strong negative relationship between mathematics anxiety levels and final exam scores.

Table 6. Coefficient of determination

Item	Value
Coefficient of determination, r^2	0.35

In this study, the coefficient of determination, r^2 in Table 6 measures the proportion of variance in dependent variable that is explained by the independent variables. The value of 0.35 means that 35% of the variability of result mathematics of engineering technology 2 is explained by SPM mathematics, SPM additional mathematics and mathematics anxiety (adjusted $R^2 = 0.30$; $F(3, 39) = 6.91, p <$

0.001). The remaining 65% could be attributed to several other factors that are not included in this regression model.

The Quantile-Quantile (Q-Q) plot in Figure 3 is to compare the distribution of residuals against a normal distribution. The residuals are normally distributed due to the points lie approximately along the reference line.

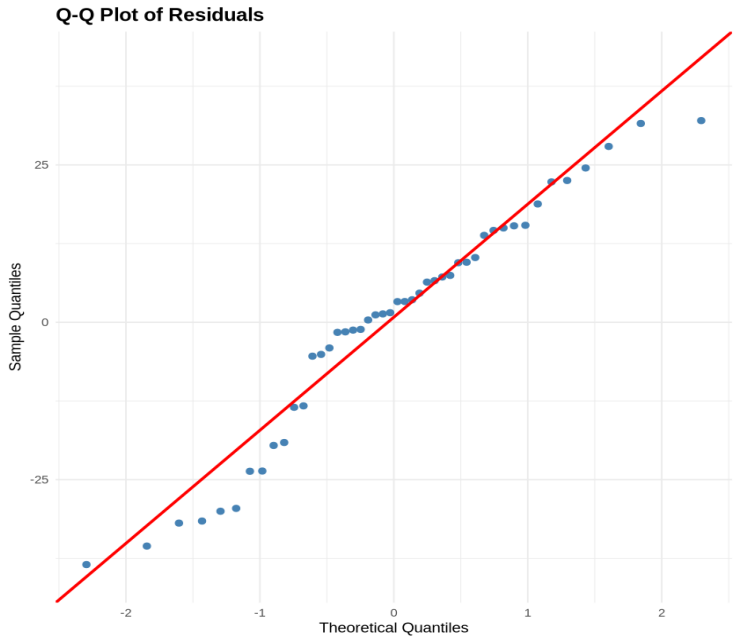

Figure 3. Normality Assumption for the Regression Error

To test the normality of the residual, this study employed the Shapiro-Wilk test in Equation (5) which has the following hypotheses:

$$H_0 \text{ (Null hypothesis): The residuals are normally distributed}$$
$$H_1 \text{ (Alternative Hypothesis): The residuals are not normally distributed} \quad (5)$$

The Shapiro-Wilk test results indicate a *p*-value of 0.10, exceeding the significance threshold $(\alpha = 0.05)$. Thus, we fail to reject the null hypothesis, indicating no evidence against normality of the residuals. The Breusch-Pagan test showed no evidence of heteroscedasticity (p = 0.10), and all variance inflation factors were below 2.

4. Discussion

This finding aligns with existing research, which highlights the importance of fundamental mathematical knowledge and the impact of mathematics anxiety on students in technical University. This study reports a significant positive association between SPM additional mathematics and performance, indicating that students with a strong background in SPM additional mathematics perform better in university mathematics courses. Furthermore, this result aligns with prior literature as pre-existing knowledge of higher mathematics has a substantial influence on students' outcomes in engineering and technology courses (Azizan & Shim, 2021; Jaafar et al., 2021; Salim et al., 2017; Tan Geok Shim et al., 2017). The study also postulated that the exposure to advanced mathematics enhances performance in solving complex problems (Derr et al., 2018). The pattern of analysis of mathematics

anxiety is in line with studies by (Al-Shannaq & Leppavirta, 2020; Mendoza et al., 2021), which show that mathematics anxiety rises during anxiety-provoking situations of a stressful nature, such as surprise exams where elevated anxiety levels are expected. Lower anxiety levels during passive learning activities, like “Listening to a math lecture”, are in line with the studies of (Brezavšček et al., 2020).

The class's average anxiety score, ranging from mild to moderate anxiety, suggests a moderate level of mathematics anxiety, consistent with increased anxiety rates among students in college during the COVID-19 pandemic (Ongcoy et al., 2023; Zakaria et al., 2021). Likewise, the variation of the anxiety scores probably corresponds to the differences in the backgrounds (Al-Shannaq & Leppavirta, 2020; Macmull & Ashkenazi, 2019) and previous mathematics education in particular, as noted by (Brezavšček et al., 2020; Jaafar et al., 2021; Md Saleh et al., 2024; Wan Mohd Zawawi Wan Yunus et al., 2017). The negative relationship between mathematics anxiety and performance established in the current study confirms that there is a decline in final examination scores whenever there is an increase in anxiety level which in line with the findings of (Md Saleh et al., 2024; Rameli et al., 2014). This underscores the need to address the fear of mathematics among technical students, as mastery of mathematics is essential for studying engineering technology. Technical students must also dispel the concept of inferior education, as it will impede their capacity to put forth their best effort. Meanwhile, a technical student's educator needs to employ approaches that strike a balance between theory and practical applications, incorporating real-world applications and technology (Mohd Noh & Yusvana, 2024).

These studies emphasized the importance of addressing the fear of math at an early age, as this can improve academic outcomes by reducing students' aversion to math-related tasks. Ideally, mathematics anxiety should be addressed from the elementary level. Early interventions are particularly relevant as they can help students enhance their early mathematical skills and self-efficacy, thereby enabling them to advance their achievements in higher education, such as at the degree level and beyond. It is crucial for educators to identify the initial signs of mathematics anxiety. This will enable them to provide prompt assistance, tailor instruction to each student's needs, and foster their confidence. Therefore, to optimize mathematics results in engineering technology courses, future efforts should prioritise reducing anxiety as much as developing skills.

5. Conclusion

This study investigated the impact of prior knowledge and mathematics anxiety on the mathematical performance of university students enrolled in an engineering technology programme. This was done by examining the coefficients of an MLR model between the dependent variable (final exam score) and the independent variables (SPM mathematics score, SPM additional mathematics score, and mathematics anxiety score). The findings indicate that while prior knowledge, particularly in SPM additional mathematics, is positively associated with final exam performance, mathematics anxiety is also significantly and negatively associated with it, with a comparable unique contribution. The negative relationship between mathematics anxiety and performance suggests that higher mathematics anxiety is associated with lower academic results in this cohort. Accordingly, these results highlight the significance of addressing mathematics anxiety early through targeted interventions, such as providing emotional support, building confidence, and fostering a positive learning environment. Notably, such measures are relevant for enhancing students' performance and supporting their success in university-level mathematics. This study has several limitations. The data were obtained from a single cohort of 46 students enrolled in Mathematics for Engineering Technology 2 in Semester 2 of the 2023/2024 academic session, and participation was voluntary. The regression included only students with SPM Additional Mathematics results (n = 43), so the findings may not apply to students without this background. Students who agreed to participate may not be representative of the class as a whole. For

example, students who felt most anxious about mathematics may have been the least willing to respond. The sample was also drawn from a single faculty at one university, and prior knowledge was represented solely by SPM grades. For these reasons, the regression coefficients describe only what was observed in this particular group. They should not be interpreted as estimates for engineering technology students at UTHM, across the MTUN network, or in Malaysian higher education generally. The study is therefore best treated as a case study, with its findings serving as a starting point for larger-scale research rather than as definitive conclusions.

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