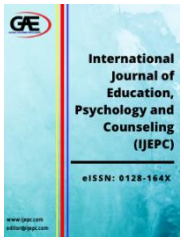
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MATHEMATICS PERFORMANCE ACROSS MULTIPLE ASSESSMENT STAGES: A COMPARISON OF THREE ACADEMIC PROGRAMMES

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Abstract:

Although students from different diploma programmes may differ in their mathematics performance, it remains unclear whether such differences persist across successive assessment stages. Therefore, this study examines whether students' performance in the Business Mathematics course differs across three diploma programmes at different assessment stages. The sample included 117 Part 1 diploma students at the UiTM Kedah Branch who were enrolled in the course. The individual assessment stages, namely quiz, test, and final examination, are also taken into account. A quantitative approach was used, and the results were analysed with IBM SPSS Statistics using a one-way analysis of variance (ANOVA). This analysis was used to determine whether significant differences existed between the three academic programmes at each assessment stage. The outcomes showed a significant difference in students' mathematics performance across the three programmes in the quiz at the early assessment stage, $F(2, 114)$

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= 3.184, $p < 0.05$. However, no significant differences were identified among the three programmes in the test and final examination. The implementation of targeted mathematics workshops before the test may explain the disappearance of these differences; however, their specific effect was not directly evaluated in this study. Overall, the findings indicate that differences in students' mathematics performance were more evident at the early assessment stage and did not persist in subsequent assessments. These outcomes highlight the potential value of continuous assessment and targeted academic support in monitoring and addressing differences in students' performance.

Keywords:

ANOVA, Assessments, Different Programmes, and Mathematics Performance

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Introduction

In education, mathematics plays a crucial role by helping students strengthen problem-solving skills, quantitative reasoning, and logical thinking, which are essential in daily life, academic settings, and professional settings (National Research Council, 2001). Beyond science and engineering, mathematics is also widely used in business, finance, economics, and management. These areas require students to apply mathematical skills to interpret numerical data, analyse information, and make significant quantitative decisions. At the higher education level, the Business Mathematics course provides students with fundamental mathematical skills and supports their understanding of business concepts. At the UiTM Kedah Branch, the Business Mathematics course is offered to students in several academic programmes, including the Diploma in Public Administration, the Diploma in Banking Studies, and the Diploma in Business Studies, providing them with opportunities to apply mathematical concepts across various business contexts.

In the Business Mathematics course at UiTM, three individual assessments, namely the quiz, the test, and the final examination, were conducted to assess the students' performance. Examining students' performance at various assessment stages can provide useful information on their progress and learning achievements throughout the semester, rather than relying solely on final exam results. The National Research Council (1993) emphasises that assessment is not only a way to measure students' achievement but also supports teaching and learning by examining students' strengths, weaknesses, and areas requiring further consideration. Some studies have also found that formative assessment and feedback can help students monitor and enhance their learning (Black & Wiliam, 1998; Nicol & Macfarlane-Dick, 2006).

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Several academic interventions, such as a mathematics workshop, have been conducted to enhance students' learning throughout the semester. These initiatives offer additional opportunities for students to strengthen their understanding, seek academic guidance, and practice mathematical skills. However, insufficient emphasis has been placed on examining students' performance in the Business Mathematics course across different assessment stages and academic programmes. Understanding how performance varies across quizzes, tests, and the final examination may help lecturers identify learning patterns and determine whether additional academic support is needed.

Therefore, this study examines whether students' Business Mathematics performance differs across three diploma programmes at different assessment stages. The study presents an overview of students' achievement across the assessment stages and compares their mathematics performance among the three academic programmes. Thus, the following research questions were addressed:

1. Is there a significant difference in quiz performance among students from the three academic programmes?
2. Is there a significant difference in test performance among students from the three academic programmes?
3. Is there a significant difference in final examination performance among students from the three academic programmes?

Literature Review

Mathematics Performance among University Students

Prior mathematical background has been identified as an important factor in university performance. For example, Jaafar et al. (2021) studied the determinants of mathematics performance among 480 students from different academic programmes who were enrolled in a pre-calculus course at Universiti Teknologi MARA (UiTM), Negeri Sembilan. The study found that several variables, such as students' previous performance in Modern Mathematics and Additional Mathematics at the secondary-school level, were significantly associated with the likelihood of students becoming high achievers at the university, as determined by logistic regression. Therefore, the authors stressed the importance of a strong mathematical background at the tertiary level.

However, prior academic achievement is not a sufficient explanation for differences in mathematics achievement. Students' attitudes, motivation, learning styles, and experiences with teaching may also influence their achievement. Pizon and Ytoc (2022) conducted a path analysis of these relationships in a sample of 240 college students. Their findings revealed that attitude toward mathematics, learning style, and teaching strategies were significant predictors of mathematics performance and had both direct and indirect effects on achievement. The results suggest that differences in mathematics performance are due not only to students' prior knowledge but also to their approaches to mathematics and their experiences with its instruction.

In multilingual university contexts, the association between student characteristics and academic performance may be more complex. For example, Stoffelsma and Spooren (2019) investigated 133 first-year science and mathematics students in Ghana and found that English

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reading proficiency was significantly related to first-year academic achievement. Their longitudinal analysis further showed that students' first-year performance was an important predictor of their achievement at the end of their studies. Although the study examined overall academic achievement rather than mathematics performance alone, its findings suggest that students' ability to comprehend the language used in teaching may influence their performance, particularly in a quantitatively oriented programme.

Recently, Aznam et al. (2025) argued that raw scores and average marks may not fully reflect students' mathematics achievement. They applied the Slack-Based Measure Data Envelopment Analysis (SBM-DEA) method to examine how efficiently students converted learning inputs into mathematics outcomes. Inputs were past performance in mathematics and students' engagement, while outputs were the results of mathematics at chapter level. This approach enabled the researchers to explore not just whether students achieved high or low scores but also how well they leveraged their current academic preparation and learning engagement to produce mathematics outcomes.

The findings of these studies suggest that mathematics performance among university students is multidimensional. Prior mathematical knowledge can be an important basis for university (Jaafar et al., 2021). Attitudes, learning styles, and teaching strategies can influence students' ability to engage in mathematical learning (Pizon & Ytoc, 2022). At the same time, other academic characteristics, such as language skills in multilingual settings, may affect students' overall academic achievement (Stoffelsma & Spooren, 2019). This view is further developed by Aznam et al. (2025), who show that students may vary in the extent to which they translate their academic preparation and engagement into mathematics outcomes

Mathematics Performance Across Academic Programmes

The association between mathematics and students' choice of academic programme has been demonstrated in recent research. Lunardon et al. (2025) examined 837 German university students enrolled in programmes characterised by low, medium, and high levels of mathematical content. The researchers identified seven profiles based on combinations of mathematics anxiety and mathematics-related attitudes and found that these profiles were distributed differently across programmes with varying mathematical intensity. Importantly, students' study choices were more strongly associated with mathematics attitudes than with mathematics anxiety. These findings suggest that students entering programmes with different mathematical requirements may already represent different populations in terms of their relationship with mathematics.

Evidence from studies involving students from multiple academic programmes further supports the importance of considering programme background. Jaafar et al. (2021) studied 480 students from various academic programmes who were enrolled in the same pre-calculus course. Their findings showed a significant relationship between the students' previous mathematical background and their achievement in the course. Studying students from different programmes within the same course is useful because they receive similar mathematical instruction but enter the classroom with different academic experiences and disciplinary backgrounds. This setting makes it possible to examine how these differences may influence their mathematics performance.

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Differences in mathematics performance across academic programmes may also be influenced by how students engage with the subject. Pizon and Ytoc (2022) found that students' attitudes toward mathematics, learning style, and teaching strategies used were associated with their performance. Consistent with Lunardon et al. (2025), the results suggest that the factors related to mathematics achievement may vary across programmes. For instance, students enrolled in mathematics-intensive programmes may have different attitudes toward mathematics and be more willing to engage in mathematical tasks. Comparing students across academic programmes may therefore reveal patterns that could be overlooked if they were treated as a single group.

Extending mathematics performance by academic programme can reveal differences that may be hidden by an overall class or university average. For instance, two programmes may have similar mean scores but show different levels of achievement across mathematical topics. A lower average in one programme does not necessarily mean that its students have lower ability. It may instead reflect differences in their previous mathematical preparation, level of engagement, or exposure to mathematics. Comparing performance across programmes can therefore help identify students who may benefit from additional academic support, or alternative teaching approaches

Assessment Stages and Mathematics Performance

Assessment is an important component of the teaching and learning process because it provides evidence of students' understanding, monitors their learning progress, and evaluates their academic achievement. In higher education, formative assessment and feedback can provide valuable information about students' current level of understanding and help instructors make informed decisions about subsequent teaching and learning activities (Morris et al., 2021). Formative assessment is particularly relevant to mathematics education because it can provide diagnostic information about students' mathematical understanding and learning progress, allowing teachers to identify areas of difficulty and make appropriate instructional adjustments (Maskos et al., 2025). Recent research indicates that the effectiveness of formative assessment depends not only on the assessment activity itself but also on how the information obtained is interpreted and used to guide subsequent learning and teaching (Maskos et al., 2025).

In higher education, evidence also suggests that formative assessment approaches, including low-stakes quizzes and feedback, can contribute positively to students' learning (Morris et al., 2021). Low-stakes quizzes can promote the retrieval of previously learned knowledge and help students develop greater awareness of their level of understanding (Kenney & Bailey, 2021). Therefore, conducting formative assessment at an early stage of a course can help identify students' initial learning needs before they progress to more advanced topics.

Following the early assessment, an intermediate test can be used to monitor students' learning progress after further instruction and learning activities. The use of multiple assessment opportunities allows students' performance to be monitored progressively rather than relying on a single measurement at the end of the course. Such an approach is consistent with the role of assessment in providing evidence that can inform subsequent teaching and learning decisions (Morris et al., 2021; Maskos et al., 2025). Comparing students' performance on the quiz and the intermediate test can indicate changes in their mathematical performance and whether learning difficulties identified at the earlier stage have been reduced. This intermediate

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assessment therefore provides an important opportunity to monitor students' progress before the completion of the course.

At the end of the instructional period, the final examination serves as the summative, end-of-course assessment, providing an overall evaluation of students' achievement upon completion of the course. Unlike formative assessment, which is primarily intended to generate information to support subsequent learning and instruction, summative assessment evaluates the extent to which students have achieved the intended learning outcomes at the conclusion of a learning period (French et al., 2024). Final examinations remain widely used in higher education as a form of summative assessment because they provide a formal measure of students' attainment. However, recent literature has also highlighted limitations associated with relying heavily on high-stakes examinations as the sole indicator of students' learning and achievement (French et al., 2024).

Targeted Academic Support

Targeted academic support refers to providing additional learning assistance to students who demonstrate learning difficulties or lower academic performance and therefore require further support beyond regular classroom instruction. Such support is particularly relevant in mathematics, where students enter higher education with varying levels of prior mathematical knowledge and may experience difficulties in understanding concepts, applying mathematical procedures, and solving problems. A recent scoping review of mathematics and statistics support in higher education identified various forms of supplementary support, including workshops, tutorials, individual assistance, and other organised learning activities, with evidence of positive effects across several student outcomes (Mullen et al., 2024).

Targeted support is most meaningful when informed by evidence of students' learning needs rather than provided uniformly to all students. In this respect, assessment results can be used to identify students who perform more poorly and determine the appropriate type of additional support for them. Students experiencing difficulties in mathematics may benefit from additional practice, which provides opportunities to reinforce previously introduced concepts and develop procedural fluency. Guided problem-solving can also assist students by providing structured support for understanding mathematical problems, selecting appropriate strategies, and developing solutions. In addition, clarifying mathematical concepts and providing timely feedback can help students identify misconceptions and improve their understanding of mathematical procedures and solutions. Evidence from higher education suggests that tutoring and structured academic support can improve students' learning behaviours and academic outcomes, particularly when directed toward students who require additional assistance (Hardt et al., 2023; Nwaesei & Liao, 2023).

Peer learning can provide an additional form of academic assistance by allowing students to discuss mathematical concepts, compare problem-solving strategies, and receive guidance from peers. Nwaesei and Liao (2023) reported that a structured, peer-led tutoring programme supported students experiencing academic difficulties, demonstrating the potential of peer-based approaches as an additional form of academic assistance. Similarly, experimental evidence from higher education indicates that personalised tutoring can improve students' study behaviour and academic outcomes (Hardt et al., 2023). Focused revision may further assist students by revisiting essential mathematical concepts and providing structured opportunities to practice areas in which difficulties have previously been identified.

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Importantly, targeted academic support should complement regular classroom instruction rather than replace it. The scoping review by Mullen et al. (2024) indicates that mathematics and statistics support in higher education is commonly delivered through supplementary formats such as workshops and tutorials, although the effectiveness of such interventions may vary depending on their design, implementation, student engagement, and the outcomes used to evaluate them. For example, Büchele and Schürmann (2024) found no direct effect of participation in a course-specific mathematical learning support centre on mathematics performance, although positive effects were observed for students' affective outcomes. These findings suggest that targeted support should be carefully designed according to students identified learning needs and implemented at an appropriate stage of the learning process.

Methodology

Population and Sample

The study population comprises 146 students registered for the Business Mathematics course (MAT112) at the UiTM Kedah Branch during the March-August 2025 session. However, the study only focused on Part 1 students enrolled in the course. The final sample included 117 Part 1 diploma students, of whom 34 (29.06%) were male, and 83 (70.94%) were female, across three academic programmes. Throughout the analysis, these programmes are referred to as Programme A, Programme B, and Programme C.

Data Collection

Data on students' programmes of study and their mathematics scores at different individual assessment stages, including quiz, test, and final examination, were collected. The quiz was conducted in the early stage of assessment in week 5 of the semester, the test was conducted in week 13 of the semester, while the final examination provides a summative evaluation of end-of-course achievement. To ensure consistency in the evaluation process, each assessment was marked using the provided rubric, which aligned with the answer scheme. The scores from each assessment were converted to 100% to ensure comparability across assessment components in the analysis.

Data Analysis

The Statistical Package for Social Sciences (SPSS) was used to analyse the collected data through descriptive and inferential statistics. Descriptive statistics such as the mean and standard deviation summarised students' math performance across the academic programmes and the chosen assessment levels. To determine whether there were significant differences in mathematics performance among students across the three diploma programmes, a one-way Analysis of Variance (ANOVA) was conducted for each assessment level. The assumptions of normality and homogeneity of variance were also confirmed to determine whether they were satisfied before running the ANOVA. In addition, if significant differences appeared in the ANOVA results, Tukey's Honestly Significant Difference (HSD) post hoc test was used to determine which pairs of programmes differed.

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Result and Findings

RQ1: Is There A Significant Difference in Quiz Performance Among Students from The Three Academic Programmes?

The results of the quiz score analysis are presented in Tables 1, 2, and 3. Table 1 demonstrates the descriptive statistics for the three academic programmes. It showed that students from Programme B obtained the highest mean score of 65.12 on the quiz, followed by those from Programme A and Programme C.

Table 1: Descriptive Statistics for Students' Performance in Quiz

Programme	N	Mean	Std. Deviation
A	55	56.12	23.97
B	28	65.12	22.71
C	34	49.81	24.41
Total	117	56.44	24.25

Table 2 gives the ANOVA results for the quiz. The results revealed a statistically significant difference in students' quiz performance or scores by programme of study, $F(2, 114) = 3.184$, $p < 0.05$. Since the ANOVA indicated a significant difference in quiz performance, Tukey's HSD post hoc test was conducted to identify the specific programme differences. The results in Table 3 revealed a statistically significant difference between Programme B and Programme C, with Programme B achieving higher mean quiz scores than Programme C (MD = 15.31, $p = 0.035$).

Table 2: One-way ANOVA for Mathematics Performance in Quiz

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3609.757	2	1804.879	3.184	.045
Within Groups	64621.427	114	566.855		
Total	68231.184	116			

Table 3: Tukey HSD Post Hoc Comparison for Quiz Performance

Programme Comparison	Mean Difference	Sig.
Programme A – Programme B	-8.997	.238
Programme A – Programme C	6.313	.447
Programme B – Programme C	15.310	.035

RQ2: Is There A Significant Difference in Test Performance Among Students from The Three Academic Programmes?

The results of the test score analysis are presented in Tables 4 and 5. The descriptive results in Table 4 showed relatively small variation in test scores across the three programmes, with the highest mean score of 69.41 by programme C.

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Table 4: Descriptive Statistics for Students' Mathematics Performance in the Test

Programme	N	Mean	Std. Deviation
A	55	66.75	24.74
B	28	68.17	24.58
C	34	69.41	18.79
Total	117	67.86	22.96

Table 5: One-way ANOVA for Performance in Test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	152.715	2	76.358	.143	.867
Within Groups	60978.529	114	534.899		
Total	61131.244	116			

In Table 5, the one-way ANOVA showed no significant difference in students' mathematics performance on the test across their respective programmes of study ($p > 0.05$). Therefore, the results indicate that the students from the three programmes of study demonstrated comparable performance on the test.

RQ3: Is There A Significant Difference in Final Examination Performance Among Students from The Three Academic Programmes?

Table 6: One-way ANOVA for Performance in Final Examination.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	439.389	2	219.695	.689	.504
Within Groups	36360.064	114	318.948		
Total	36799.453	116			

The one-way ANOVA revealed no statistically significant difference in final examination performance among students across the different programmes of study ($p > 0.05$), as illustrated in Table 6. Thus, the programme affiliation was not associated with significant differences in students' final examination performance.

Discussion and Conclusion

The results from the study indicate that mathematics performance differed significantly across the three programmes on the quiz assessment. This finding suggests that the difference in students' performance appears to be during the early stages of the assessment. The significant difference observed at the quiz stage aligns with the findings of John and Oh (2024), which showed that student performance changes from the initial formative assessment to subsequent assessments, indicating that it does not remain consistent throughout the assessment process.
In contrast, no statistically significant differences in the student performance were observed across academic programmes at the test stage or in the final examination. A possible explanation for this pattern is the implementation of mathematics workshops conducted prior to the test for students identified as underperforming on their initial assessment. The workshop may have provided additional opportunities for these students to strengthen their understanding

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and may have contributed to the reduced performance differences observed at subsequent assessment stages. However, the specific effect of the workshop was not directly evaluated in the present study; their contribution should be regarded as a possible explanation rather than an established effect. Van Veggel and Amory (2014) reported a similar approach that provided a mathematics support tutorial to students identified through an initial diagnostic assessment, resulting in improvements in subsequent mathematics performance.

Rather than relying on final examination performance, the results highlighted the importance of examining students' performance across multiple assessment stages. The significant differences observed at the quiz stage suggest that early assessment can serve as an early-warning mechanism for lecturers to identify students who may require additional mathematical support. Therefore, monitoring performance trajectories across successive assessments may provide a more informative basis for timely academic support than relying solely on final examination results.

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