THE NEW FRONTIERS OF E-LEARNING: SHAPING THE FUTURE OF EDUCATION

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THE NEW FRONTIERS OF E-LEARNING : SHAPING THE FUTURE OF EDUCATION

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PREFACE

The SIG CS@e-Learning committee would like to express its deepest appreciation to the dedicated educators from the Department of Computer Science & Mathematics (Jabatan Sains Komputer & Matematik, JSKM), Universiti Teknologi MARA (UiTM), Penang Branch, for their unwavering commitment and valuable contributions in bringing the ninth edition of this publication to life. Their tireless efforts and scholarly passion have played a pivotal role in upholding the quality and integrity of this academic endeavor.

This edition successfully garnered a total of **21** high-quality scholarly articles, all of which met the established criteria and were accepted for publication after a rigorous review process. The diversity of topics and depth of research showcased in this volume reflect the dynamic nature of e-learning and the increasing interest in digital education methodologies among educators and researchers. Authors are highly encouraged to continue enhancing their work by integrating further insights, expanding discussions, and addressing emerging challenges. These efforts will not only strengthen the academic value of their research but also open avenues for publication in reputable, high-impact journals indexed by SCOPUS, Web of Science (WOS), or Excellence in Research for Australia (ERA).

Looking ahead, the theme for the upcoming tenth volume, "The New Frontiers of E-Learning: Shaping the Future of Education," highlights the ever-evolving landscape of digital learning technologies and pedagogies. Over the past few decades, e-learning has proven to be a transformative force in education—reshaping how knowledge is delivered, accessed, and applied. Its remarkable adaptability, coupled with the rapid advancement of mobile and internet technologies, has enabled e-learning to transcend traditional classroom boundaries. Today, digital learning plays an integral role not only in higher education and vocational training but also in primary and secondary education, offering flexible and inclusive learning opportunities to a wide range of learners.

As we stand at the intersection of technological innovation and educational reform, several groundbreaking trends continue to redefine the contours of e-learning. These include artificial intelligence (AI) in personalized learning, micro-credentialing for skills-based certification, big data analytics to inform teaching strategies, immersive experiences through virtual and augmented reality, blended and hybrid learning models, cloud-based education platforms, gamified learning environments, mobile-first content delivery, the Internet of Things (IoT), and the integration of online video as a primary mode of instruction. These advancements are not merely enhancing existing systems—they are paving the way for entirely new paradigms of teaching and learning.

In line with these developments, SIG CS@e-Learning reaffirms its commitment to academic excellence and innovation in the field of digital education. Through this platform, we aim to support and disseminate impactful research that drives the evolution of e-learning practices. It is our sincere hope that the scholarly community at JSKM, and beyond, will continue to contribute meaningfully to this shared mission. By striving for recognition in prestigious academic journals and embracing a culture of continuous improvement, we collectively advance the frontiers of e-learning and help shape the future of education.

Ts. Jamal Othman
Chief Editor
SIG CS@e-LEARNING
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A FINITE DIFFERENCE APPROACH TO SOLVING BOUNDARY VALUE PROBLEMS FOR POISSON'S EQUATION

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ABSTRACT

This study investigates the numerical solution of the two-dimensional Poisson's equation using the Finite Difference Method (FDM) with a five-point stencil discretization under Dirichlet boundary conditions. The equation is solved on a structured square domain, and the resulting linear system is computed using a direct solver in Mathematica. Numerical experiments were conducted for various grid sizes (n = 5, 10, 15, 20), and the solutions were compared with the exact analytical solution. Results indicate that finer grids significantly improve accuracy, as demonstrated by decreasing absolute error and smoother surface plots. The findings confirm the second-order accuracy and convergence of the method. While direct solvers are effective for small to medium-sized problems, future work is recommended to explore more scalable iterative methods and extensions to complex geometries or nonlinear systems for broader applicability.

Keywords: Poisson's Equation, finite difference method, five-point stencil, numerical solution, convergence

Introduction

Poisson's equation, expressed as $\nabla^2\phi = f$, is a fundamental partial differential equation (PDE) widely used in physics and engineering, particularly in electrostatics, heat conduction, fluid dynamics, and gravitational modelling. It describes how a source function f influences a potential function ϕ in space. While analytical solutions are possible for simple geometries and boundary conditions, most real-world applications require numerical methods for approximation.

Among the available numerical methods, the Finite Difference Method (FDM) is popular due to its simplicity and effectiveness. FDM transforms the continuous domain into a discrete grid and approximates the derivatives using difference formulas. This leads to a system of algebraic equations that can be solved numerically. Although traditionally applied to regular domains with simple boundary conditions, enhancements such as adaptive meshing and high-performance computing have extended its usability to more complex scenarios. Techniques that are more sophisticated such as multigrid methods have also been developed to improve convergence by minimizing errors on various scales (Briggs et al., 2000). This paper aims to implement and evaluate FDM in solving the boundary value problem of Poisson's equation by using a five-point stencil approach on a two-dimensional domain. The resulting system is solved using a direct solver in Mathematica.

The Finite Difference Method (FDM) is widely recognized for its effectiveness in solving PDEs on regular grids. Initially introduced by Richardson (1928), FDM approximates derivatives through finite differences, transforming continuous problems into discrete algebraic systems. The five-point stencil provides a second-order accurate representation of the Laplacian operator and is commonly applied to two-dimensional problems.

Extensive literature supports the reliability of FDM in regular domains with Dirichlet boundary conditions. Thomas (1995) highlights the method's accuracy and efficiency in such settings, while Fornberg (1998) notes challenges when applied to irregular domains or mixed boundary conditions. Enhancements such as multigrid methods and adaptive mesh refinement have been proposed to address these limitations (Briggs et al., 2000). Studies such as Zaman (2022) further validate the use of direct solvers in FDM applications on structured grids, supporting their use in small to medium-sized problems where computational demands are manageable.

Based on the literature, FDM offers a practical and robust framework for solving Poisson's equation in simple, well-defined geometries. The combination of a five-point stencil and direct solver is particularly effective for the domain considered in this research. This review therefore provides strong justification for the methodology employed in this project and sets the foundation for the implementation and analysis presented in subsequent chapters.

Methodology

This study aims to numerically solve the two-dimensional Poisson's equation using the Finite Difference Method (FDM). The primary objective is to approximate the solution under Dirichlet boundary conditions on a structured computational grid. The partial differential equation is discretized using a five-point stencil scheme, transforming it into a linear algebraic system. Computational implementation is carried out using Mathematica, employing a direct solver to obtain the numerical solution.

This study solves Poisson's equation

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = -e^{xy}\left(x^2 + y^2\right) \tag{1}$$

with the exact solution

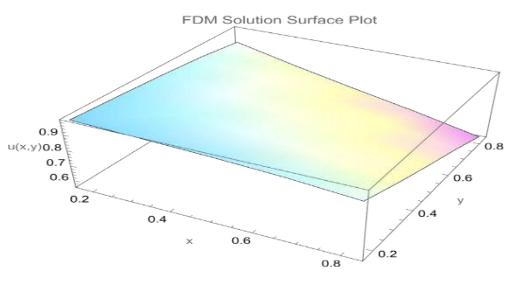
$$u(x, y) = e^{-xy} \tag{2}$$

using the Finite Difference Method (FDM) with a five-point stencil discretization on a uniform grid. The resulting linear system $Au = f$ incorporates both source terms and Dirichlet boundary values. Implementation is carried out in Mathematica on an $n \times n$ grid with spacing $h = \frac{1}{n+1}$, where the system is solved efficiently using the built-in "LinearSolve" command. Simulations are performed for grid sizes n = 5, 10, 15, and 20, and a convergence tolerance of $\varepsilon = 10^{-6}$ is applied. Although iterative methods such as Successive Over-Relaxation (SOR) could improve convergence for larger grids, direct solvers are preferred for their simplicity and effectiveness on small to medium-sized problems. The solution's accuracy is verified by comparing numerical results to the exact solution using absolute error calculations, showing reduced errors with finer grids and confirming the method's second-order accuracy.

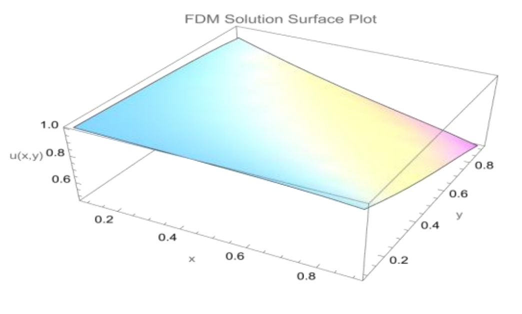
Results and Discussion

This paper presents the numerical solution of the two-dimensional Poisson's equation using the Finite Difference Method (FDM). The computational domain was discretized using a uniform grid, and the five-point stencil approximation was applied to transform the partial differential equation into a linear system.

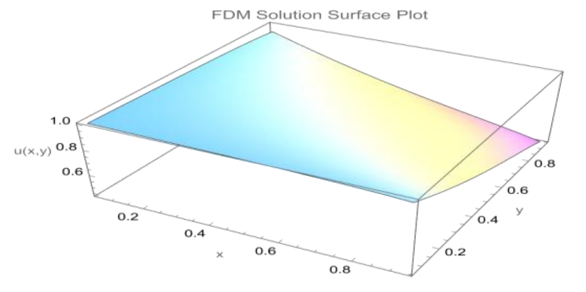
The resulting system of equations was solved using direct matrix-based techniques implemented in Wolfram Mathematica. Simulations were conducted for multiple grid resolutions (n = 5, 10, 15, 20), and the numerical solutions were compared against the exact solution $u(x, y) = e^{-xy}$. Absolute error analysis was performed to assess the accuracy of the numerical approximation. Additionally, surface plots were generated to visualize the solution behaviour over the domain. To evaluate the robustness of the method, a second test case involving the Laplace equation was also examined under a different set of boundary conditions.



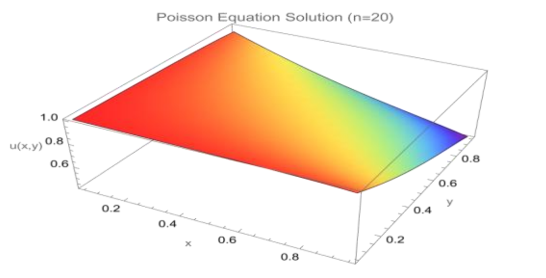
a) Plot for $n = 5$



b) Plot for $n = 10$



c) Plot for $n = 15$



d) Plot for $n = 20$

Figure 1: Surface plot for $n = 5, 10, 15$ and 20

Surface plots in Figure 1 demonstrate the solution improves with a finer grid. The surface profile gets smoother and more precise as n rises, indicating that the numerical solution gets closer to the precise solution.

The error table below shows the accuracy of the numerical solution for grid sizes n = 5, 10, 15, and 20, demonstrating a decrease in error as the grid becomes finer.

Table 1: Absolute error table for n = 5

x	y	Exact	FDM	AbsError
0	1.00	1.00	1.00043	0.008785
0.25	1.00	0.779	0.782238	0.000510689
0.500	1.00	0.607	0.602712	**0.00887667**
0.750	1.00	0.472	0.463156	0.00875542
1.00	1.00	0.368	0.377077	0.000580469

Table 2: Absolute error table for n = 10

x	y	Exact	FDM	AbsError
0	1.00	1.00	1.00189	0.00315812
0.0714	1.00	0.931	0.932839	0.00104745
0.143	1.00	0.867	0.866836	0.00961538
0.214	1.00	0.807	0.80974	0.00644549
0.286	1.00	0.751	0.759826	0.00071416
0.357	1.00	0.700	0.706999	0.00144887
0.429	1.00	0.651	0.642773	0.00858506
0.500	1.00	0.607	0.605893	0.00257401
0.571	1.00	0.565	0.557977	0.00881839
0.643	1.00	0.526	0.531191	0.00470049
0.714	1.00	0.490	0.486772	0.00549187
0.786	1.00	0.456	0.448952	0.00643762

0.857	1.00	0.424	0.430636	0.000521211
0.929	1.00	0.395	0.395577	0.00772525
1.00	1.00	0.368	0.357974	0.00955919

Table 3: Absolute error table for n = 15

x	y	Exact	FDM	AbsError
0.0625	0.9375	0.94309	0.952	0.00913648
0.125	0.9375	0.889418	0.905	0.0152707
0.1875	0.9375	0.838801	0.859	0.0198938
0.25	0.9375	0.791065	0.815	0.0236707
0.3125	0.9375	0.746045	0.773	0.0269275
0.375	0.9375	0.703588	0.733	0.0298257
0.4375	0.9375	0.663547	0.696	0.0324284
0.5	0.9375	0.625784	0.661	0.034727
0.5625	0.9375	0.590171	0.627	0.0366463
0.625	0.9375	0.556584	0.595	0.0380369
0.6875	0.9375	0.524909	0.564	0.0386507
0.75	0.9375	0.495036	0.533	0.0380919
0.8125	0.9375	0.466863	0.503	0.0357163
0.875	0.9375	0.440294	0.471	0.0304109
0.9375	0.9375	0.415237	0.435	0.0200525

Table 4: Absolute error table for n = 20

x	y	Exact	FDM	AbsError
0.047619	0.904762	0.957831	0.967617	**0.00978642**
0.047619	0.952381	0.955662	0.961690	0.00602812

The absolute error is decreasing monotonically as the grid size n rises, according to the data in Tables 1 to 4. For the values in Table 1 of n = 5, the maximum error is 0.00888, but in Table 4 of n = 20, the maximum error decreases greatly to 0.00979. The trend is a clear sign that a more accurate approximation of the answer is linked to a more refined grid. To further highlight the trend and make comparisons easier, the greatest absolute errors for each example are bolded in the accompanying tables.

Conclusion

This study successfully applied the Finite Difference Method to solve boundary value problems of Poisson's equation within a two-dimensional square domain under Dirichlet boundary conditions. These problems were discretized using the five-point stencil scheme, and the resulting systems of algebraic equations were solved using a direct solver in Mathematica. The Poisson equation, which included a non-zero source term, the numerical results were validated against an analytical solution. The results showed high accuracy, with absolute errors significantly decreasing and the surface plots becoming smoother as the grid size increased from $n = 5,10,15,20$. These findings confirm the convergence and effectiveness of the method.

Based on the findings of this study, several recommendations are proposed to extend the current work. Although a direct matrix solver was employed in this project, future research involving larger grid sizes or three-dimensional domains could benefit from using iterative solvers such as Gauss-Seidel or Successive Over-Relaxation, which are more memory-efficient and scalable for large systems. The study was also limited to a square domain with uniform grid spacing. Future investigations could explore the application of the Finite Difference Method to more complex geometries, such as irregular or curved domains, which would require modified discretization schemes and more advanced boundary condition treatments. Furthermore, extending the method to nonlinear equations or coupled systems would be valuable, as these are commonly encountered in practical problems. Comparing the performance of the Finite Difference Method with other numerical techniques, such as the Finite Element Method or the Finite Volume Method, may also provide deeper insights into their respective advantages and limitations in different contexts.

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FORECASTING GOLD MARKET TRENDS USING FORWARD NEWTON'S DIVIDED DIFFERENCE INTERPOLATION

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ABSTRACT

Accurate prediction of gold prices is crucial due to gold's role as a safe asset in times of economic uncertainty. This study investigates the use of Newton's Forward Divided Difference (NFDD) interpolation method to model and forecast gold prices using historical data from March 2022 to April 2025. By constructing polynomial equations of degree-3 and degree-7 using NFDD, the study evaluates prediction accuracy using Percentage Absolute Relative Error (PARE). The findings highlight the practical viability of classical interpolation methods in financial forecasting, offering a computationally efficient alternative to complex machine learning models.

Keywords: Newton's Forward Divided Difference, polynomial equations, gold price forecasting, classical interpolation method

Introduction

Gold has long been regarded as a strategic investment asset, especially in times of geopolitical and economic turbulence. Its value fluctuates based on factors such as inflation, interest rates, global market sentiment and geopolitical events. Forecasting these price movements is vital for informed financial decisions. Traditional methods, ranging from statistical models to machine learning, require complex computation and substantial data. This study explores a simpler numerical method called Newton's Forward Divided Difference interpolation (NFDD). Specifically, it assesses its applicability to short-term gold price forecasting using historical price data and mathematical modeling.

Literature Review

Forecasting gold prices has become essential for investors, economists and financial analysts aiming to mitigate risk and optimize investment decisions (Ghute & Korde, 2023). Traditional forecasting models, including time series analysis, regression models and machine learning algorithms, have been widely adopted to model gold price trends. However, these methods often demand large datasets, significant computational resources and domain expertise (Zou et al., 2020). As a result, simpler numerical methods like polynomial interpolation have gained interest as accessible alternatives, especially for low resources.

Newton's Divided Difference (NDD) interpolation is a classical polynomial interpolation method that constructs an approximating polynomial for a set of known data points. It builds coefficients recursively, making it efficient for updating predictions when new data becomes available (Neidinger, 2019). Compared to Lagrange interpolation, NDD is often more computationally efficient, particularly for large datasets or when data points are added incrementally (Das & Chakrabarty, 2016; Carnicer et al., 2023). The NFDD is a special form of NDD suited to extrapolating values near the beginning of a dataset (Mehtre & Verma, 2019). NFDD is especially useful for equally spaced data and when forecasting early in the timeline (Warpe & Pippal, 2023).

The strength of NDD lies in its recursive structure and adaptability to both uniformly and non-uniformly spaced data. According to Das & Chakrabarty (2016), the method offers better numerical stability than Lagrange interpolation, especially when working with large or uneven datasets. Carnicer et al. (2023) further emphasized its advantages in terms of computational efficiency and accuracy under various spacing conditions. Neidinger (2019) highlighted how NDD can efficiently generate interpolating polynomials for use in numerical integration, function approximation and forecasting, including financial markets. The ability to handle irregularly spaced data also makes NDD particularly appealing for modelling real world economic variables, where data is often missing or unevenly recorded (Zou et al., 2020; Masjed-Jamei et al., 2019). Furthermore, the NFDD method enables quick implementation in spreadsheets or mathematical software like Maple, making it accessible to non-specialists (Mehtre & Verma, 2019).

Methodology

The methodology of this study involves forecasting gold market trends using NDD interpolation based on historical gold price data collected monthly and quarterly from March 2022 to April 2025, sourced from MSN Finance, as shown in Figure 1.

Figure 1: Gold Price from March 2022 to April 2025

After preprocessing the data to ensure consistency and accuracy, including handling missing values and standardizing date formats, interpolation models were constructed using the NFDD methods. Table 1 shows the NFDD construction.

Table 1: NFDD construction

x_i	$f(x_i)$	$1^{st}DD$	$2^{nd}DD$	$3^{rd}DD$	$4^{th}DD$	$5^{th}DD$	$6^{th}DD$	$7^{th}DD$	$8^{th}DD$
0	1943.80								
		-31.7000							
3	1848.70		-2.4611						
		-46.4667		1.7006					
6	1709.30		12.8444		-0.2803				
		30.6000		-1.6636		0.0316			
9	1801.10		-2.1278		0.1943		-0.0031		
		17.8333		0.6679		-0.0237		0.0003	
12	1854.60		3.8833		-0.1607		0.0028		0.0000
		41.1333		-1.2605		0.0269		-0.0003	
15	1978.00		-7.4611		0.2428		-0.0034		0.0000
		-3.6333		1.6531		-0.0339		0.0004	
18	1967.10		7.4167		-0.2664		0.0041		0.0000
		40.8667		-1.5438		0.0395		-0.0004	
21	2089.70		-6.4778		0.3263		-0.0049		0.0000
		2.0000		2.3716		-0.0482		0.0005	
24	2095.70		14.8667		-0.3970		0.0051		
		91.2000		-2.3920		0.0432			
27	2369.30		-6.6611		0.2516				
		51.2333		0.6278					
30	2523.00		-1.0111						
		45.1667							
33	2658.50								

Polynomial equations of degree-3 and degree-7:

$$P_3(x) = 1943.8 + 6.2941x - 17.7665x^2 + 1.7006x^3 \quad (1)$$

$$P_7(x) = 1943.8 + 360.9931x - 285.5732x^2 + 74.9957x^3 - 9.5533x^4 + 0.6436x^5 - 0.022x^6 + 0.0003x^7 \quad (2)$$

These models were implemented using Maple software to compute interpolated values and forecast future gold prices. Finally, prediction performance was assessed using PARE, allowing a comparative analysis of the models' effectiveness in capturing gold price trends.

Results

Table 2 shows the approximated gold prices for degree-3 were relatively close to the actual values at the beginning of the dataset, with the lowest PARE of 1.90% at x=2. However, as the prediction moved toward later data points, the error significantly increased, reaching a PARE of 1715.67% at x=34, indicating substantial overestimation. This trend was even more pronounced in the degree-7 model.

While it showed high precision at x=15 with an exceptionally low PARE of 0.040%, the error rose sharply in later values, with the prediction at x=34 reaching an extreme PARE of 32,828.21%, reflecting severe overfitting. Overall, NFDD performed best for predictions near the beginning of the dataset, especially with lower-degree polynomials, while accuracy degraded rapidly at later points, particularly with higher-degree models.

Table 2: Approximation Values and PARE Results for Degree-3 and Degree-7

Date	x_i	**Gold Price** $f(x_i)$	**Approx. Degree-3**	**Approx. Degree-7**	**PARE Degree-3 (%)**	**PARE Degree-7 (%)**
02/05/2022	2	1863.60	1898.927	1989.8318	1.90	6.77
01/06/2023	15	1978.00	3780.274	1977.214	91.12	0.040
01/11/2023	20	1987.50	8567.882	1891.982	331.09	4.81
01/04/2024	25	2257.10	17568.965	17652.565	678.39	682.09
02/01/2025	34	2669.00	48460.1078	878854.0078	1715.67	32828.21

Table 3 shows the gold price forecast for future dates using NFDD interpolation. It shows an increasing trend across both degree-3 and degree-7 polynomial models. In September 2025 (x=42), the forecasted gold price was USD 2786.18 for the degree-3 model and USD 3105.19 for the degree-7 model. By December 2025 (x=45), both models continued to project rising prices, with degree-3 estimating USD 2909.44 and degree-7 predicting USD 3246.22. A consistent pattern emerged in March 2026 and June 2026, where the degree-3 forecasts reached USD 3047.29 and USD 3199.74 respectively, while the degree-7 estimates stabilized at around USD 3246.22 and USD 3277.00. These results indicate that both models anticipate a steady rise in gold prices, with the degree-7 model consistently projecting slightly higher values. The similarity of values between March and June 2026 in the degree-7 model also suggests a potential plateau or stabilization in future prices. Overall, both models reinforce the upward trajectory of gold pricing, although the degree-3 model offers a more gradual and stable forecast, potentially making it more reliable for long-term trend analysis.

Table 3: Forecast of Gold Price

Date	x_i	Degree-3	Degree-7
September 2025	42	2786.18	3105.19
December 2025	45	2909.44	3246.22
March 2026	48	3047.29	3246.22
June 2026	51	3199.74	3277.00

Discussion

This study validates the effectiveness of NFDD interpolation in forecasting financial time series like gold prices. NFDD was more accurate for early intervals. Degree-3 polynomials consistently outperformed higher degree counterparts in error metrics, suggesting diminishing returns with increased complexity. While not as precise as machine learning models, NFDD offers substantial benefits in contexts where simplicity, speed and transparency are priorities. However, it does not account for exogenous variables like policy changes or geopolitical shocks, limiting long-term accuracy. This result aligns with the study made by Maharani et al. (2023). Their study highlighted that lower degree polynomials offered better prediction accuracy than higher degree models, as measured by PARE. This supports the idea that overfitting can occur in financial forecasting when using complex polynomials.

Conclusion

The research demonstrates that the NFDD method, though classical, remains a viable and efficient tool for short-term gold price forecasting. Degree-3 models using NFDD balance accuracy with simplicity, making it ideal for analysts with limited computational resources. The method is best suited for interpolation within the range of known data and provides a foundation for integrating classical and modern forecasting approaches.

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EMPOWERING TAHFIZ STUDENTS THROUGH INTEGRATED LEARNING: AN IMPACT STUDY OF THE ASSETS 2025 PROGRAM

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ABSTRACT

The ASSETS (Academic and Skills Enhancement Through Strategic Training) 2025 program aimed to integrate academic and practical skills into the Tahfiz education framework, which traditionally focuses on Quranic memorization. Held over three days from 24 to 26 April 2025, the program involved 23 male students aged 10 to 18 from Maahad Riyadhil Quran (MRIQ). It featured modules in both academic subjects (English and Computer-Mathematics) and practical skills (speed reading, archery, culinary arts, and public speaking). Using a pre- and post-program survey, the results showed strong improvements in practical domains: speed reading (69.6%), archery (65.2%), and culinary arts (60.9%). Academic progress was also evident in English (65.2%) and Computer-Mathematics (60.9%), suggesting better engagement strategies compared to the previous year. The study affirms the ASSETS model's effectiveness in promoting holistic student development, though continued refinement is needed for long-term skill retention and diversified implementation across other Tahfiz centers.

Keywords: Education, STEM, Skill Enhancement, Tahfiz, MRIQ

Introduction

Tahfiz education in Malaysia has traditionally centered on Quranic memorization, often at the expense of integrating secular academic subjects and practical life skills. This narrow focus has resulted in students being less equipped for diverse career paths and real-world challenges beyond religious contexts. Numerous studies have emphasized the need to balance religious and secular education in Tahfiz institutions by incorporating academic and vocational components. For example, Norsalim et al. (2021) reported significant challenges in integrating vocational skills into the Tahfiz curriculum, citing financial limitations and the absence of a standardized framework. In a similar vein, Bani et al. (2017) emphasized the importance of expanding Tahfiz education to include practical skills, which are vital for students' overall development. Supporting this, Yahya et al. (2020) advocated for a well-rounded curriculum that incorporates co-curricular activities to enhance students' general competencies. Likewise, Taat et al. (2021) found that school climate and curriculum structure significantly affect students' academic attitudes, underscoring the benefit of a diversified curriculum.

In response to this educational gap, the ASSETS 2025 program was introduced to offer a more balanced curriculum that integrates both academic subjects and practical skills. This holistic approach is essential for fostering well-rounded student development. The study by Ishak et al. (2022) on the Huffaz ProHealth module highlights the importance of including physical, nutritional, and psychological health components in the curriculum, pointing to the need for a comprehensive educational model. Similarly, the Tahfiz Model Ulul Albab (TMUA), as outlined by Ambo and Mokhsein (2019), seeks to develop professionals who are proficient in both religious knowledge and the skills necessary for broader career success. However, despite these efforts, the effectiveness of programs like ASSETS has not been rigorously assessed. Evaluation is key to ensuring these initiatives meet their intended goals. For instance, Daud et al. (2018) emphasized the need to evaluate teaching methods in Tahfiz schools, particularly in mastering Tajwid. Norsalim et al. (2021) also stressed the importance of assessing vocational training efforts to identify and close gaps. This research therefore aims to evaluate the ASSETS program's impact on academic and practical skill development among students, with the goal of informing future improvements and ensuring long-term educational effectiveness.

Literature Review

Integrated educational programs that blend academic learning with practical skills are essential for cultivating individuals who are well-prepared for the demands of contemporary life. In Malaysia, the Tahfiz Model Ulul Albab (TMUA) serves as a notable example, combining Quranic memorization with secular education to produce students who are proficient in both religious and worldly knowledge (Jamil & Othman, 2023). The integration of practical skills into education is also emphasized by Ibrahim and Jaaffar (2017), who highlight the role of work-integrated learning in building students' competencies, self-efficacy, and employability.

Experiential learning theories, such as Kolb's model, support the use of hands-on activities to improve educational outcomes. This pedagogical approach has been applied effectively in the TMUA, where experiential learning is utilized in both religious and academic subjects to foster a more dynamic and meaningful learning experience (Ridyah & Sriyati, 2019). The broader implementation of experiential learning in Malaysia's vocational and technical education sectors has also demonstrated success in improving students' practical abilities and workforce readiness (Norsalim et al., 2021).

Given that Quranic memorization remains the core focus in Tahfiz schools, integrating academic and practical skills is crucial to better equip students for the multifaceted challenges of life. The TMUA curriculum represents a robust model of this integration, offering a holistic education by aligning religious teachings with academic and practical subjects (Ambo & Mokhsein, 2019). Nonetheless, studies have also identified ongoing challenges in embedding vocational skills within Tahfiz education, pointing to the need for improved curriculum planning and better allocation of resources to support the development of these essential life skills (Norsalim et al., 2021).

Studies have shown that exposing students to a diverse set of skills—including those beyond their core academic focus—enhances their self-efficacy, adaptability, and preparedness for future challenges. In Malaysian educational contexts, research on the development of metacognitive skills in secondary schools reveals that incorporating various learning methods fosters improvements in both cognitive and non-cognitive abilities (Bakar & Ismail, 2020). Similarly, studies in vocational and technical education highlight the value of skill diversity in enhancing students' employability and flexibility across different job sectors (Aziz et al., 2020).

Programs that combine academic subjects such as computer skills, mathematics, and English proficiency with practical and physical activities like speed-reading, culinary arts, and archery have demonstrated positive outcomes in student development. In Malaysia, co-curricular programs structured to support this kind of dual enrichment have been found to simultaneously boost cognitive performance and physical well-being (Shaharanee et al., 2021). Integrated learning models that merge cognitive and physical engagement further contribute to academic success and student well-being (Rashed & Tamuri, 2022).

Incorporating practical life skills like cooking and archery into the curriculum not only enriches students' learning experiences but also opens avenues for personal and economic growth. This is particularly significant in Tahfiz institutions, where vocational training is being increasingly adopted to support students' long-term financial independence. Despite challenges in implementation, integrating vocational elements has shown to enhance students' capacity for income generation and self-reliance (Norsalim et al., 2021). Promoting such skill diversification aligns with broader educational objectives aimed at developing well-rounded individuals capable of succeeding in a range of professional contexts (Ahmad & Iksan, 2023).

However, the success of such integrated educational programs largely depends on the quality of instruction and the relevance of the skills included. Research indicates that teacher preparedness and the alignment of curricular content with students' actual needs are key determinants of program effectiveness (Suriman & Tahar, 2018). Moreover, studies on curriculum integration stress that the selected skills—such as computer literacy, mathematics, English proficiency, speed-reading, culinary arts, and archery—must be relevant to the challenges students are likely to face in the future to ensure overall program success (Jamil & Othman, 2023).

Personalizing instructional methods to suit students' individual learning needs is also essential for improving outcomes, particularly in areas where students commonly struggle. In the Tahfiz education context, teaching strategies tailored to students' learning preferences have been shown to significantly enhance both academic performance and knowledge retention (Taat et al., 2021). Furthermore, integrating experiential learning with contextual teaching strategies—such as applying English and computer skills through real-world scenarios or embedding mathematics in archery or culinary exercises—has been found to increase student engagement and deepen understanding (Raub et al., 2015).

This study builds upon these insights by evaluating the ASSETS program's effectiveness in enhancing both academic and practical competencies among Tahfiz students—a demographic traditionally underrepresented in integrated education research.

Methodology

The Aiding in Sustainable Skills Empowerment & Transfer (ASSETS) program was organized by the Academy of Language Studies (APB) and English Language Society of UiTM Cawangan Pulau Pinang, in collaboration with Maahad Riyadhil Quran (MRIQ), and took place from 24 to 26 April 2025. It provided a structured three-day schedule from 6:00 AM to 9:00 PM, alternating between academic enrichment and skill-building workshops. Participants were male Tahfiz students aged 10 to 18. Activities included modules in computer mathematics, English proficiency, and skill-based sessions in archery, culinary arts, speed reading, and public speaking.

A quantitative research design was used, relying on matched pre- and post-program self-assessment surveys. Each student rated their own knowledge or skills across the six learning areas on a Likert scale ranging from "*Sangat Rendah*" (Very Low) to "*Sangat Tinggi*" (Very High). Skill development was evaluated based on the percentage of students whose post-program scores exceeded their pre-program levels.

A total of 23 male students from Maahad Riyadhil Quran (MRIQ) participated in the ASSETS 2025 program held from 24 to 26 April 2025. The participants were aged between 10 and 16 years, representing a typical cohort of Tahfiz students with diverse levels of prior exposure to academic and practical skills. The selection of an all-male group reflected the demographic composition of the partnering institution and ensured consistency in program delivery. All participants voluntarily completed both the pre- and post-program self-assessment surveys, which served as the primary data source for measuring perceived skill improvement.

Results

The data collected was analyzed to determine the extent of skill development across five core areas: Computer-Mathematics, Speed Reading, Archery, English Language, and Culinary Skills. Table 1 summarizes the self-reported improvement of each participant in these domains. Improvement was identified based on upward changes in skill ratings from pre- to post-program assessments using a five-point ordinal scale ranging from "*Sangat Rendah*" (Very Low) to "*Sangat Tinggi*" (Very High). The table offers an overview of individual growth, forming the basis for the detailed discussion that follows. Table 1 also presents the skill improvement profiles of participants in the ASSETS 2025 program. A total of 23 male students from Maahad Riyadhil Quran (MRIQ), aged between 10 and 18 years, participated in the three-day program held from 24 to 26 April 2025. The evaluation focused on five key areas: Computer-Mathematics, Speed Reading, Archery, English, and Culinary Skills. Pre- and post-program self-assessments were analyzed to determine changes in perceived skill levels.

Table 1. Profile of Participants

	Improvement post-program				
Participant (Age)	**Computer-Mathematics**	**Speed Reading**	**Archery**	**English**	**Culinary Skills**
Male A (11)	Yes	Yes	Yes	Yes	Yes
Male B (14)	No	No	No	No	No
Male C (10)	No	No	No	No	No
Male D (13)	Yes	Yes	Yes	Yes	Yes
Male E (14)	Yes	Yes	Yes	Yes	No
Male F (13)	Yes	Yes	Yes	Yes	Yes
Male G (14)	No	No	No	No	No
Male H (12)	No	No	No	No	No
Male I (17)	Yes	Yes	Yes	Yes	Yes
Male J (16)	Yes	Yes	Yes	Yes	Yes
Male K (16)	No	No	No	No	No
Male L (13)	No	Yes	Yes	No	Yes
Male M (18)	Yes	Yes	Yes	Yes	Yes
Male N (17)	No	No	No	No	No
Male O (17)	Yes	Yes	Yes	Yes	Yes
Male P (13)	No	Yes	No	Yes	No
Male Q (17)	Yes	Yes	Yes	Yes	Yes
Male R (13)	Yes	Yes	Yes	Yes	Yes
Male S (15)	Yes	Yes	Yes	Yes	Yes
Male T (17)	Yes	Yes	Yes	Yes	Yes
Male U (15)	No	No	No	No	No
Male V (17)	Yes	Yes	Yes	Yes	Yes
Male W (14)	Yes	Yes	Yes	Yes	Yes

In the area of Computer-Mathematics, 60.9% of the participants (14 out of 23) reported improvements. These students generally progressed from a pre-assessment rating of "*Sangat Rendah*" or "*Rendah*" to "*Sederhana*" or higher in the post-assessment. The remaining 9 participants did not report improvement, suggesting the need for further intervention or differentiated instruction to address varied learning needs in this subject.

Speed Reading saw the highest rate of improvement among participants, with 69.6% (16 students) demonstrating positive change. Many students moved from lower-tier ratings such as "*Sangat Rendah*" or "*Rendah*" to more advanced levels, indicating the program’s effectiveness in cultivating foundational reading techniques and cognitive processing speed. This suggests that the hands-on and engaging format of the speed-reading module resonated well with the Tahfiz students.

In Archery, 15 participants (65.2%) showed improvement post-program. This is consistent with the high level of enthusiasm observed during the physical activity sessions and highlights the alignment of traditional physical skills like, archery with the values and interests of the Tahfiz community. Participants who improved typically advanced from beginner to intermediate competency levels, showing stronger form, focus, and confidence by the end of the program.

The findings also indicate a substantial improvement in English language skills, with 65.2% of the participants showing positive changes in their self-assessed proficiency. This marks a significant increase compared to the 2024 cohort, suggesting that revised instructional strategies and interactive lesson designs may have enhanced engagement. Students moved from “*Sangat Rendah*” or “*Rendah*” levels to “*Sederhana*” or “*Tinggi*,” though a minority of students still did not exhibit measurable gains, warranting continued refinement in pedagogical delivery.

Culinary Skills also showed encouraging outcomes, with 14 students (60.9%) reporting improved abilities following the program. The hands-on nature of this module allowed participants to actively engage in real-world culinary tasks, such as preparing basic dishes and managing kitchen hygiene. These experiences not only enriched their practical knowledge but also fostered a sense of independence and confidence in applying life skills beyond the religious classroom context.

Overall, the ASSETS 2025 program successfully facilitated multidimensional learning outcomes, with the majority of participants reporting growth in both academic and practical areas. The results underscore the effectiveness of a balanced educational model in Tahfiz settings, particularly when it incorporates interactive and experiential learning components.

Discussions

The ASSETS 2025 program demonstrated meaningful progress in equipping Tahfiz students with both academic and practical skills, based on improvements reported through pre- and post-program assessments. This integrated approach addresses the need for holistic student development, particularly in traditionally Quran-focused education environments. Research has emphasized that the success of such programs is often influenced by factors like teacher readiness and curriculum alignment (Suriman & Tahar, 2018), as well as the relevance of the skills taught to students' real-world challenges (Jamil & Othman, 2023). The ASSETS 2025 outcomes affirm the potential of balanced and interactive modules in fostering both academic achievement and life competencies.

Academic Skill Development

The program recorded moderate yet promising improvements in academic skills, with 65.2% of students reporting progress in English and 60.9% in Computer-Mathematics. This reflects a modest increase compared to the previous year, indicating that enhancements in content delivery and interactive engagement strategies were effective. These findings align with the importance of metacognitive regulation in academic success (Bakar & Ismail, 2020) and support prior research emphasizing the need for tailored, subject-specific instructional approaches in areas where students commonly face difficulties (Rasid et al., 2020).

The disparity between English and Computer-Mathematics outcomes suggests the necessity for differentiated teaching strategies. While English instruction benefited from more communicative and contextualized learning, Mathematics instruction may require further refinement, particularly in scaffolding concepts and integrating problem-solving techniques. Higher-order thinking skills, which are essential in Mathematics, require educators to employ more nuanced pedagogy (Chandran et al., 2023), highlighting the importance of continuous training for teachers and adaptable curriculum design.

Practical Skill Development

The program was notably more effective in improving practical skills. Speed reading (69.6%), archery (65.2%), and culinary arts (60.9%) all recorded strong gains. These outcomes reaffirm the effectiveness of experiential and hands-on learning in fostering engagement and retention, particularly in non-academic domains. The physical and interactive nature of these modules aligns with findings from earlier studies emphasizing that active learning strategies significantly enhance self-efficacy and real-world skill application (Suriman & Tahar, 2018; Bakar & Ismail, 2020).

Practical modules like archery and culinary arts not only developed technical skills but also contributed to character building, discipline, and teamwork attributes critical for students' personal and professional growth. The results suggest that such modules should remain integral to future iterations of the program and could be further diversified to include digital literacy or entrepreneurship, in line with evolving societal needs.

Program Design Considerations

Although the results were largely positive, the mixed improvement levels across different domains underscore the need for refinement. Targeted interventions are necessary, particularly in Computer Mathematics, where some students continued to report difficulties. Future program designs should integrate differentiated instructional tools and real-time feedback mechanisms to better accommodate varied learning profiles (Fuad et al., 2020).

Furthermore, the hands-on modules' success highlights the value of maintaining a strong practical component. Longitudinal follow-ups could evaluate the retention and transferability of these skills, ensuring sustained impact. Additionally, expanding the participant pool and incorporating industry-aligned training would improve scalability and relevance.

Conclusion

Overall, participant feedback strongly supports the program's relevance and effectiveness, with near-unanimous agreement on its necessity, clarity, impact, and desire for continuity. This affirmation from the students suggests a readiness and appetite within the Tahfiz community for more integrative, skill-based education. The ASSETS 2025 program successfully demonstrated its value in enriching Tahfiz education through integrated skill-building and academic engagement. Improvements across both academic and practical domains indicate that the program design is sound and impactful. Students reported meaningful growth in skills such as speed reading, archery, English, and culinary arts, while also voicing enthusiasm for further involvement. The findings affirm the importance of balancing traditional Quranic studies with broader life skills and highlight the feasibility of implementing such models in similar settings.

For future iterations of the ASSETS program, several refinements can be made to enhance its reach and effectiveness. First, differentiated instructional strategies should be developed to better support participants with lower baseline proficiency, particularly in academic areas like Computer-Mathematics, and English. Incorporating more interactive, scaffolded learning tools and personalized feedback could help bridge these gaps. Additionally, expanding the program to include female participants and students from a wider range of Tahfiz institutions would improve the generalizability of findings and foster broader community impact. It is also recommended that future programs include longitudinal follow-up to assess the retention and real-life application of skills acquired. Finally, integrating industry-relevant modules—such as digital literacy, entrepreneurship, or health education—

would further align the program with contemporary societal and economic needs, ensuring that Tahfiz students are better equipped for diverse life pathways beyond their religious studies.

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Conflict of Interest Statement

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

Authors' Contributions

Noor Azli Affendy Lee: Conceptualisation, methodology, formal analysis, investigation and writing-original draft, editing; **Nor Hanim Abd Rahman**: Conceptualisation, editing and validation.

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DETERMINATION OF TEXT POLARITY CLASSIFICATION USING SENTIMENT ANALYSIS

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ABSTRACT

To effectively, analyzing the unstructured data or text for reviewing purposes need a robust tool to process and represent the result in comprehensive data visualization. Texts reviews as responded from thousands of reviewers, customers' experiences or reputations and comments from the netizens are classified accordingly to derive overall perceptions on certain issues, products or views. The text reviews from the social media such as Facebook, twitter, Instagram or WhatsApp are the best platform to retrieve the specific field to perform the polarity classification. Polarity can be expressed as the numerical rating or sentiment score conveyed by a particular text, phrase or word. This paper will discuss phases that involves in Sentiment Analysis (SA) such as the Data Extraction, Data Pre-processing, Data Annotation, Polarity Detection, Evaluation and finally the Data Visualization. Two methods for data classification such as Machine Learning and Lexicon-based approaches have been employed to train the machine or tools to learn the data. Samples of python codes were provided at each phase of SA processes to demonstrate the classification and perform the data visualization based on the text reviews.

Keywords: classification, sentiment analysis, phyton, machine learning, lexicon-based

Introduction

With the growth of Internet infrastructure, users are increasingly engaging with social media platforms like Twitter, WhatsApp, Instagram, Facebook, and blogs to share reviews and comments. Today, when shopping online, you don't need to inquire about the quality of a product or service from others. Instead, you can rely on numerous product reviews available online, which provide detailed analyses to help you make informed decisions. In fact, Ghenie et al., 2025 has highlighted the crucial role of social media in modern business strategies, offering diverse perspectives on leveraging these platforms for feedback and engagement.

Sentiment Analysis (SA), or Opinion Mining, is a widely adopted approach by researchers and marketers to process and interpret significant volumes of public opinions and feedback on different subjects, products, and services. (Sánchez-Rada & Iglesias, 2019). This opinion mining involves the computational examination of feelings, opinions, and emotions conveyed through written text. This area has experienced considerable expansion in both scholarly research and practical applications within various industries. It falls under the category of Natural Language Processing(NLP), utilizes sophisticated computational techniques to categorize sentiments as positive, negative, or neutral (Neethu & Rajasree, 2013). Numerous studies have explored the application of Sentiment

Analysis to mine extensive datasets of reviews. For instance, Soleymani et al. (2017) and Yadav & Vishwakarma (2020) have published research on sentiment classification. Furthermore, Yue et al. (2019) and Liu et al. (2012) investigated the efficacy of online reviews. Jain et al. (2021) have discussed machine learning applications that utilize online reviews for sentiment categorization, predictive decision-making, and the identification of fraudulent reviews.

The process of extracting pertinent text reviews frequently entails managing noisy or ambiguous data. This noise may originate from diverse sources, including extraneous material, spam, or debates that are not pertinent to the analysis. A product review thread may contain irrelevant personal anecdotes, ads, or automated bot messaging, which might obfuscate the useful insights found inside authentic reviews. (Islam et al., 2024). Furthermore, the ambiguity in the data stems from the subjective characteristics of human language. Individuals articulate their viewpoints through various means, employing slang, abbreviations, emojis, and differing degrees of detail. This diversity complicates the uniform interpretation of the sentiment and significance of each review. A sarcastic remark may be misconstrued as affirmative feedback if the subtleties of sarcasm are not accurately recognised by the extraction algorithms (Almansour et al., 2022). The context of the reviews significantly influences their interpretation. A review pertinent in one context may be deemed irrelevant in another. A comprehensive analysis of a product's durability may be vital for a buyer seeking longevity, while meaningless for an individual focused on the product's aesthetic qualities. Consequently, comprehending the context and objective of the data extraction is crucial for precisely finding and employing pertinent reviews (Khalaf et al., 2024). In summary, extracting pertinent text reviews necessitates traversing an overwhelming amount of noisy and ambiguous data. It necessitates a synthesis of sophisticated NLP methodologies, ongoing model enhancement, and contextual comprehension to efficiently eliminate extraneous information and precisely extract key insights that appropriately characterise the data. (Almansour et al., 2022).

This study explores the methodological framework for conducting Sentiment Analysis, outlining the necessary procedures to assess classification polarity through the use of the Python programming language. The phases of Sentiment Analysis encompass Data Extraction, Data Pre-processing, Data Labelling, Polarity Detection, Evaluation, and Data Visualisation. The study utilised further polarity metrics, lexicon-based methods, and machine learning models to identify sentiment analysis in airline reviews.

Methodology

Sentiment Analysis (SA) in text reviews or opinion requires the execution of several critical phases in order to produce accurate results. These phases include Data Extraction, Data Pre-processing, Data Classification, Polarity Detection, and Evaluation. The ultimate objective of this process is to achieve comprehensive Data Visualization (Aqlan et. al, 2019) as has been illustrated in Fig.1.

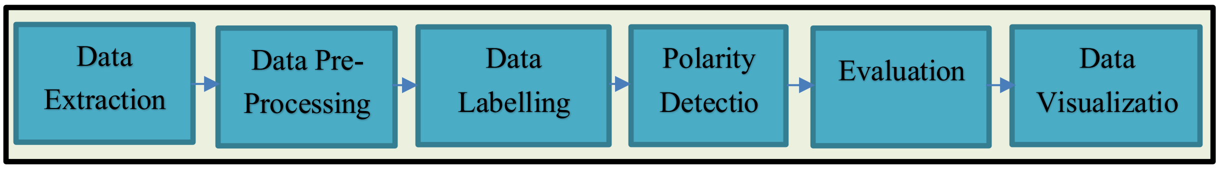


Figure1: sentiment analysis phases

The implementation was executed using the Python programming language within the Anaconda3 software platform. This platform offers a comprehensive suite of libraries and tools specifically designed for data preprocessing and classification in Sentiment Analysis (SA). Python's versatility makes it an effective tool for data classification, leveraging both machine learning and lexicon-based approaches through the implementation of specialized libraries available in Anaconda3.

The dataset used for this study, titled **"Airlines Reviews and Rating,"** was sourced from Kaggle and comprises an extensive collection of reviews and ratings from passengers across various airlines. It includes multiple columns containing different data types, such as textual reviews, numerical ratings, travel dates, and other relevant information. The dataset is rich in information and offers valuable insights into passengers' experiences with different airlines. However, they also pose challenges in terms of data quality, completeness, and the need for suitable preprocessing to ensure accurate analysis and visualization. Data preprocessing, or data cleansing, was applied to improve data quality and minimize noise, with the primary objective of ensuring the data was consistent and free from errors. Cleaned data enhances the effectiveness of data visualization, enabling the quick identification of patterns and making it easier to forecast or predict future trends.

Data extraction phase

The dataset on airline reviews and rating has been downloaded from the Kaggle website (https://www.kaggle.com/datasets/anandshaw2001/airlines-reviews-and-rating). This source file was used to determine the polarity classification using the Sentiment Analysis approach. The downloaded data source file was imported to Data Frame of Python programming language using Pandas library in the Anaconda3 as shown in the following Fig. 2. The created Data Frame was used for further processing after all records from the data source file have been loaded into the memory.

```
import pandas as pd

df_airlines_rev_rat = pd.read_csv("Airlines Review and Rating.csv")
```

Figure 2: load all records from the data source into the data frame using pandas.

The dataset's content was organised into columns and rows, representing fields and records, respectively. The *print()* command was employed to display the records, revealing the initial five records for each column or field. The following Fig. 3 shows the commands in Python and the output. The data source consists of 3290 rows or records and 15 columns.

```
[7]: print (df_airlines_rev_rat.head)
<bound method NDFrame.head of      Aircraft Type                                       Users Reviews  \
0              NaN  ✅Trip Verified|  Cancelled our flight last-min...
1              NaN  ✅Trip Verified| I had a flight from Miami, Flo...
2              NaN  ✅Trip Verified|  We started our day with BA in...
3              NaN  ✅Trip Verified|  I fly British Airways weekly ...
4              NaN  Not Verified|  Everything was ok until our con...
...            ...                                                 ...
3285           NaN  LAX to LHR - 25 Oct 2014. I agree with other r...
3286           NaN  Toronto to London Heathrow - 26/10/14. After r...
3287           NaN  I have after years of loyalty finally had it w...
3288           NaN  Traveled with British Airways ORD-LHR last mon...
3289           NaN  Travelled to Palma in new BA 'sardine' busines...

             Country Type_of_Travellers                                Route  \
0     United Kingdom     Couple Leisure             London Heathrow to Tokyo
1      United States       Solo Leisure  Miami to Dublin via London Heathrow
2      United States           Business   Prague to San Francisco via London
3     United Kingdom           Business                London to Glasgow
4             France     Family Leisure   San Diego to Marseille via London
...              ...                ...                                  ...
3285  United Kingdom                NaN                                  NaN
3286  United Kingdom                NaN                                  NaN
3287  United Kingdom                NaN                                  NaN
3288   United States                NaN                                  NaN
3289  United Kingdom                NaN                                  NaN

           Seat_Types  Seat Comfort Date Flown  Cabin Staff Service  \
0       Economy Class           1.0     Sep-23                  1.0
1      Business Class           1.0     Aug-23                  3.0
2      Business Class           1.0     Sep-23                  3.0
3       Economy Class           1.0     Sep-23                  1.0
4       Economy Class           3.0     Aug-23                  2.0
...               ...           ...        ...                  ...
3285   Business Class           3.0        NaN                  2.0
3286   Business Class           4.0        NaN                  5.0
3287   Business Class           3.0        NaN                  1.0
3288   Business Class           5.0        NaN                  5.0
3289   Business Class           1.0        NaN                  1.0
```

```
      Ground Service  Food & Beverages  Wifi & Connectivity  \
0                2.0               1.0                  NaN
1                1.0               2.0                  1.0
2                1.0               3.0                  1.0
3                1.0               1.0                  1.0
4                1.0               3.0                  1.0
...              ...               ...                  ...
3285             NaN               1.0                  NaN
3286             NaN               5.0                  NaN
3287             NaN               1.0                  NaN
3288             NaN               4.0                  NaN
3289             NaN               1.0                  NaN

      Inflight Entertainment  Value For Money Recommended
0                        3.0                1          no
1                        1.0                1          no
2                        NaN                1          no
3                        1.0                1          no
4                        3.0                3          no
...                      ...              ...         ...
3285                     3.0                2          no
3286                     5.0                4         yes
3287                     2.0                1          no
3288                     4.0                4         yes
3289                     1.0                1          no

[3290 rows x 15 columns]>
```

Figure 3: display the first five records for each column from the data frame.

The `dtypes` function in a Pandas data frame, was used to determine the type and names of all fields or columns that exists in the data source file as illustrated in Fig. 4.

```
[11]: df_airlines_rev_rat.dtypes

[11]: Aircraft Type              object
      Users Reviews              object
      Country                    object
      Type_of_Travellers         object
      Route                      object
      Seat_Types                 object
      Seat Comfort              float64
      Date Flown                 object
      Cabin Staff Service       float64
      Ground Service            float64
      Food & Beverages          float64
      Wifi & Connectivity       float64
      Inflight Entertainment    float64
      Value For Money             int64
      Recommended                object
      dtype: object
```

Figure 4: List of fields of the data source file in the data frame

Before determining which columns and rows to extract for further preprocessing and classification, it is crucial to examine the presence of null data in each column. Fig. 5 below provides a detailed overview of null occurrences per column. Notably, only 20% of the columns, including "user reviews," "value for money," and "recommended," contain no null values.

```
print(df_airlines_rev_rat.isnull().sum())

Aircraft Type             1394
Users Reviews                0
Country                      1
Type_of_Travellers         403
Route                      407
Seat_Types                   3
Seat Comfort               114
Date Flown                 410
Cabin Staff Service        125
Ground Service             478
Food & Beverages           379
Wifi & Connectivity       2698
Inflight Entertainment    1119
Value For Money              0
Recommended                  0
dtype: int64
```

Figure 5: number of null values occurrences *for* each column.

Focusing to the aircraft type under consideration was 'A320', Fig. 6 presents the comprehensive code for the extraction. The code filters the 'A320' aircraft type from the data frame and assigned the result into a new data frame called a320_df. Subsequently, the number of records and the count of null values in each column or attribute were recorded, culminating in a total extraction of 352 rows.

```
filter = = df_airlines_rev_rat['Aircraft Type']=='A320'

a320_df = df_airlines_rev_rat[filter]

a320_df.shape
```

Figure 6: codes to filter and store into new data frame specifically for ‘A320’ aircraft.

Next, the distribution of null values across all attributes using a simple command were depicted in a presentable bar chart, as shown in Fig. 7. The chart reveals the count of NaN or null values across attributes as follows: Seat Comfort (7), Date Flown (1), Cabin Staff Service (7), Ground Service (1), Food & Beverages (51), Wifi & Connectivity (300), and Inflight Entertainment (288), with the number of null values indicated in parentheses.

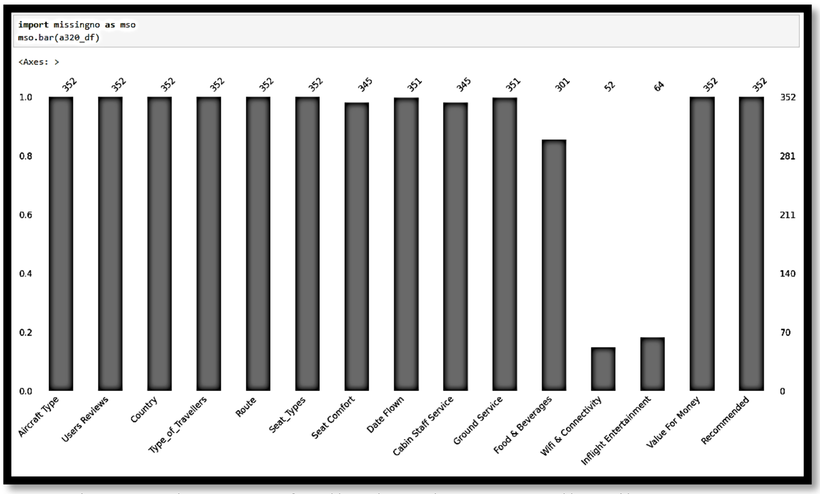


Figure 7: the count of null values data across all attributes.

Data preprocessing phase

Using the a320_df data frame, a simple Sentiment Analysis (SA) was conducted to assess the polarity of passengers' reviews on seat comfort and cabin staff service. First, we need to remove unrelated attributes to the sentiment analysis, such as Date Flown, Ground Service, Food & Beverages, WIFI & Connectivity, and Inflight Entertainment. Fig. 8 illustrates the method used to drop these columns from the data frame.

```
a320_df.columns

Index(['Aircraft Type', 'Users Reviews', 'Country', 'Type_of_Travellers',
       'Route', 'Seat_Types', 'Seat Comfort', 'Cabin Staff Service'],
      dtype='object')

a320_df = a320_df.drop(columns= ["Date Flown","Ground Service", "Food & Beverages",
       "Wifi & Connectivity", "Inflight Entertainment", "Value For Money",
       "Recommended"])

a320_df.columns

Index(['Aircraft Type', 'Users Reviews', 'Country', 'Type_of_Travellers',
       'Route', 'Seat_Types', 'Seat Comfort', 'Cabin Staff Service'],
      dtype='object')
```

Figure 8: dropping unrelated columns from the data frame before further pre-processing.

Next, identified the columns that still contain null values and apply the dropna function to remove the corresponding rows from the a320_df data frame. Fig. 9 demonstrates the implementation of the dropna function to eliminate records with null values. Previously, the data frame contained 352 rows, but 7 of these rows had null values in the "seat comfort" and "cabin staff service" columns were eliminated. After this step, the data frame contains only the clean data with no null values remaining in any column.

```
print(a320_df.isnull().sum())

Aircraft Type          0
Users Reviews          0
Country                0
Type_of_Travellers     0
Route                  0
Seat_Types             0
Seat Comfort           7
Cabin Staff Service    7
dtype: int64

a320_df.dropna(inplace=True)

print(a320_df.isnull().sum())

Aircraft Type          0
Users Reviews          0
Country                0
Type_of_Travellers     0
Route                  0
Seat_Types             0
Seat Comfort           0
Cabin Staff Service    0
dtype: int64

a320_df.shape

(345, 8)
```

Figure 9: `dropna` function will remove those records with null values.

Currently, a320_df data frame consists of two columns which were rated by the passengers. The columns are “Seat Comfort” and “Cabin Staff Service”. The data underwent preprocessing steps to calculate the average rate of these two columns and the result have been added as new column in the data frame as “Average Rate” as illustrated in Fig. 10.

```
a320_df['Average Rate'] = (a320_df['Seat Comfort'] + a320_df['Cabin Staff Service'])/2

print(a320_df[['Seat Comfort','Cabin Staff Service','Average Rate']])

      Seat Comfort  Cabin Staff Service  Average Rate
7              3.0                  4.0           3.5
14             1.0                  3.0           2.0
23             1.0                  1.0           1.0
25             1.0                  3.0           2.0
26             2.0                  2.0           2.0
...            ...                  ...           ...
2860           2.0                  5.0           3.5
2863           3.0                  3.0           3.0
2864           2.0                  4.0           3.0
2870           4.0                  5.0           4.5
2875           3.0                  5.0           4.0
```

Figure 10: the new column average rate calculated and added in the data frame.

Data labelling phase

Polarity of text commonly given in decimal value in range of [-1,1], where positive sentiment when polarity >0; negative sentiment when polarity <0; and neutral when polarity=0. Using the data from the a320_df, the "average rate" column was considered as polarity measure where an average rate below 2.99 is classified as negative, 3.00 as neutral, and above 3.0 as positive. Fig. 11 below illustrates the commands used to carry out the process of polarity rating.

```
a320_df['Polarity Rating'] = a320_df['Average Rate'].apply(lambda x: 'Positive' if x > 3 else('Neutral' if x == 3 else 'Negative'))

print(a320_df[['Average Rate','Polarity Rating']])

      Average Rate Polarity Rating
7              3.5        Positive
14             2.0        Negative
23             1.0        Negative
25             2.0        Negative
26             2.0        Negative
...            ...             ...
2860           3.5        Positive
2863           3.0         Neutral
2864           3.0         Neutral
2870           4.5        Positive
2875           4.0        Positive
```

Figure 11: the new column of polarity rating created after the classification has been performed.

The next step involves conducting a basic Sentiment Analysis (SA) and visualizing the results using the matplotlib and seaborn libraries. Fig. 12 illustrates the outcome, presented in a comprehensive graph. Based on the findings, the service provided by the cabin staff and the seat comfort of the A320 aircraft are not particularly well-received, as the levels of negative and positive sentiment are nearly equal. Consequently, the airline should consider strategies to enhance passenger satisfaction in these areas to improve overall ratings.

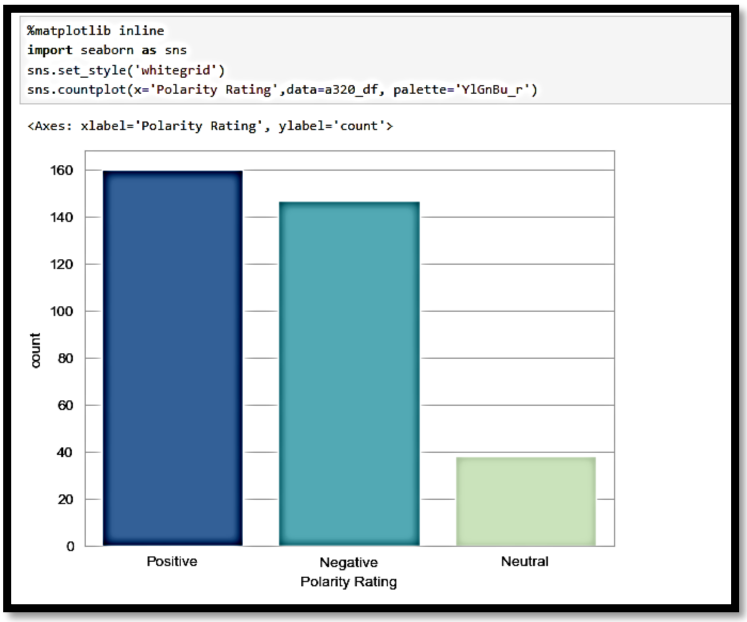
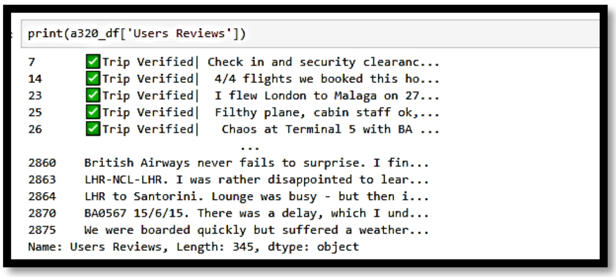


Figure 12: the bar chart graph of polarity rating among the passengers.

Polarity detection and evaluation phase

The previous example, as illustrated in Fig. 12, demonstrates a basic application of Sentiment Analysis (SA). In the next example, we will utilize a specialized library called AFINN to classify and conclude the sentiment in the user reviews column. The AFINN library is a dictionary that contains words which help to identify whether each word in a users' reviews column is matched with the words stored in the AFINN dictionary to determine the corresponding score either negative or positive and finally conclude the sentiment. This method of classification is known as lexicon-based classification.

The implementation of lexicon-based classification for the same a320_df data was focusing on the attribute column "Users Reviews". Fig. 13 presents the user reviews column for the A320 aircraft.



```
print(a320_df['Users Reviews'])

7       ✅Trip Verified|  Check in and security clearanc...
14      ✅Trip Verified|  4/4 flights we booked this ho...
23      ✅Trip Verified|  I flew London to Malaga on 27...
25      ✅Trip Verified|  Filthy plane, cabin staff ok,...
26      ✅Trip Verified|   Chaos at Terminal 5 with BA ...
                              ...
2860    British Airways never fails to surprise. I fin...
2863    LHR-NCL-LHR. I was rather disappointed to lear...
2864    LHR to Santorini. Lounge was busy - but then i...
2870    BA0567 15/6/15. There was a delay, which I und...
2875    We were boarded quickly but suffered a weather...
Name: Users Reviews, Length: 345, dtype: object
```

Figure 13: the users' reviews on the aircraft A320

The code in Fig. 14 illustrates how to extract the users' reviews column from the a320_df data frame and copied into the new data frame named users_review_df. Next, determine the score and polarity sentiment and the result will be added as separate column in the same data frame users_review_df, next to the column of users' reviews.

```
from afinn import Afinn
#instantiate afinn
afn = Afinn()
#creating list sentences
users_reviews_df = a320_df['Users Reviews']
# compute scores (polarity) and labels
scores = [afn.score(article) for article in users_reviews_df]
sentiment = ['positive' if score > 0
                         else 'negative' if score < 0
                             else 'neutral'
                                for score in scores]
#sentimen & lexicon

# dataframe creation
a320_sa_df = pd.DataFrame()
a320_sa_df['Users Reviews'] = users_reviews_df
a320_sa_df['scores'] = scores
a320_sa_df['sentiments'] = sentiment
print(a320_sa_df)

#plot the bar chart graph
%matplotlib inline
sns.set_style('whitegrid')
sns.countplot(x='sentiments',data=a320_sa_df, palette='YlGnBu_r')
```

Figure 14: codes in Python to determine the score and sentiment based on the users' reviews.

The following Fig. 15 depicts the bar chart shows that overall sentiment on the users' reviews toward the A320 aircraft. From the reported graph almost 40% of the passengers are not happy with the service on A320 aircraft and the same result was also reported in the previous sentiment analysis in Fig. 12. Further investigation needs to be done to scrutinize the reasons and plan the new strategies to improve the services to passengers.

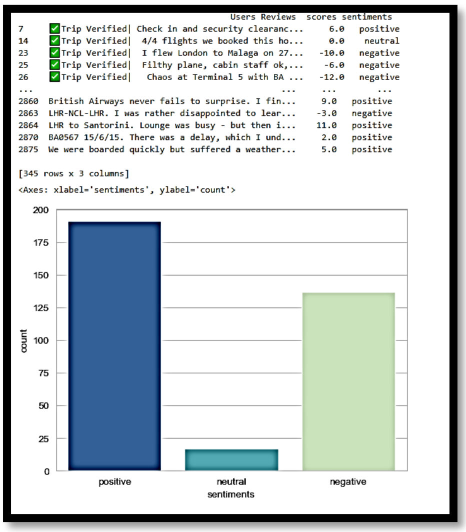


Figure 15: the bar chart of A320 sentiment by using the lexicon-based approach.

Evaluation and Discussion

Finally at this phase, this study has conducted sentiment analysis on passenger reviews using a machine learning technique. Machine learning leverages algorithms to learn from data, which is divided into training and testing subsets. It trains on the training data to learn patterns and uses the learning model to classify sentiment. In the example provided in Fig. 16, this study utilized a cleansed dataset that exclusively features records from 'Malaysia Airlines' (https://www.kaggle.com/datasets/khushipitroda/airline-reviews). This approach specifically targets the reviews column, applying machine learning techniques to derive insights. Fig. 17 presents the results of the machine learning approach utilizing the logistic regression algorithm.

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import nltk
from sklearn.model_selection import train_test_split
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.linear_model import LogisticRegression
from sklearn.metrics import classification_report, accuracy_score, confusion_matrix

# Load the dataset
df_airline_reviews = pd.read_csv('airline_reviews.csv')

#filter the 'Malaysia Airlines' from the airline name column
filter = df_airline_reviews['Airline Name']=='Malaysia Airlines'
df_malaysia_airlines = df_airline_reviews[filter]

# Add a 'Sentiment' column based on the 'Recommended' column
# Assuming 'Recommended' 1 as positive sentiment and 0 as negative sentiment
df_malaysia_airlines['Sentiment'] = df_malaysia_airlines['Recommended']

# Text preprocessing
nltk.download('stopwords')
from nltk.corpus import stopwords
from nltk.stem.porter import PorterStemmer
import re

corpus = []
ps = PorterStemmer()
for review in df_malaysia_airlines['Review']:
    review = re.sub('[^a-zA-Z]', ' ', review)
    review = review.lower()
    review = review.split()
    review = [ps.stem(word) for word in review if not word in set(stopwords.words('english'))]
    review = ' '.join(review)
    corpus.append(review)

# Convert text to features
tfidf = TfidfVectorizer(max_features=5000)
X = tfidf.fit_transform(corpus).toarray()
y = df_malaysia_airlines['Sentiment'].values
```

```
# Split the data
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=0)

# Train the model
classifier = LogisticRegression()
classifier.fit(X_train, y_train)

# Make predictions
y_pred = classifier.predict(X_test)

# Evaluate the model
print("Accuracy:", accuracy_score(y_test, y_pred))
print("\nClassification Report:\n", classification_report(y_test, y_pred))
print("\nConfusion Matrix:\n", confusion_matrix(y_test, y_pred))

# Save the model and vectorizer for future use
import joblib
joblib.dump(classifier, 'logistic_regression_model.pkl')
joblib.dump(tfidf, 'tfidf_vectorizer.pkl')
```

Figure 16: apply the logistic regression algorithm in machine learning approach for sentiment analysis.

```
Accuracy: 0.6

Classification Report:
               precision    recall  f1-score   support

           0       0.60      1.00      0.75        12
           1       0.00      0.00      0.00         8

    accuracy                           0.60        20
   macro avg       0.30      0.50      0.37        20
weighted avg       0.36      0.60      0.45        20


Confusion Matrix:
 [[12  0]
 [ 8  0]]
```

Figure 17: result of sentiment analysis processing by using the machine learning approach with the logistic regression algorithm.

The model achieved an overall accuracy of 0.6, indicating that 60% of the instances in the dataset were correctly classified. The classification report provides key metrics such as precision, recall, and F1-score for both class 0 and class 1. For class 0, the model achieved a precision of 60%, meaning that 60% of the instances predicted as class 0 were correct. The recall for class 0 was 100%, indicating that all instances of class 0 were accurately identified. The F1-score for class 0 was 0.75, representing a balance between precision and recall. The support for class 0 is 12, reflecting the 12 instances of class 0 in the dataset.

In contrast, the model performed poorly for class 1. The precision for class 1 was 0%, indicating that the model failed to correctly predict any instances of class 1. Similarly, the recall for class 1 was 0%, meaning none of the actual class 1 instances were identified. The F1-score was also 0, reflecting the poor performance in both precision and recall. There were 8 instances of class 1 in the dataset, as indicated by the support value.

The macro average provides an unweighted mean score for each metric, treating each class equally. The weighted average, however, accounts for the support, or the number of true instances for each class, to provide a weighted mean score. The confusion matrix shows that all 12 instances of class 0 were correctly classified as 0, while all 8 instances of class 1 were misclassified as class 0. There were no correct or incorrect classifications of class 1.

Based on the Fig. 16 results indicate that the model was unable to distinguish instances of class 1, likely due to class imbalance or a lack of distinguishing features for class 1. To enhance the model's performance, particularly for class 1, it might be beneficial to balance the dataset through resampling (either by oversampling class 1 or under sampling class 0), adjust class weights to penalize misclassification of the minority class, or explore alternative algorithms or model architecture. Without addressing these issues, the model remained biased towards predicting class 0, limiting its overall effectiveness.

Data visualisation is the depiction of results through charts or specialised graphics. The results have been presented in a comprehensible way that aids strategic management in decision-making. This study demonstrated Sentiment Analysis processing with specialised graphs, which were updated in real-time using Python. Fig. 17 depicts a radar graph that shows the positive or negative reviews given to each airline from South East Asia airlines. It shows that highest positive reviews were given to Garuda Indonesia.

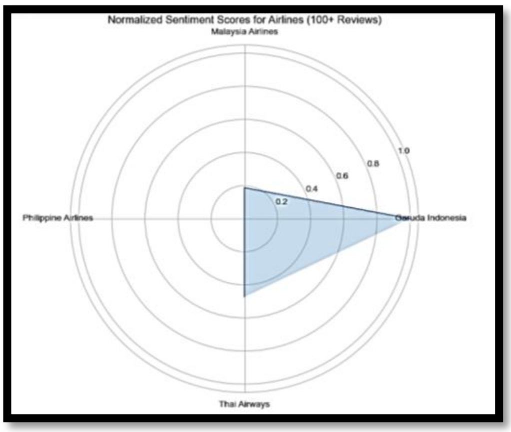


Figure 17: radar graph.

Next, Fig. 18 shows the usage of word cloud specifically for the Malaysia Airline sentiment. The words were extracted from the users' reviews. Meanwhile Fig. 19 depicts the bar chart that visualized the rates given by the passengers of Malaysia Airline specifically on the seat comfort.

Figure 18: word cloud graph.

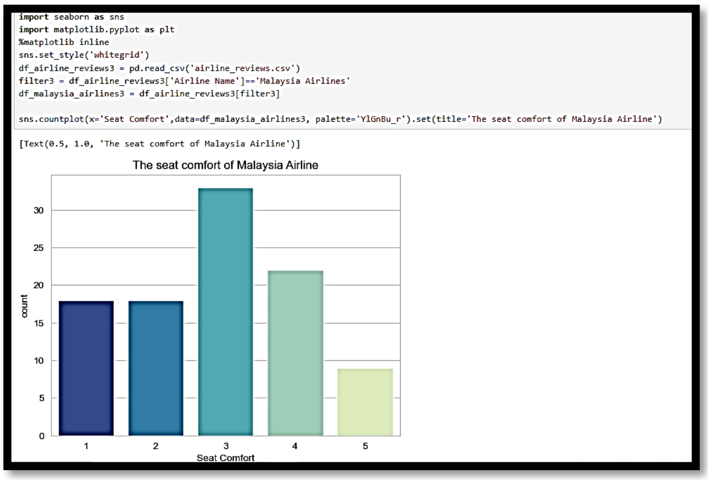


Figure 19: bar chart graph

Python programming provides a diverse array of graph types, enabling researchers to choose and implement the most appropriate chart for presenting elegant reports in a straightforward and visually appealing manner.

Conclusion

Sentiment analysis is a powerful tool used to interpret and classify emotions expressed in textual data, offering valuable insights into public opinion, customer feedback, or social media trends. By analyzing the tones of reviews, comments or feedbacks either positive, negative or neutral, this technique helps businesses and organizations make informed decisions, improve customer satisfaction, and gauge overall sentiment towards products, services, or topics. With advancements in natural language processing and machine learning, sentiment analysis continues to evolve, enabling more accurate and nuanced interpretations of complex human emotions in large datasets. The sentiment analysis process begins with data extraction and culminates in presenting the results through the most suitable and visually appealing data visualization methods. Many practitioners now utilize the concept of a dashboard as a one-stop centre, where all key results are displayed in one place. This approach makes it easier for users to quickly grasp the latest information or trends, facilitating informed decision-making.

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TRANSFORMING ASSESSMENT IN HIGHER EDUCATION WITH CANVA FOR CREATIVE AND VISUAL LEARNING

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ABSTRACT

Canva is a cutting-edge technology for developing evaluations in higher education, and this study investigates its application. Traditional assessments often rely on text-based formats that may not effectively engage all learners or support the development of essential 21st-century skills. Canva provides a creative and user-friendly platform that allows educators to design visually appealing, interactive, and student-centered assessments such as infographics, digital journals, and collaborative presentations. Its features, including real-time collaboration, artificial intelligence tools, and integration with learning management systems, help enhance student engagement, support various learning styles, and encourage critical thinking and creativity. Based on constructivist and social learning theories, the study highlights how Canva fosters deeper understanding and promotes teamwork among students. It also emphasizes the platform's usefulness in both online and blended learning environments, offering flexible and inclusive assessment approaches. The findings suggest that Canva can improve traditional assessment practices by making them more meaningful, accessible, and aligned with the needs of modern education.

Keywords: Canva, assessment, educators, learning, education

Introduction

Assessment is a core component of effective teaching and learning, providing valuable feedback for both instructors and students. Traditional assessment formats often rely heavily on textual responses and standard test papers, which may not cater to diverse learning styles. In contrast, Canva offers a creative platform for designing formative and summative assessments that are visually engaging, student centered and aligned with 21st-century skills. Several studies have emphasized the importance of incorporating visual and interactive elements in assessments to enhance student motivation, comprehension, and retention (Susanti et al., 2024).

With Canva's wide range of templates, educators can design dynamic quizzes, mind maps, infographics, and reflection journals that support visual learning and critical thinking. For instance, students can demonstrate understanding by creating infographics summarizing key concepts or digital posters showing the links between causes and effects in scientific or historical contexts. These alternative assessments promote deeper cognitive processing and allow students to engage with content meaningfully, rather than merely recalling facts. According to Ulya (2024), students who participated in an evaluation based on infographics demonstrated better conceptual understanding and were more engaged compared to those assessed through traditional written methods.

Canva also supports collaborative assessment formats. Through real-time editing and shared access, group projects such as digital storytelling, team-created presentations, and multimedia reports can be easily developed and submitted. This aligns with Vygotsky's social development theory, which highlights the role of interaction in cognitive development. Additionally, instructors can use Canva to create rubrics and feedback sheets, which can be shared with students as part of the assessment cycle. The visual clarity of these tools facilitates transparent evaluation and promotes student self-assessment and peer feedback.

Furthermore, Canva's integration with platforms such as Google Classroom and Microsoft Teams enhances its utility in digital assessment workflows. Educators can embed Canva created content into learning management systems (LMS), allowing for seamless distribution and submission tracking. The platform's design features also make it easier to differentiate assessments based on learners' needs, ensuring inclusivity and accessibility.

Canva is not only a tool for content creation but also a valuable resource for reimagining assessment practices in higher education. By fostering creativity, collaboration, and visual literacy, Canva based assessments can provide a more holistic view of student learning and align more closely with the demands of an education in the digital age.

Despite the increasing use of digital tools in education, traditional assessment methods often fail to engage students meaningfully or support diverse learning preferences, particularly in online and blended learning environments. Many educators still rely on text-heavy tests and static assignments that do not fully harness the creative or collaborative potential of digital platforms. This gap highlights the need for alternative assessment approaches that are visually engaging, interactive, and adaptable to various academic contexts. The objective of this study is to explore how Canva, a user friendly and AI-powered design platform, can be effectively utilized for innovative assessment design in higher education, to enhance student engagement, promote creativity, and supporting formative and summative assessment practices in a digital learning environment.

Literature Review

Assessment in education has undergone a significant transformation with the integration of digital technologies. Despite their continued relevance, traditional pen-and-paper exams frequently fail to foster critical thinking, creativity, and engagement, particularly in the context of 21st-century learning (Andrade, 2019). Alternative assessments that involve multimedia and visual communication have gained traction in recent years, particularly in constructivist and student-centered learning environments.

Canva, as a digital design platform, provides a powerful tool for creating visually rich and interactive assessment materials. According to Ulya (2024), the use of visual tools such as infographics in assessments enhances student comprehension, particularly for abstract and complex topics. Similarly, Susanti et al. (2024) found that students assessed through Canva-based materials showed higher motivation and interest compared to those evaluated through conventional methods. These findings support the broader educational consensus that multimodal assessments contribute to deeper learning and improved retention (Mayer, 2009).

Furthermore, Canva aligns well with formative assessment practices. Educators can use Canva to create digital journals, concept maps, and tools for group project templates that help monitor student understanding throughout the learning process (Black & Wiliam, 2009). Canva's collaborative features also support peer assessment and self-reflection activities, consistent with Vygotsky's emphasis on social interaction as a driver for learning.

Significance of the study

This study highlights the growing potential of Canva as a tool not only for instructional content creation but also for innovative assessment design in higher education. By leveraging Canva's visual, interactive, and collaborative features, educators can develop assessments that better engage students, accommodate diverse learning preferences, and promote higher order thinking skills.

The significance in the post-pandemic educational landscape, where online and blended learning models have become prevalent. With Canva's accessibility across devices, integration with Learning Management Systems (LMS), and AI-powered tools, instructors can streamline assessment processes and enhance digital literacy for both teachers and students. Moreover, this study offers practical insights for universities and policymakers aiming to modernize curriculum delivery by incorporating flexible, inclusive, and creative assessment practices that go beyond traditional testing formats.

Benefits of the study

This study explains how Canva can help improve assessments in universities. It allows educators to create fun, creative, and student-friendly tasks. Canva also helps students build important skills like teamwork, creativity, and using digital tools. It works well with online platforms like Google Classroom and Microsoft Teams. Table 1 lists the benefits of the study and how Canva improves instruction and makes learning more engaging.

Table 1: Benefits of the study

Benefit	Description
Enhance Assessment Innovation	Promotes the use of Canva for creating alternative assessments that are visual, interactive, and student-centered.
Supports 21st-Century Skills	Encourages the development of creativity, digital literacy, collaboration, and design thinking among students.
Improve Teaching Practices	Provides educators with practical strategies to design formative and summative assessments using AI-powered and collaborative tools.
Integrate with Digital Platforms	Demonstrates how Canva integrates with LMS platforms like Google Classroom and Microsoft Teams to streamline workflow.
Supports Education Transformation	Aligns with global trends in digital education by offering flexible, engaging, and modern alternatives to traditional assessment methods.

Through providing educators and representatives with pertinent information, this study encourages a reconsideration of conventional assessment methods and the utilization of digital resources that complement contemporary learning goals. In a variety of academic fields, the study demonstrates Canva's potential as an assessment tool that aids in the creation of more efficient, welcoming, and stimulating learning environments.

Features in Canva for Assessment and Learning

The integration of digital tools in education has transformed how assessments are designed, delivered, and experienced by students. Canva, as a versatile and user-friendly platform, offers a wide range of features that support innovative assessment practices in higher education. These features not only enhance the visual quality of learning materials but also promote student engagement, collaboration, and creativity. Table 2 below highlights key Canva tools that provide practical benefits for educators, students, and institutions seeking to modernize their assessment strategies.

Table 2: Related Features in Canva for Assessment and Learning

Feature	Description	Use in Education
Templates Library	Thousands of customizable templates for infographics, posters, reports, worksheets, and presentations.	Design visually rich assignments, rubrics, or student projects quickly.
Real-Time Collaboration	Multiple users can edit the same design simultaneously.	Supports group work, peer editing, and collaborative assessments.

Magic Write	AI-powered text generator within Canva Docs and designs.	Helps students brainstorm, draft reflections, or summarize content.
Magic Design	AI generates design layouts based on uploaded content or prompts.	Speeds up creation of assessment visuals like comparison charts or timelines.
Presentation Mode	Interactive presentation tools, including transitions and animations.	Useful for student-led presentations or digital storytelling assessments.
LMS Integration	Canva integrates with Google Classroom, Microsoft Teams, and others.	Makes it easy to distribute, collect, and track student submissions.
Folder and Version Control	Organize content and revert to previous versions.	Helps manage different versions of assignments or shared group work.
Canva Docs	Combines document writing with design elements.	Ideal for reflective journals, visual essays, or digital portfolios.

Canva empowers educators with practical, creative, and accessible tools that transform traditional teaching and assessment methods. Its versatile features support the development of visually engaging, collaborative, and interactive learning materials that cater to diverse student needs. By integrating Canva into educational practices, educators can enhance student engagement, streamline content creation, and foster a more dynamic and inclusive learning environment.

Conclusion

Incorporating Canva into assessment design represents a shift toward more student-centered, visually engaging, and technologically aligned evaluation methods in higher education. As demonstrated in prior research, Canva based assessments can increase student motivation, foster creativity, and enhance comprehension by allowing learners to express their knowledge through infographics, presentations, and other digital media formats.

By providing a flexible platform for designing both formative and summative assessments, Canva addresses the need for diverse evaluation strategies that support 21st-century skills such as critical thinking, collaboration, and digital fluency. Moving forward, educational institutions should consider training educators in Canva based assessment design and encouraging its integration into teaching and learning practices. Doing so will help create more meaningful, engaging, and equitable learning experiences for all students.

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NUMERICAL SOLUTION OF THE HEAT EQUATION USING THE FINITE DIFFERENCE METHOD

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ABSTRACT

This paper focuses on solving the one-dimensional heat equation numerically through the Finite Difference Method (FDM), highlighting the application of the Crank-Nicolson approach. The heat equation, a key partial differential equation in physics and engineering, describes how heat diffuses over time within a material. Although exact analytical solutions exist for simple scenarios, they are often inadequate for more complex problems, making numerical techniques essential. In this study, the continuous domain is discretized in both time and space, converting the heat equation into a set of algebraic expressions. The Crank-Nicolson method, well-regarded for its numerical stability and second-order precision, is applied to examine temperature variations under different types of boundary conditions, such as Dirichlet and Neumann. Implementation is carried out using Wolfram Mathematica, which also enables dynamic visualizations through animated plots and 3D surfaces. The accuracy of the numerical results is checked by comparing them to known exact solutions, using measures like the L_2-Norm and maximum absolute error. The analysis demonstrates that the Crank-Nicolson method is an effective and accurate tool for simulating heat transfer, offering a reliable solution strategy for practical thermal conduction problems.

Keywords: Heat equation, Finite Difference Method, Crank-Nicolson Method, Numerical Solution, Error Analysis

Introduction

The heat equation is a fundamental partial differential equation that models the diffusion of thermal energy through a medium over time. Its applications span across various scientific and engineering domains, including thermal analysis in mechanical systems, environmental simulations, and materials science. Although analytical solutions exist for idealized cases with simple boundary conditions and uniform materials, real-world problems often involve complexities such as irregular geometries, non-homogeneous materials, and mixed or time-dependent boundary conditions that make exact solutions infeasible. In such cases, numerical methods provide an effective alternative. Among these, the Finite Difference Method (FDM) is one of the most widely used techniques for approximating the solution of partial differential equations. By discretizing both space and time, FDM transforms the continuous heat equation into a solvable system of algebraic equations.

This study focuses on the Crank-Nicolson scheme, an implicit finite difference approach known for its second order accuracy and unconditional stability. It is particularly effective in handling transient heat conduction problems and supports a wide range of boundary conditions, including Dirichlet and Neumann types. To investigate the performance of this method, the one-dimensional heat equation was solved using Wolfram Mathematica under different boundary conditions. The numerical results were then validated against analytical solutions using error metrics such as the $L_2 - \text{Norm}$ and maximum absolute error. The findings confirmed the method's high accuracy and robustness, with minimal deviation from the exact solutions. This research demonstrates the Crank-Nicolson method's adaptability and efficiency, offering a reliable computational tool for solving practical heat transfer problems. While the study is limited to one-dimensional cases and fixed boundary conditions, it lays the groundwork for future research in higher dimensions, variable boundaries, and more complex thermal systems

Literature Review

Numerical methods are always employed to resolve the heat equation when analytical solutions are impossible due to complex geometries, time-varying boundary conditions, or inhomogeneous material properties. One of the most well-known and effective is the Finite Difference Method (FDM), which converts the differential equations into algebraic systems by discretizing space and time (Song et al., 2018). For homogeneous equations, FDM yields exact results, especially for steady-state heat conduction problems with uniform materials like copper and aluminium (Loskor & Sarkar, 2022). For non-homogeneous equations with internal heat sources or non-uniform thermal properties, more advanced extensions of FDM such as the Crank-Nicolson method demonstrate improved accuracy and stability (Safari, 2024).

The Crank-Nicolson scheme, which was presented by Crank and Nicolson in 1947, is an implicit technique that provides a trade-off between second order accuracy in time and space and numerical stability (Liu & Hao, 2022). Besides that, the Crank-Nicolson scheme is particularly suitable for transient problems and, due to its trapezoidal time-stepping, is ideal for simulations with fine spatial meshes or long times (Mohebbi & Dehghan, 2010). The boundary conditions are also crucial for effective heat transfer modelling. Studies have shown its effectiveness in both homogeneous and non-homogeneous heat equations, as well as its adaptability to boundary conditions such as Dirichlet and Neumann types (Mojumder et al., 2023). Dirichlet conditions yield prescribed temperatures, and Neumann conditions yield a constant heat flux. Both conditions have been utilized effectively in FDM simulations (Hajrulla et al., 2024). The Crank-Nicolson scheme has also been noted to be extremely stable when used under mixed boundary conditions or on non-regular domains (Chai et al., 2020). Besides, optimization techniques such as adaptive mesh refinement, hybrid schemes, and iterative solvers such as the Gauss-Seidel or Conjugate Gradient methods have been employed to ensure computational efficiency (Tafrikan & Ghani, 2022). Computational software such as Wolfram

Mathematica also enables the use of FDM via symbolic computation and advanced visualization (Narahari et al., 2013). The literature as a whole show that FDM, especially the Crank-Nicolson variation, is a strong, accurate, and flexible way to represent one-dimensional heat transfer problems in many different situations.

Methodology

The process of solving the one-dimensional heat equation in this study begins with the selection of the equation, expressed as

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2} \tag{1}$$

where T = temperature, t = time, x = spatial coordinates, and α = thermal diffusivity constant.

The equation is then solved using the Finite Difference Method (FDM), a numerical approach that discretizes the continuous problem. To enhance accuracy and ensure stability, the Crank-Nicolson method which is a semi-implicit scheme, is used for time discretization. After that, the heat equation is used on a one-dimensional model, which is solved using the discretized scheme. Numerical results are then generated, and visual representations such as surface and line plots are produced using Wolfram Mathematica to illustrate the temperature distribution over time. Finally, the accuracy of the numerical solution is evaluated through error analysis, including the $L_2 -$Norm and maximum absolute error, and comparing the results with the exact analytical solution to validate the effectiveness of the Crank-Nicolson method.

Result and Discussion

This model problem examines the temperature distribution along a one-dimensional rod subjected to mixed boundary conditions, where one end is Dirichlet and the other is Neumann. Using Wolfram Mathematica and the Crank-Nicolson finite difference scheme, the simulation visualizes heat transfer through surface plots and animations. The domain considered is $0 \le x \le 10,\ t > 0$ and the numerical solution is compared with the analytical solution. The analysis evaluates the effect of spatial and temporal step sizes on accuracy and stability, using error metrics such as absolute error, $L_2 -$Norm, and maximum norm. The findings show that even with mixed boundary conditions, the Crank-Nicolson approach yields reliable and accurate approximations.

The heat equation, along with its initial and boundary conditions for model problem is formulated as:

$$u_t = \alpha^2 u_{xx} \text{ for } 0 \le x \le 10, t > 0 \tag{2}$$

Initial condition

$$u(x,0) = 3\sin\left(\frac{5x}{2}\right) \quad (3)$$

Boundary condition

Dirichlet: $u(0,t) = 0$ (4)

Neumann: $u_x(10,t) = 0$ (5)

The simulation was implemented in Wolfram Mathematica over a domain of length $L = 10$ and run until $T_{max} = 1.0$. The spatial and temporal grids were discretized into 200 steps each, resulting in $dx = 0.05$ and $dt = 0.005$. A key dimensionless parameter $r = \alpha \frac{\partial t}{\partial x^2}$ was used to form the tridiagonal matrix in the Crank-Nicolson scheme. These discretization choices provided a fine resolution for capturing heat transfer dynamics efficiently and accurately, particularly near the boundaries.

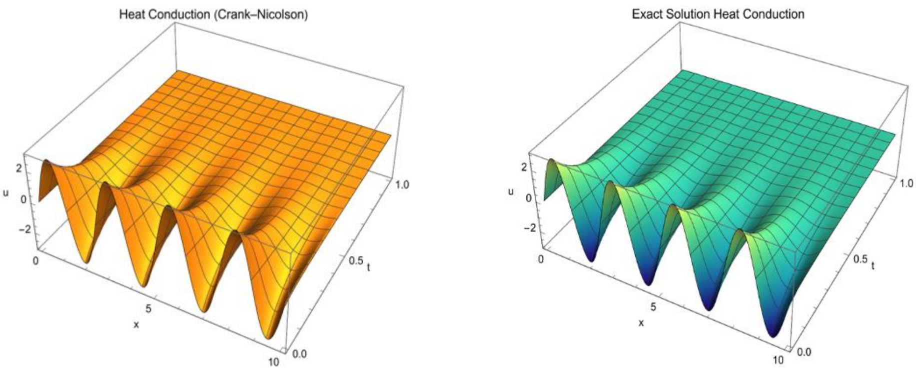

Figure 1: 3D-plot of Crank-Nicolson Solution and the Exact Solution

The temperature changes over time and along the rod are clearly illustrated through surface and line plots. Figure 1 above show that the Crank-Nicolson method produces results that closely match the exact solution, highlighting its accuracy. The 3D plots reveal smooth and consistent heat flow, and the visible symmetry and wave patterns further support the method's reliability in solving heat transfer problems effectively.

Table 1: Comparison of Exact Solution and Crank-Nicolson Solution with Error

x	Exact Solution	FDM (Ucn)	Absolute Error
0	0.0000000	0	0.0000000
1	0.0034660	0.0034925	0.0000265
2	-0.0055535	-0.0055960	0.0000425
3	0.0054323	0.0054741	0.0000418
4	-0.0031506	-0.0031691	0.0000185
5	-0.0003841	-0.0002969	0.0000872
6	0.0037661	0.0046497	0.0008836
7	-0.0037661	-0.0010337	0.0046165

8	0.0052872	0.0190347	0.0137475
9	-0.0028214	0.0152562	0.0180776
10	-0.0007665	0.0005732	0.0013397
$L_2 - \text{Norm}$	-	-	0.1042487
$L_\infty - \text{Norm}$	-	-	0.0186432

Table 1 shows a comparison between the exact analytical solution and the numerical results from the Crank-Nicolson method for the one-dimensional heat equation with mixed boundary conditions. The table shows the temperature at different points along the rod at a certain period. Overall, the numerical solution closely matches the exact values, particularly near the center of the domain. Small differences begin to appear near the edges, peaking at $x = 9$ where the maximum deviation is recorded. The method was verified to be accurate with the $L_2 - \text{Norm}$ and the maximum absolute error, which were 0.1042 and 0.0186 respectively. These relatively low error values indicate that the numerical scheme is both accurate and stable throughout the simulation. The smooth progression of temperature over time also reflects the Crank-Nicolson method's strong stability and second-order accuracy. In summary, the method effectively replicates heat transfer under the boundary conditions imposed, with minimal errors near the boundaries due to boundary behavior. The use of small spatial grid size and an appropriate time step assisted in enhancing the precision of the results.

Conclusion

This study reports that the Crank-Nicolson finite difference scheme we found to be a stable and accurate tool for the solution of the one-dimensional heat equation under mixed Dirichlet and Neumann boundary conditions. Low $L_2 - \text{Norm}$ and maximum absolute error values verified that the simulation findings, which were implemented and visualized using Wolfram Mathematica, closely matched analytical answers. Although there were slight variations in the area of the Neumann boundary, the overall accuracy was within acceptable limits. These results confirm that the Crank-Nicolson method's reliability as a useful instrument for real-world thermal analysis, especially when boundary conditions are irregular. Kubacka and Ostrowski (2021) demonstrated that the Crank-Nicolson method is stable and accurate even when they are applied in Robin-type boundary condition. The method may be extended to two- or three-dimensional systems in future research, or adaptive time-stepping may be investigated.

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THE ROLE OF DIGITAL WELL-BEING IN SUPPORTING UNIVERSITY STUDENTS' LEARNING AND MENTAL HEALTH

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ABSTRACT

In the digital age, university students rely heavily on technology for learning, communication, and academic productivity. While digital tools offer numerous educational benefits, excessive and unmanaged usage can negatively impact students' mental health and academic performance. This paper explores the concept of digital well-being and its significance in fostering a balanced academic experience. It examines the psychological effects of digital overuse such as stress, anxiety, sleep disturbances, and digital burnout and discusses how mindful technology practices can enhance concentration, emotional resilience, and social interaction. Drawing on recent literature, the study also highlights practical strategies for promoting digital well-being, including screen time management, digital detox activities, and institutional support. The findings emphasize the importance of cultivating healthy digital habits to ensure that technology serves as a tool for learning rather than a source of distress. Ultimately, promoting digital well-being is essential for creating supportive university environments that nurture both academic success and student mental health.

Keywords: University students', digital well-being, mental health, learning

Introduction

In today's university setting, students are deeply immersed in a digital environment where technology plays an essential role in academic life. From attending lectures and accessing course materials to conducting research and collaborating with peers, digital tools such as laptops, smartphones, and online platforms have become indispensable. This technological integration offers flexibility, efficiency, and convenience, enabling students to learn anytime and anywhere. However, constant exposure to digital devices also introduces new challenges, particularly in relation to students' mental health and learning behaviors.

Many students experience digital overload due to the pressure of being constantly connected, responding to notifications, multitasking across multiple platforms, and managing academic responsibilities online. This persistent engagement can lead to concentration difficulties, mental fatigue, sleep disturbances, and elevated stress levels. As digital boundaries between study time and personal time become increasingly blurred, students often struggle to maintain a healthy balance.

The concept of digital well-being has emerged as a response to these challenges. According to the Organization for Economic Co-operation and Development (OECD, 2021), digital well-being refers to the ability to use technology in ways that promote physical, mental, and social health. It involves developing conscious and healthy digital habits, such as managing screen time, setting boundaries, avoiding digital distractions, and engaging positively with online content. For university students, cultivating digital well-being is crucial not only for maintaining psychological resilience but also for sustaining academic motivation and performance.

This paper explores the role of digital well-being in supporting university students' learning and mental health. Specifically, it aims to examine how students' digital usage patterns impact their academic outcomes and emotional well-being, and to identify strategies that students and institutions can adopt to promote healthier digital engagement. By understanding the link between digital behavior and student well-being, educators and policymakers can foster learning environments that are both technologically advanced and supportive of holistic student development.

Literature Review

Digital well-being, a concept gaining prominence in education and technology, lacks a consensus definition but generally refers to the impact of digital technologies on human flourishing (Cao & Li, 2023). It encompasses various dimensions, including emotional and mental well-being, particularly in technology-enhanced learning contexts (El Aadmi-Laamech et al., 2022). Research has identified factors contributing to digital well-being, such as duration and place of digital use, demographic characteristics, and parental influences (Cao & Li, 2023). Active learning methodologies and digital technologies in higher education have shown potential benefits for students' well-being, impacting academic achievement, physical health, and social life (Ribeiro-Silva et al., 2022). However, measuring digital well-being, especially in young children, remains challenging (Cao & Li, 2023). The ethical implications of digital well-being span multiple domains, including healthcare, education, governance, and entertainment, with ongoing discussions centered on positive computing, personalized human-computer interaction, and autonomy (Burr et al., 2019).

Many research indicates that excessive digital technology use can negatively impact health, particularly among children and adolescents. Common issues include visual strain, musculoskeletal problems, sleep disorders, and reduced physical activity (Shubochkina, 2021). Psychological effects such as internet addiction, depressive symptoms, and aggressive behavior have also been observed (Shubochkina, 2021). While general effects are small and negative, impacts vary based on usage type: procrastination and passive use correlate with negative outcomes, while social and active use tend to be more positive (Dienlin & Johannes, 2020). Moderate use appears to be associated with increased well-being, whereas both low and excessive use relate to decreased well-being (Dienlin & Johannes, 2020). To mitigate risks, experts recommend monitoring children's technology use in terms of content, duration, and frequency, while ensuring adequate physical activity, healthy eating habits, and proper sleep cycles (Prakash et al., 2024).

Impact of Digital Technology on Mental Health

The influence of digital technology on university students' mental health has become a growing area of concern. While digital tools provide convenience and access to information, prolonged and unregulated use can contribute to various psychological challenges. One of the most reported issues among students is the increase of anxiety due to constant connectivity. A chronic sense of urgency can be brought on by the pressure to reply to academic emails, messages, or online discussions as soon as possible, as well as by frequent notifications and alerts. Even outside of study hours, this hyper-responsiveness often referred to as "techno-stress," prevents students from fully disengaging and recovering mentally.

The quality of sleep is another important factor. Blue light exposure from excessive screen time, especially at night, has been connected to circadian rhythm disturbances. Many students report staying up late to finish online assignments or browse social media, which shortens their sleep duration and compromises their sleep hygiene. Over time, prolonged sleep deprivation can impair cognitive functioning, emotional management, and academic achievement.

Ironically, despite regular online connections, excessive digital use can also result in feelings of social isolation. While social media offers the illusion of connectedness, it can foster unhealthy comparisons, fear of missing out (FOMO), and low self-esteem especially when students compare their academic or personal achievements to curated images of others. This leads to a distorted sense of self-worth and depressed symptoms.

Additionally, students often experience mental exhaustion or "digital burnout" from spending extended hours attending online classes, participating in virtual meetings, and multitasking across multiple platforms. This constant mental engagement can reduce motivation, increase emotional irritability, and diminish one's overall sense of well-being.

Overall, the mental health effects of digital overuse are multidimensional, affecting students' emotional stability, stress levels, and capacity for focus and motivation. The need to address these challenges is urgent, especially as digital learning environments continue to evolve. To clearly organize the common mental health challenges faced by university students due to digital technology use, Table 1 below summarizes the main causes and their psychological impacts:

Table 1: Summary of Digital Challenges Faced by University Students

Challenge	Cause	Impact on Mental Health
Constant notifications	Social media alerts, academic platforms	Anxiety, distraction, reduced mental clarity
Late-night screen use	Finishing assignments, scrolling social apps	Sleep disruption, fatigue, lower concentration
Tech multitasking	Switching between tabs and platforms	Cognitive overload, stress, reduced retention

Social media comparison	Viewing curated content	Low self-esteem, depressive feelings
Lack of digital boundaries	Always being online	Digital burnout, difficulty relaxing

Positive Effects of Digital Well-Being on Student Life

Digital well-being practice has several benefits for university students, especially for their mental health and ability to focus on their studies. By setting boundaries such as limiting screen time, turning off distractions, and taking regular breaks students often experience better concentration, time management, and learning efficiency.

Digital well-being also supports emotional health. Students who practice mindful digital habits report lower levels of stress and anxiety, improved mood, and better sleep quality. Establishing screen-free periods before bedtime, for example, helps restore healthy sleep cycles, which in turn enhances daytime alertness and emotional balance.

Moreover, healthier digital habits can strengthen real-life social interactions. Instead of passive scrolling or online comparison, students who use digital platforms intentionally are more likely to engage in meaningful communication and collaborative learning.

Overall, digital well-being empowers students to manage their technology use in ways that enhance not hinder their academic performance and mental resilience. Promoting these habits encourages a more balanced, focused, and fulfilling university experience.

Recommended Strategies for Promoting Digital Well-Being

In order to help university students maintain a healthier relationship with digital technology, it is essential to implement practical and evidence-based strategies that promote digital well-being. These strategies should aim to reduce digital fatigue, enhance self-regulation, and support both academic focus and emotional balance. Educational institutions play a crucial role in creating supportive environments that encourage students to adopt mindful digital habits. Table 2 outlines several recommended strategies, their intended purposes, and examples of how they can be implemented in a university setting.

Table 2: Recommended Strategies for Promoting Digital Well-Being

Strategy	Purpose	Implementation Example
Screen time limits	Prevent overuse and mental fatigue	Set daily application timers (e.g., 2 hours max)

Digital detox activities	Encourage offline balance	"Tech-Free Weekend" campaign
Sleep hygiene improvement	Encourage offline balance	Screen curfew 1 hour before bed
Digital literacy education	Raise awareness of healthy tech use	Workshops or orientation sessions
Balanced online learning design	Reduce digital overload from academic content	Mix of video, readings, and offline tasks

Conclusion

Digital well-being is essential in maintaining a healthy balance between academic demands and mental health among university students. While technology enhances access to learning and increases flexibility, unregulated and excessive digital engagement can lead to psychological strain, including anxiety, digital fatigue, poor sleep quality, and social isolation. These negative effects can hinder students' academic motivation and overall well-being.

This paper highlights that digital well-being is not about rejecting technology, but it is about using it mindfully and intentionally. When students adopt healthy digital habits such as setting boundaries, taking breaks, and engaging meaningfully with online content, they experience improved focus, emotional regulation, and resilience.

To support this, universities must play a proactive role by promoting digital literacy, designing balanced online learning environments, and implementing well-being initiatives. Through institutional commitment and individual self-regulation, a more supportive and productive digital learning experience can be cultivated. As digital learning continues to evolve, prioritizing student well-being will be vital to fostering both academic success and holistic personal development.

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PERFORMANCE TRENDS IN CONTINUOUS ASSESSMENTS: A CASE STUDY OF ENGINEERING STUDENTS IN A STATISTICS COURSE

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ABSTRACT

This case study describes and compares the academic performance of engineering students enrolled in the Statistics for Science and Engineering course, focusing on three formative assessments: a quiz, a group assignment, and a test. A total of 43 students from Mechanical, Electrical, and Chemical Engineering programs participated, representing academic semesters from Semester 5 to Semester 9. Descriptive statistics were used to analyse score distributions and identify performance patterns across programs and assessment types. The findings show variations in achievement, with Mechanical Engineering students generally outperforming others. These results highlight the need for targeted teaching approaches based on program-specific learning needs. In conclusion, understanding performance trends can help educators enhance assessment design and support student learning more effectively.

Keywords: engineering students, academic performance, quiz, test, descriptive statistics

Introduction

Assessment plays a crucial role in higher education as it provides feedback on student learning and reflects the effectiveness of teaching strategies. In engineering programmes, where conceptual understanding and analytical skills are vital, the use of continuous assessment such as quizzes, tests, and group assignments is increasingly adopted to track student progress before the final examination. Continuous assessment not only encourages consistent learning but also helps to identify students who may require additional support throughout the semester.

This study focuses on the performance of undergraduate students enrolled in the *Statistics for Science and Engineering* course. The course comprises 50% coursework (quizzes, tests, and group assignments) and 50% summative assessment (final examination). While final exams are designed to test cumulative understanding, coursework allows for ongoing engagement with core topics including probability distributions, hypothesis testing, estimation, analysis of variance (ANOVA) and regression. The present study analyses the performance of 43 students from three different engineering programmes; Mechanical, Electrical, and Chemical Engineering enrolled across several academic semesters. By comparing student achievement in both coursework and final examinations, this study aims to examine the relationship between programme enrolment, semester grouping, and student performance. Such comparison is important to identify whether performance patterns vary across academic progression and discipline background. This study also provides a descriptive analysis to explore the distribution of marks and possible performance gaps between coursework and examination results. The findings may help academic coordinators and instructors to improve assessment practices, support struggling students, and enhance instructional alignment across programmes and levels of study.

Recent studies have explored the impact of continuous assessment on student performance in engineering programmes and statistics courses. Shifting from final exams to continuous assessment methods, such as weekly homework, has been shown to improve student performance and learning experiences (Paloposki et al., 2024). Field-based continuous assessments have been found to better evaluate key learning outcomes and foster student engagement compared to traditional end-of-year examinations (McNabola & O'Farrell, 2015). Educational data mining techniques have been used to identify factors affecting student performance in engineering statistics courses, allowing for targeted support and interventions (Zakaria et al., 2018). Additionally, continuous assessment has been demonstrated to act as a mediating variable between class attendance and final examination performance, highlighting the importance of consistent participation throughout the semester (Noh et al., 2019). These findings suggest that incorporating continuous assessment methods can positively impact student learning and performance in engineering and statistics courses.

Assignments, often more comprehensive and problem-based, require students to apply theoretical knowledge to practical scenarios. These can encompass homework problems, data analysis projects, or short reports. In a statistics course for engineering students, such assignments would likely involve applying statistical methods to engineering-specific problems, utilizing statistical software, or interpreting complex data outputs. While essential for cultivating deeper understanding and practical application skills, the direct predictive power of graded homework for test or final examination performance has been a subject of varying findings, with some studies suggesting a weaker correlation compared to in-class tests (Latif & Miles, 2020). Nevertheless, assignments remain invaluable for fostering the nuanced problem-solving abilities crucial for engineering disciplines.

Studies have examined the performance of engineering students in statistics courses, employing various analytical methods. N. Lohgheswary et al. (2022) applied the Rasch model to evaluate exam performance, categorizing students into high and low performers and questions into difficulty levels. Both studies aimed to improve student outcomes by identifying areas for targeted support. In other field, Rivera et al. (2013) investigated poor performance in a Statics course, which led to high dropout rates in engineering programs. These studies highlight the importance of understanding and addressing factors influencing student performance in engineering courses to enhance academic success and retention rates in engineering programs.

Understanding the interplay between different continuous assessment components and student demographics is vital for optimizing pedagogical practices in statistics courses for engineering students. The distinct roles of quizzes (formative, frequent checks), assignments (deep application, problem-solving), and tests (summative, comprehensive evaluation) each contribute uniquely to student learning and assessment outcomes. Furthermore, acknowledging the varying academic maturity of students across semesters and the disciplinary context of their specific engineering programs allows educators to tailor assessment strategies, provide targeted support, and ultimately enhance student success in mastering statistical concepts crucial for their engineering careers. This nuanced understanding supports the development of effective learning environments tailored to the diverse needs of engineering cohorts.

Methodology

This study adopted a quantitative case study approach involving a small, purposive sample of 43 engineering students enrolled in a Statistics course at a public university. The participants consisted of both male and female students from three engineering programs: Mechanical Engineering, Chemical Engineering, and Electrical Engineering. The students were from various semesters, ranging from Semester 5 to Semester 9. This study involved a total of 43 students enrolled in the Statistics for Science and Engineering course. As shown in Figure 1, students were from three academic programs: Mechanical Engineering (34.8%), Chemical Engineering (14.0%), and Electrical Engineering (51.2%).

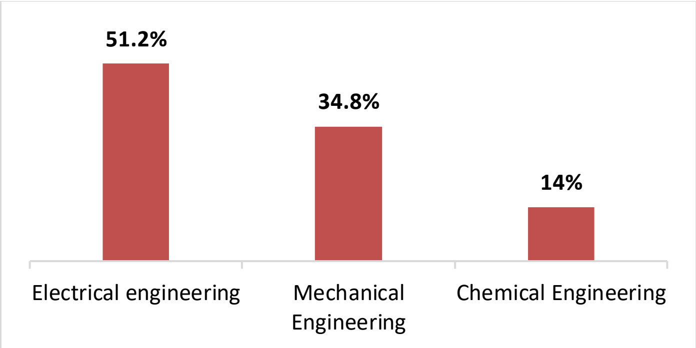

Figure 1: Percentage of Students by Programme

Figure 2 further illustrates the semester distribution of the students. The majority were from Part 5 (65.1%), while the rest were from Part 8 (14%), Part 7 (11.6%), Part 6 (7%), and Part 9 (2.3%). This diverse composition across programs and semesters helped ensure the representation of varying academic backgrounds and levels of experience in the analysis.

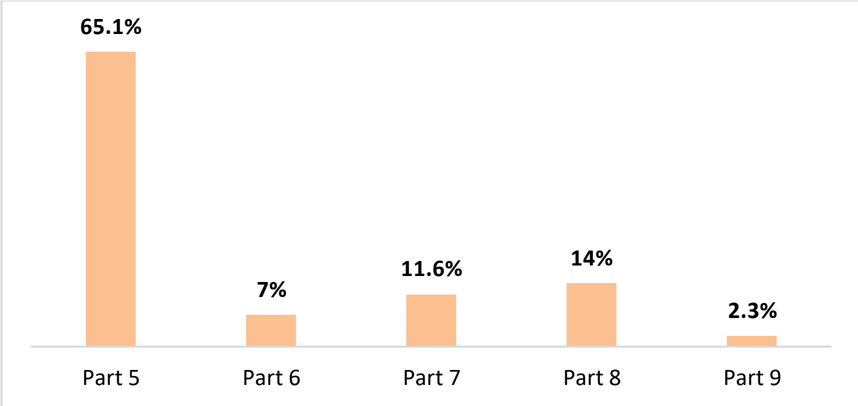

Figure 2: Percentage of Students by Student Semester

Data for this study comprised students' marks from three types of continuous assessments: quiz (10%), test (20%), and group assignment (20%), forming the overall coursework component (50%). The scores were compiled from two different lecturers who taught separate groups within the same course and coordinated the assessments together to ensure consistency. The data were analyzed using descriptive statistics, specifically means to identify general trends in student performance across the three programs and the three types of assessments. Each assessment type was compared across the programs to examine which program performed better or worse in each component. Additionally, the highest and lowest mean scores across the three assessments were identified to determine which type of assessment posed more challenges to students. The comparison was visualized using tables. This provides a clearer view of the student distribution within the sample, helping to contextualize the performance results. All analyses were conducted using Microsoft Excel and IBM SPSS Statistics software.

Results and Discussion

Table 1 presents descriptive statistics of quiz, assignment, and test scores for students from three engineering programmes: Electrical, Mechanical, and Chemical Engineering. The data were collected from **43 students** enrolled in the course and analysed using descriptive measures including minimum, maximum, and mean values. This approach enables comparison of student performance across different types of assessments. Electrical engineering students obtained a mean score of 63.1 in the quiz, with scores ranging from 25.0 to 100.0. For the assignment, their mean score was 68.3, with a minimum of 56.0 and a maximum of 84.0. The test results showed a lower mean score of 52.2, ranging from 24.0 to 96.0. Mechanical engineering students achieved the highest overall performance among the three groups. Their quiz mean score was 78.0 (min: 48.3, max: 100.0), assignment mean was 83.4 (min: 71.0, max: 93.0), and test mean was 75.0 (min: 37.0, max: 99.0). Chemical engineering students recorded the lowest performance across all assessments, with a quiz mean of 38.6 (min: 20.0, max: 70.0), assignment mean of 66.8 (min: 60.0, max: 80.0), and test mean of 40.7 (min: 32.0, max: 55.0).

Table 1: Descriptive Statistics of Assessment Results by Engineering Programme

Programme	Assessment	Minimum	Maximum	Mean
Electrical Engineering	Quiz	25.0	100.0	63.1
	Assignment	56.0	84.0	68.3
	Test	24.0	96.0	52.2
Mechanical Engineering	Quiz	48.3	100.0	78.0
	Assignment	71.0	93.0	83.4
	Test	37.0	99.0	75.0
Chemical Engineering	Quiz	20.0	70.0	38.6
	Assignment	60.0	80.0	66.8
	Test	32.0	55.0	40.7

Table 2 shows the mean marks of quiz, assignment, and test results according to student semester. Students from Part 5 showed the highest overall mean scores across all assessments, with 72.6 in the quiz, 76.1 in the assignment, and 67.5 in the test. These results suggest that Part 5 students were the most consistent performers, possibly due to being in their core academic phase with strong engagement. Part 6 students had high assignment marks (78.0) but lower performance in quizzes (63.9) and particularly in the test (43.3), indicating challenges in time-pressured assessments. Part 7 students recorded even lower mean scores, with 52.3 in quiz, 61.6 in assignment, and 44.0 in test. Interestingly, Part 8 students, although small in number, scored similarly to Part 7, with relatively low means in all assessments. Part 9 students showed a mixed pattern, achieving high quiz (71.7) and assignment (80.0) scores, but their test mean was the lowest among all groups (32.0). This might be due to reduced academic focus nearing the end of their programme or low test-taking motivation. Overall, the trend highlights that middle-semester students (especially Part 5) tend to perform better across all types of assessments compared to students in early or late semesters.

Table 2: Mean Marks of Assessment Results by Student Semester

Semester	Quiz	Assignment	Test
Part 5	72.6	76.1	67.5
Part 6	63.9	78	43.3
Part 7	52.3	61.6	44.0
Part 8	38.6	66.8	40.7
Part 9	71.7	80.0	32.0

Conclusion

This study analysed the performance of 43 engineering students in a Statistics course. The students came from three programmes and different semesters. Mechanical engineering students scored the highest in all components; quiz, assignment, and test. Electrical and chemical engineering students had lower scores, especially in the test. Part 5 students performed the best overall. Part 8 and Part 9 students, mostly from chemical and electrical programmes, had lower test scores. This may be due to final-year workload or lower focus. Assignments gave better scores than tests. This may be because students had more time to complete them. Test scores were lower, possibly due to time limits or poor preparation. Programme and semester level may affect student performance. Educators can use this information to support weaker groups. Future studies should explore other factors such as learning methods, workload, and student motivation.

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THE INFLUENCE OF CONVERSATIONAL AI ON STUDENT LEARNING BEHAVIORS AND OUTCOMES

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ABSTRACT

The integration of Artificial Intelligence (AI) into education has introduced new opportunities and challenges in shaping the learning process. Among the most influential innovations is conversational AI, including tools such as ChatGPT, Google Gemini, and Bing Chat, which provide instant, interactive, and personalized support to students. This paper explores the dual impact of AI on education, with particular focus on student learning behaviors. AI enhances motivation, promotes self-directed learning, and enables learners to access information and feedback in real time. These tools also support adaptive learning environments that adjust to individual progress, fostering autonomy and engagement. On the other hand, the growing reliance on AI also presents significant concerns. Students may misuse AI to complete tasks dishonestly, leading to academic integrity issues and weakening essential skills such as critical thinking, problem solving, and creativity. Furthermore, the possibility of inaccurate or misleading AI generated content may negatively affect students' understanding and decision making. This paper highlights the importance of ethical implementation, digital literacy, and the redesign of assessment methods to ensure that AI supports rather than undermines meaningful learning. Ultimately, the impact of AI on student learning behaviors depends on how responsibly and strategically it is integrated into educational contexts.

Keywords: Artificial Intelligence (AI), ChatGPT, OpenAI, Chatbot, learning behaviors

Introduction

Artificial Intelligence (AI) refers to the ability of a computer system or machine to perform tasks that typically require human intelligence. These tasks include learning, reasoning, problem solving, understanding language, recognizing patterns, and making decisions. The rapid development of AI has transformed a number of sectors, including education. AI technologies are increasingly integrated into learning environments, offering innovative ways to support students and teachers. Among these technologies, conversational AI, such as chatbots, has gained significant attention for its potential to enhance the overall learning experience. Tools like ChatGPT by OpenAI, Google Gemini (formerly Bard), and Bing Chat by Microsoft are now widely used by students for instant feedback, explanations, and personalized guidance. (Kasneci et al., 2023) noted that AI chatbots provide a free judgment environment where students can ask questions without hesitation, improving motivation and engagement. Similarly,(Schmid et al., 2024)found that chatbot assisted learning can lead to improved knowledge retention and academic performance due to the instant feedback and adaptive responses these systems offer. Besides that, AI conversional provide a real time responses, enabling students to learn at their own pace and seek assistance outside traditional classroom hours.

Artificial intelligence integration, specifically ChatGPT, is becoming increasingly popular in educational contexts (Bettayeb et al., 2024). ChatGPT, was launched in November 2022 and is capable of generating cohesive and informative human like responses to user input (Lo, 2023). ChatGPT is a powerful tool that has the potential to transform the way we interact with technology, enabling more natural and intuitive communication between humans and machines (Božić & Poola, n.d.). This powerful language model fosters dynamic and evolving learning environments by transcending traditional search engine constraints.

Despite its success, ChatGPT has introduced new challenges and threats to education. With its ability to provide specific answers to user questions, it can be used to complete written assignments and examinations on behalf of students, leading to concerns about AI-assisted cheating (Lo, 2023). While (Sok & Heng, 2023) also stated that there are risks related to academic integrity issues, unfair learning assessment, inaccurate information, and over-reliance on AI. In some instances, the information generated by ChatGPT may exhibit factual errors. While ChatGPT is designed to provide accurate and relevant information, it is not infallible and may generate inaccurate responses(Pokkakillath & Suleri, 2023).

Positive impact of AI on educations and students learning behaviors

According to (Pokkakillath & Suleri, 2023), AI technologies contribute positively to education through the following areas as shown in Table 1:

Table 1: Positive Impacts of AI

No	Aspect	Descriptions
1	Adaptive Learning	This pedagogical approach utilizes AI technology to dynamically adapt the content and difficulty level of a learning experience in response to a student's progress or performance.
2	Personalised recommendation/individual instructions/early identification of learning needs	Using AI technology, the school can analyze students' learning styles and interests to provide recommendations for content and resources.
3	Grading and assessment	In 1990, an intelligent essay assessor (IEA) was developed to evaluate the quality of essays written by students and provide feedback on their writing

		skills. Over the years, AI has been used in grading/marking and assessment, such as scoring objective questions, multiple choice tests, essay evaluation and others.
4	Creating assessment	It provides an innovative and flexible approach to generating assessments, offering real-time formative feedback. This process involves developing open-ended question prompts that align with the learning outcomes, reducing the workload and time required for teachers to prepare quizzes and tests. Additionally, ChatGPT can assist in brainstorming ideas for research projects, facilitating idea development and gathering.
5	Virtual personal tutoring	This offers students round the clock feedback and support for tasks, including mathematics problem-solving. However, clear guidelines from educational institutions are necessary to ensure students are well-informed about efficient and responsible utilization of these resources.
6	Enhanced pedagogical practice	This assists educator to design interactive classroom activities and develop comprehensive lesson plans, presentations and teaching materials

Negative impact of AI on educations and students learning behaviors

Table 2 shows the summary of the negative impacts of AI especially ChatGPT on education which specifically focusing on student learning, academic integrity, and teaching practices:

Table 2: Negative Impacts of AI

Aspect	**Impact**	**Explanation**
Academic Integrity	Plagiarism & cheating	Students may submit AI generated work as their own, especially in online exams or assignments.
Critical Thinking	Decline in analytical and original thinking	Overuse of AI can discourage students from thinking deeply or solving problems independently.
Creativity	Reduced creativity and ideation	Students rely on AI for content generation, which may limit their own ability to generate new or original ideas.

Factual Accuracy	Inaccurate or misleading information	ChatGPT may generate incorrect or fabricated content that sounds believable but lacks factual reliability.
Overreliance on AI	Passive learning habits	Students may become dependent on AI tools, bypassing personal effort, exploration, or study.
Assessment Validity	Challenges in evaluating genuine student work	AI-generated text can be difficult to distinguish from original work, affecting fairness and reliability of grading.
Bias & Ethics	Ethical concerns and AI bias	AI may reflect bias in training data; unclear ownership and usage responsibility raise concerns.
Educational Practices	Need to revise assessment methods	Traditional assessments may be ineffective; push for oral exams or handwritten tasks is increasing.
Misuse by Students	Use of AI without understanding its limitations	Students may trust AI blindly or misuse it for academic shortcuts, leading to shallow or incorrect learning.

Conclusion

As a conclusion, Artificial Intelligence (AI), particularly in the form of conversational AI like ChatGPT, has emerged as a transformative tool in education. It offers significant benefits by enhancing personalized learning, improving student engagement, and supporting teachers in instructional design and assessment. These tools have directly influenced student learning behaviors, encouraging self-directed learning, promoting curiosity, and increasing confidence in seeking knowledge independently. AI enables students to access support anytime, helping them manage their learning pace and improve academic outcomes. However, these advantages are accompanied by notable challenges. Overreliance on AI tools can reduce students' motivation to think critically, reflect deeply, or develop original ideas. This may lead to passive learning habits, where students depend on AI generated answers rather than actively constructing knowledge. Issues related to academic dishonesty, misinformation, and ethical concerns further complicate the integration of AI into education. As AI becomes more embedded in educational settings, it is essential for educators, institutions, and policymakers to establish clear guidelines, promote ethical usage, and redesign assessment strategies that prioritize student accountability, critical thinking, and creativity. The future of education in the AI era will depend on a balanced approach that embraces technological innovation while safeguarding the development of meaningful and responsible learning behaviors.

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NAVIGATING THE CHALLENGES OF TECHNOLOGY IN MATHEMATICS EDUCATION: A COMPARATIVE ANALYSIS WITH TRADITIONAL METHODS

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ABSTRACT

The introduction of technology in mathematics education has transformed instructional methods, providing new methods to improve student engagement and conceptual comprehension. Although these improvements have been made, using technology to teach maths comes with several teaching and practical issues. This paper critically examines the core challenges associated with using educational technology in mathematics classrooms, comparing them with the enduring advantages of traditional teaching methods. Based on recent research, this study acknowledges the advantages of technological affordances while highlighting problems including digital inequality, cognitive overload, and the loss of foundational abilities. Conversely, traditional methods continue to offer structured, process-oriented learning environments that support foundational skill development. This comparative analysis suggests the necessity of a balanced, pedagogically informed integration of both modalities for effective mathematics instruction

Keywords: technology, challenges, traditional, learning, mathematics

Introduction

The global expansion of educational technology has had a significant impact on mathematics education at all levels. Digital technologies present a variety of tools and platforms that enable new and more effective approaches to math learning, which may have previously been difficult to implement with traditional methods (Cirneanu, 2024). According to Moura (2023), technologies are allied with education in enhancing the quality of teaching and fostering the individual development of students, opening new perspectives for learning. From primary to tertiary instruction, educators increasingly rely on digital platforms, interactive simulations, and automated assessment tools to deliver content, facilitate practice, and evaluate learning. Tools such as GeoGebra, Desmos, and computer algebra systems (CAS) offer new avenues for visualizing abstract mathematical concepts and adapting instruction to individual learner needs. Students no longer rely just on text or figures written on a blackboard but may see realistic visualizations of how changes in variables can affect a graph, how geometric shapes alter as parameters change, or how a formula works in real time. However, despite the evident potential of these tools, their use is not without limitations.

Many educators report challenges in implementation, ranging from technical difficulties and lack of training to concerns about diminished student engagement with fundamental processes of reasoning and computation. Traditional methods of mathematics instruction—characterized by direct instruction, textbook-based exercises, and manual problem-solving—continue to hold pedagogical value, particularly for developing procedural fluency and critical thinking. Technological tools play an important role in solving and creating problems in Mathematics, providing students with a broader and more interactive learning experience. According to Lima and Rocha (2022), these tools offer a differentiated approach to teaching and learning, enabling dynamic interaction between teachers and students. It's important to stress, though, that computers and other digital tools alone are not enough to break away from standard ways of teaching.

This paper explores the primary challenges of integrating technology into mathematics education and contrasts them with the pedagogical advantages of traditional instructional methods. The objective is to present a nuanced understanding of the implications of each approach, advocating for a balanced framework that leverages the strengths of both. Technical issues such as software glitches, hardware failures, and internet connectivity problems can disrupt the learning process when technology is used for teaching mathematics.

Literature Review

Technology provides a range of instruments for teaching mathematics, including online learning platforms, visual calculators, and dynamic geometry software like GeoGebra (e.g., Khan Academy), and interactive educational applications. This technology has the potential to transform the way mathematics is taught and learned, making it more visual, interactive, and engaging. However, the transition from traditional methods to technology-based approaches is not without challenges. Thus, by incorporating technology into mathematics education, educators can create more engaging and personalized learning experiences that promote critical thinking, problem-solving, and mathematical reasoning skills among students. In a traditional classroom, teachers frequently face the issue of balancing the demands of students with varying skill levels. Technology enables more flexible customization, allowing each student to work on material that matches their level of knowledge without feeling rushed or left behind. (Denga, 2024). This change occurred with pedagogical shifts in schools and universities that encouraged active learning, engagement, and flexible access to education (Engelbrecht & Borba, 2024).

With a focus on a specific subject, several academics reviewed the use of technology in mathematics instruction in a previous study (Hwang et al., 2023) while others concentrate on a particular type of digital instrument, such as Augmented Reality (AR) (Fernandes et al., 2023; Hidayat & Wardat, 2023) and GeoGebra (Yohannes & Chen, 2021; Muslim et al., 2023). Consequently, the application of technology in mathematics education continues to provoke significant enquiries over the appropriate sorts of technology for certain topics and their overall efficacy (Engelbrecht & Borba, 2023). A substantial body of research supports the use of technology as a tool for enhancing mathematics instruction. Digital tools have been found to improve student motivation, provide visual representations of abstract concepts, and allow for differentiated learning (Pierce & Stacey, 2010). Dynamic geometry software allows students to interactively explore geometric transformations, whereas graphing calculators and computer algebra systems facilitate comprehension of functions and equations by offering immediate graphical feedback. However, these technologies' effectiveness greatly depends on how well they are incorporated into instructional frameworks. Without proper planning, the use of technology can become shallow, resulting to fractured understanding and decreased engagement with mathematical thinking (Drijvers, 2013). Additionally, research has shown that students may become dependent on technology, omitting crucial steps in problem-solving techniques and thereby impairing their procedural fluency (Roschelle et al., 2010).

Challenges of implementation

The implementation of technology in education faces several challenges, including inadequate infrastructure, lack of continuous teacher training, and unequal access to technological resources. Several critical challenges hinder the optimal integration of technology in mathematics education.

Challenge	Description	Impact/Reference
Digital Inequity	Unequal access to reliable devices and internet connections across different areas and socioeconomic groups.	Many students in remote or underdeveloped regions lack adequate devices or reliable internet, hindering digital learning. (Caswanda, 2024).
Cognitive Overload	Difficulty for students, especially younger ones, to handle the demands of digital learning tools with multiple tasks and complex interface.	Younger students struggle with complex digital tools, harming their confidence, motivation, and learning outcomes.

Challenge	Description	Impact/Reference
Inadequate Educator Preparation	Many educators lack the pedagogical expertise and technical know-how to effectively incorporate digital tools into lessons.	Teachers need training to integrate technology effectively, learning to use digital tools, create materials, and track student progress (Akram, 2022).
Overreliance on Technology	Excessive use of digital technologies may damage students' deep conceptual knowledge.	Uncontrolled technology use distracts students with social media, reducing learning effectiveness (Sagabala, 2023).
Cost associated	Providing sufficient hardware, software, and stable internet for all students and teachers demands significant investment.	Effective educational technology use requires financial consideration and ensuring tech enhances, not replaces, core knowledge to transform math learning.

Advantages of Traditional Methods

Despite the increasing emphasis on digital learning environments, traditional methods of mathematics instruction continue to offer several significant pedagogical advantages.

Aspect of Traditional Education	Description	Benefit/Mechanism
Emphasis on Process-Oriented Learning	Manual computation and step-by-step problem solution.	Unlike computer programs, it fosters procedural fluency, critical thinking, and a deeper understanding of mathematical operations and logic
Cognitive Anchoring (Handwritten Work)	Enhanced retention and engagement accompanying handwritten work.	It activates memory and understanding more effectively than typing, improving long-term recall

Aspect of Traditional Education	Description	Benefit/Mechanism
		of abstract information (Mueller & Oppenheimer, 2014).
Structured Learning Environments	Reduced tolerant of distractions caused by digital technologies.	Allows students to concentrate more attentively on mathematical activities, improves time-on-task, and reduces their cognitive burden.
Quick and Flexible Education	Teachers use questions, discussions, and feedback to guide and adjust their teaching.	The scaffolding learning more effectively than computerised methods; particularly crucial in mathematics to answer misunderstandings immediately.

In sum, traditional instructional methods offer a stable and pedagogically rich foundation for mathematics education. Their strengths in fostering procedural fluency, enhancing cognitive engagement, and supporting responsive teaching remain highly relevant, particularly when integrated thoughtfully alongside technological innovations.

Conclusion

The use of digital technologies into mathematics education has tremendous promise for improving teaching and learning. The integration of these technologies leads to more interactive, personalised, and engaging learning opportunities for students. With technology, these concepts become more understandable because students can directly observe mathematical phenomena occurring, as well as test and explore their own ideas. However, using technology-based learning applications, students can receive immediate feedback while working on tasks or experiments (Xiaohong, 2024). In traditional learning, feedback is frequently provided after the task is completed, which may not be effective in directly addressing the student's confusion. In addition to enabling cause error correction, this gives students the chance to expand their knowledge by experimenting with different approaches or problem-solving techniques. As each student's needs are met, the learning process becomes more responsive and individualised.

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GOOD MANNERS (ADAB) BEFORE KNOWLEDGE: THE TRUE MARK OF EXCELLENCE

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ABSTRACT

This study looks at how being smart and having good manners (adab) are both important for students. Today, many students achieve high marks, but some still exhibit negative behavior such as rudeness and a lack of respect. This research aims to find out how students who excel academically but lack good manners often face challenges in communication, emotional regulation, and group work. The study shows that students should not only be intelligent in class but also possess strong character. A balance between knowledge and good behavior is essential to becoming a truly successful student in today's world. Additionally, this study emphasizes the importance of character education in schools, suggesting that academic excellence alone does not guarantee lifelong success. Students with strong adab are often more empathetic, responsible, and cooperative. These qualities help them build stronger relationships and contribute positively to their communities.

Keywords: adab, student character, academic excellence, discipline, emotional intelligence.

Introduction

In today's world, students are expected to succeed in school and get good grades. Many schools focus a lot on academic success. However, being smart is not the only thing that makes a student truly successful. Good manners, or "adab," are just as important. Adab means showing respect, being polite, and having good behavior. A student who is clever but not respectful can cause problems in class and in life. Teachers and parents have noticed that even smart students sometimes have trouble listening, helping others, or staying calm when things go wrong. This shows that intelligence must go hand in hand with good character.

This research wants to find out how important it is for students to be both smart and well-mannered. It also looks at the challenges teachers face when students are lacking in adab. The goal is to find ways to help students grow both in knowledge and in good values. Many recent studies show that building good character is just as important as getting good grades. Mawaddah et al. (2024) found that when schools run proper character education programs, students become more disciplined, responsible, and better at getting along with others. This also helps them do well in school. Other research shows that small activities like reading good stories in class or helping in the community can help students become better leaders and improve their confidence and behavior. However, the results can be different depending on the school and the students.

Rif'an (2025) found that in Islamic schools, teachers have an important role in teaching good values like honesty and respect. This works better if the school has a good environment, helpful resources, and support from parents. If these are missing, students might not learn the values well. Some studies from countries like Indonesia, Turkey, and Japan show that teaching adab (good manners and respect) in schools leads to better student attitudes and success in learning. Ramatni et al. (2023) added that schools need to mix moral lessons with regular subjects and teachers should be good role models. Other programs that combine religious learning (like *tahfiz*), science, and manners have helped students become more responsible, ethical, and good at thinking critically. These programs help students grow in all areas such as mind, heart, and behavior.

Shafie and Zulkifli (2024) explain that the Pedagogy of Hikmah builds well-rounded education by combining academic success with moral values, showing that true excellence cannot exist without adab. In the same way, Jaapar et al. (2023) show that Malay poetry like pantun and gurindam teaches values of good manners and morality, passing down cultural wisdom that supports the Islamic idea that behavior should come before knowledge.

The Importance of Adab in Life and Its Impact on Academic Performance

Adab cultivates discipline and personal responsibility

Students who practice good manners such as punctuality, classroom etiquette, and respect for rules tend to develop strong self-discipline. This discipline helps them complete assignments on time, attend classes regularly, and stay focused during lessons. A strong sense of responsibility directly contributes to better academic outcomes.

Adab nurtures respect for knowledge and teachers

Respecting teachers and the learning process is a key component of academic success. Students with proper adab are more open to feedback, willing to accept corrections, and more engaged in the classroom. A respectful attitude fosters a positive teacher-student relationship, which enhances the effectiveness of teaching and learning.

Adab improves collaboration and social interaction

Students who demonstrate good character are more likely to build positive relationships with peers. They know how to communicate politely, resolve conflicts peacefully, and work well in groups. These social skills are essential for group projects, discussions, and collaborative assignments, which are now a common part of modern education.

Adab reduces stress and supports emotional well-being

Well-mannered students tend to avoid unnecessary conflict and social pressure. This contributes to better emotional stability and mental health, allowing them to concentrate on their studies and face academic challenges calmly and confidently.

Adab instills noble values such as patience, sincerity, and perseverance

Values like patience and sincerity in the pursuit of knowledge are crucial for long-term academic success. Students with adab are less likely to give up when faced with failure. Instead, they are motivated to try again with genuine effort and a positive attitude, making their learning journey more meaningful and effective.

Examples of Good Manners (Adab) Students Should Practice Today

Respecting teachers

Students should always show respect to their teachers. This includes standing up when the teacher enters the class, greeting them politely, listening carefully during lessons, and not interrupting while they are speaking. A respectful student creates a better learning environment for everyone.

Speaking politely

Students must use kind and respectful words when talking to teachers, friends, and parents. They should avoid shouting, using bad language, or mocking others. Asking questions or giving opinions should be done respectfully, especially in class.

Being punctual

Coming to school and class on time shows discipline and responsibility. Submitting assignments before the deadline and preparing early for exams are also part of being punctual. It shows that the student values time—both theirs and others.

Keeping clean and neat

Students should wear clean and proper uniforms, keep their schoolbags tidy, and make sure their surroundings (like classrooms) are clean. Throwing rubbish in the bin and keeping the toilet clean are also part of this adab. Cleanliness reflects self-respect and care for the environment.

Being honest and trustworthy

Students must not cheat during exams or copy others' homework. They should complete their own tasks and keep promises made to teachers or group members. Honesty builds trust and being responsible with small tasks leads to bigger responsibilities in the future.

Being kind and respectful to classmates

Students should avoid bullying, teasing, or excluding others. They should help friends in need, share knowledge, and work well in group activities. This creates a positive, supportive, and safe learning space for everyone.

Praying and seeking blessings in learning

Students should begin and end their lessons with prayers, asking for knowledge that is useful and blessed. They should learn with good intentions not just for exams, but to become better people. Keeping a good relationship with God and others brings peace and success.

Table 1: Key Components of Good Manners (Adab) in Students

No.	Type of Adab	Description	Example Action
1	Adab with Teachers	Respecting and obeying teachers	Greeting teachers politely
2	Adab with Friends	Being honest and kind	Sharing, apologizing when wrong
3	Adab in Communication	Speaking with manners and listening well	Not interrupting, using kind words
4	Adab in Handling Emotions	Managing anger and disappointment	Staying calm during group work issues
5	Adab in Seeking Knowledge	Humility and sincerity when learning	Not boasting about grades

Table 1 highlights five essential types of adab that students should practice to become well-rounded individuals. These include adab with teachers, friends, communication, emotions, and in seeking knowledge. Each type of adab plays a significant role in shaping a student's character and behavior in both academic and social settings.

Adab with teachers is fundamental, as it reflects a student's respect towards authority and willingness to learn. Simple actions like greeting teachers politely show humility and discipline. Adab with friends focuses on honesty and kindness, which are key to forming healthy relationships and building trust among peers. Adab in communication teaches students to speak with respect and listen attentively, which helps avoid misunderstandings and fosters a positive learning environment. Adab in handling emotions is critical in helping students stay calm and think rationally during challenging situations, such as group conflicts or academic pressure. Lastly, adab in seeking knowledge encourages students to remain humble despite their achievements and to learn sincerely, not just for grades.

The table illustrates that good manners are not limited to behavior, but are deeply connected to emotional intelligence, interpersonal skills, and learning attitudes. When students consistently practice these forms of adab, they not only become respectful individuals but also create a positive school culture that supports both personal growth and academic success.

Conclusion

This study concludes that manners are more important than knowledge in producing truly excellent students. Intelligence alone cannot build trust, respect, or leadership. Without manners, knowledge may even become dangerous or destructive. A student with both knowledge and adab is a true asset to society. Schools and families must work together to prioritize character development, ensuring that future generations are not only smart but also kind, responsible, and respectful. Investing in adab is investing in the future of a dignified and ethical society.

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ANALISA PENCAPAIAN PELAJAR BAGI KURSUS STATISTIK BERDASARKAN FAKULTI DAN PENSYARAH MENGGUNAKAN ANOVA

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ABSTRACT

Kajian ini bertujuan untuk menilai perbezaan pencapaian akademik pelajar dalam kursus Statistik berdasarkan fakulti dan pensyarah yang mengajar. Reka bentuk kajian menggunakan pendekatan kuantitatif dengan kaedah Analisis Varians (ANOVA) satu hala bersama kesan blok, di mana pensyarah dikendalikan sebagai pemboleh ubah blok untuk mengawal variasi pengajaran. Sampel kajian terdiri daripada pelajar yang mengikuti kursus Statistik daripada tiga fakulti kejuruteraan di sebuah institusi pengajian tinggi awam. Data yang dikumpulkan terdiri daripada markah peperiksaan akhir pelajar dan dianalisis menggunakan perisian statistik bagi mengenal pasti sama ada terdapat perbezaan yang signifikan dalam pencapaian akademik pelajar antara fakulti serta antara pensyarah dalam setiap fakulti. Dapatan kajian menunjukkan bahawa terdapat perbezaan yang signifikan dalam pencapaian pelajar berdasarkan fakulti, dengan pelajar dari Fakulti Kejuruteraan Mekanikal mencatatkan prestasi yang lebih tinggi berbanding Fakulti Kejuruteraan Awam. Walau bagaimanapun, faktor pensyarah tidak menunjukkan kesan yang signifikan terhadap pencapaian pelajar. Kajian ini mencadangkan agar intervensi pengajaran difokuskan kepada fakulti tertentu bagi meningkatkan keberkesanan penguasaan pelajar dalam kursus Statistik.

Kata kunci: pencapaian akademik, Statistik, ANOVA satu hala, kesan blok, fakulti

Pengenalan

Pencapaian akademik pelajar sering dianggap sebagai petunjuk utama kepada keberkesanan proses pengajaran dan pembelajaran di institusi pengajian tinggi. Dalam sesetengah kursus seperti Statistik, pelajar daripada pelbagai program pengajian seperti Kejuruteraan Awam, Kejuruteraan Mekanikal dan Kejuruteraan Elektrik yang didaftarkan di bawah kursus yang sama, namun diajar secara berasingan oleh pensyarah yang berbeza. Kepelbagaian latar belakang pelajar berdasarkan fakulti, serta pendekatan pengajaran yang berbeza antara pensyarah, berpotensi mempengaruhi tahap pencapaian pelajar. Oleh itu, kajian ini dijalankan bagi menilai sama ada perbezaan ini memberi kesan yang signifikan terhadap pencapaian akademik pelajar dalam kursus Statistik menggunakan kaedah Analisis Varians (ANOVA).

Pencapaian akademik lazimnya diukur melalui penilaian berasaskan ujian, kuiz dan peperiksaan akhir. Harlen (2005) menyatakan bahawa pencapaian pelajar dipengaruhi oleh pelbagai faktor, termasuk kemahiran sedia ada, motivasi, strategi pembelajaran dan disiplin kendiri. Kpolovie et al. (2014) pula menekankan kepentingan sokongan keluarga, beban kerja kursus dan kemudahan pembelajaran sebagai antara faktor penyumbang. Dalam kajian terkini, Wang et al. (2024) menambah bahawa sokongan pensyarah turut mempengaruhi prestasi pelajar secara tidak langsung melalui keyakinan kendiri akademik dan emosi pembelajaran. Oleh itu, pemahaman terhadap pelbagai faktor ini penting bagi menyokong analisis prestasi pelajar dalam konteks pengajaran sebenar.

Latar belakang akademik pelajar yang berbeza, khususnya berdasarkan fakulti atau program pengajian, turut memainkan peranan dalam pencapaian kursus yang bersifat umum seperti Statistik. Pelajar daripada bidang Kejuruteraan Awam, Mekanikal dan Elektrik mempunyai pendedahan dan pengalaman yang berbeza dalam aplikasi kuantitatif dan matematik. Yusoff et al. (2017) menunjukkan bahawa perbezaan ini boleh mempengaruhi pemahaman pelajar terhadap konsep Statistik dan seterusnya prestasi mereka dalam kursus tersebut. Kajian oleh Liu et al. (2024) turut menyokong pandangan bahawa walaupun kandungan kursus adalah seragam, perbezaan dalam pendekatan pengajaran dan penilaian antara fakulti boleh menyumbang kepada variasi pencapaian pelajar. Oleh itu, adalah wajar untuk meneliti sama ada wujud perbezaan pencapaian berdasarkan fakulti, memandangkan latar belakang pembelajaran yang berbeza mungkin memberi kesan terhadap penguasaan kursus.

Selain itu, faktor pensyarah turut dikenalpasti sebagai antara unsur penting yang mempengaruhi hasil pembelajaran pelajar. Marsh (2007) menyatakan bahawa kualiti pengajaran pensyarah boleh mempengaruhi persepsi dan prestasi pelajar terhadap kursus yang diambil. Chingos dan West (2012) mendapati bahawa terdapat perbezaan signifikan dalam prestasi pelajar yang diajar oleh pensyarah berbeza untuk kursus yang sama. Kajian Zhang et al. (2024) pula menekankan bahawa strategi pengajaran yang berstruktur dan interaktif dapat meningkatkan penglibatan pelajar serta memperbaiki pencapaian akademik mereka. Malah, persepsi pelajar terhadap jangkaan pensyarah juga dilihat memberi kesan terhadap keterlibatan emosi dan tahap motivasi dalam kelas. Maka, kajian ini turut mempertimbangkan faktor pensyarah sebagai satu dimensi penting dalam menilai pencapaian pelajar, meskipun kandungan kursus Statistik yang diajar adalah seragam.

Metodologi

Populasi kajian terdiri daripada pelajar yang mengikuti kursus Statistik di sebuah institusi pengajian tinggi awam. Sampel kajian melibatkan pelajar daripada tiga fakulti berbeza dalam bidang kejuruteraan, iaitu Kejuruteraan Awam, Kejuruteraan Mekanikal, dan Kejuruteraan Elektrik. Setiap fakulti diwakili oleh dua hingga tiga orang pensyarah yang mengendalikan kumpulan kelas masing-masing dan keseluruhan pensyarah yang terlibat adalah seramai 6 orang. Pemilihan pelajar dilakukan secara rawak daripada kelas-kelas yang diajar oleh pensyarah tertentu, dengan anggaran sebanyak 75% daripada keseluruhan kes menggunakan perisian statistik SPSS. Pendekatan ini bertujuan untuk memperoleh sampel yang mewakili populasi dengan baik serta mengekalkan kebolehpercayaan dalam analisis statistik.

Kajian ini menggunakan pendekatan kuantitatif dengan reka bentuk eksperimen berasaskan perbandingan kumpulan bagi menilai perbezaan pencapaian akademik pelajar dalam kursus Statistik berdasarkan fakulti yang berbeza. Bagi tujuan ini, reka bentuk Analisis Varians (ANOVA) satu hala dengan rekabentuk blok telah digunakan, di mana fakulti bertindak sebagai faktor utama manakala pensyarah dimasukkan sebagai kesan blok. Pendekatan ini membolehkan penyelidik mengawal variasi yang mungkin disebabkan oleh perbezaan individu dalam pengajaran serta mengasingkan kesan utama fakulti daripada varians antara pensyarah, seterusnya meningkatkan ketepatan analisis.

Data yang diperoleh dianalisis menggunakan perisian statistik SPSS. Sebelum menjalankan analisis ANOVA, andaian homogeniti varians diuji menggunakan Ujian Levene, manakala andaian normaliti dianggap dipenuhi berdasarkan Teorem Had Pusat (Central Limit Theorem) memandangkan saiz sampel melebihi 30. Aras signifikan ditetapkan pada $\alpha = 0.05$ bagi menentukan kebermaknaan statistik.

Kajian ini menguji dua hipotesis utama seperti berikut:

Hipotesis 1

H_{01}: Tidak terdapat perbezaan yang signifikan dalam pencapaian akademik pelajar dalam kursus Statistik berdasarkan fakulti.

H_{11}: Terdapat perbezaan yang signifikan dalam pencapaian akademik pelajar dalam kursus Statistik berdasarkan fakulti.

Hipotesis 2

H_{02}: Tidak terdapat perbezaan yang signifikan dalam pencapaian akademik pelajar antara pensyarah (sebagai blok) yang mengajar.

H_{12}: Terdapat perbezaan yang signifikan dalam pencapaian akademik pelajar antara pensyarah (sebagai blok) yang mengajar.

Keputusan

Ujian Homogeniti Varians (Levene’s Test) Ujian Levene telah dijalankan terlebih dahulu untuk menguji andaian homogeniti varians. Berdasarkan Jadual 1, keputusan menunjukkan nilai $F = 0.692$, $p = 0.502$

(> 0.05), maka andaian homogeniti varians dipenuhi. Oleh itu, analisis ANOVA boleh diteruskan kerana andaian kesamaan varians dipenuhi.

Jadual 1 : Ujian homogeniti varians (Levene's Test)

Statistik	F	df1	df2	Sig.
Nilai	0.692	2	176	0.502

Seterusnya, analisis ANOVA iaitu Reka Bentuk Blok Ujian ANOVA dua hala telah dijalankan bagi mengkaji perbezaan skor markah berdasarkan faktor "Fakulti" (sebagai rawatan) dan "Pensyarah" (sebagai blok).

Jadual 2: Analisis ANOVA dua hala (reka bentuk blok)

Sumber	df	F	Sig.
Fakulti	2	4.343	0.014
Pensyarah	1	0.071	0.791
Model keseluruhan		2.897	0.037

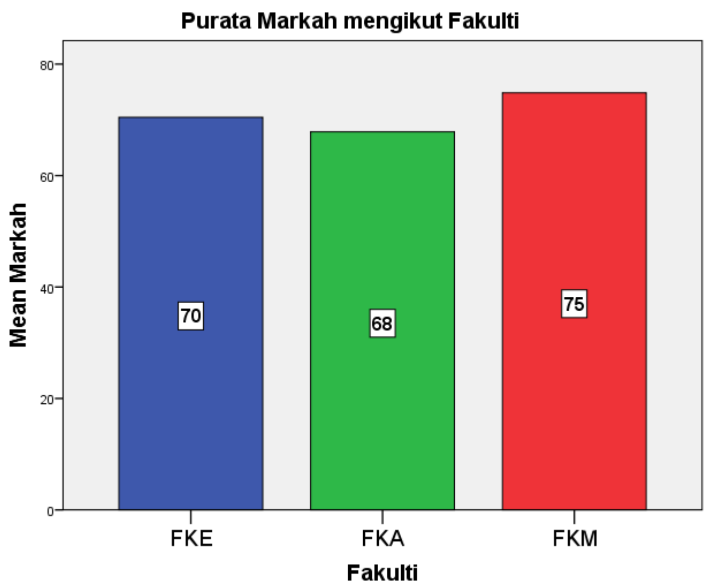
Hasil ujian ANOVA daripada Jadual 2 menunjukkan bahawa kesan utama bagi Fakulti adalah signifikan: $F(2,175) = 4.343$, $p = 0.014 < 0.05$, yang menunjukkan kesan kecil. Manakala kesan utama bagi Pensyarah adalah tidak signifikan: $F(1,175) = 0.071$, $p = 0.791 > 0.05$. Oleh itu dapat disimpulkan bahawa faktor 'Fakulti' memberikan pengaruh yang signifikan terhadap pencapaian markah pelajar, manakala faktor 'Pensyarah' sebagai blok tidak menunjukkan sebarang kesan yang bermakna.

Berdasarkan keputusan model keseluruhan ANOVA dua hala, didapati bahawa terdapat perbezaan yang signifikan terhadap markah pelajar berdasarkan faktor fakulti ($p = 0.014$). Sehubungan itu, ujian lanjutan Bonferroni telah dijalankan bagi mengenal pasti perbezaan yang wujud di antara kumpulan fakulti secara lebih terperinci. Hasil daripada Jadual 3 telah menunjukkan bahawa terdapat perbezaan signifikan antara FKA dan FKM dengan nilai $p = 0.012$ (< 0.05). Pelajar daripada FKA mencatatkan markah yang lebih rendah berbanding FKM dengan perbezaan min sebanyak -7.010. Manakala bagi kombinasi fakulti yang lain, tiada perbezaan yang signifikan direkodkan kerana nilai $p > 0.05$.

Jadual 3: Perbandingan Pasangan (Bonferroni)

Perbandingan	Beza Min	Nilai p
FKE vs FKA	1.950	1.000
FKE vs FKM	-5.060	0.439
FKA vs FKM	-7.010	0.012

Visualisasi Graf pada Rajah 1 menunjukkan purata markah mengikut fakulti. Didapati bahawa Fakulti FKM mencatatkan purata tertinggi iaitu 75 markah manakala FKA paling rendah iaitu 68 markah. Purata markah bagi ketiga-tiga fakulti ini tidak la begitu ketara dan Analisis lanjut menggunakan Bonferroni juga telah menunjukkan bahawa hanya terdapat perbezaan signifikan antara Fakulti FKM dan FKA ($p = 0.012$), manakala perbezaan antara fakulti lain tidak signifikan ($p > 0.05$). Ini mencadangkan bahawa pelajar FKM secara purata memperoleh markah lebih tinggi berbanding pelajar FKA.



Rajah 1 : Purata Markah mengikut Fakulti

Secara keseluruhan, keputusan kajian ini menunjukkan bahawa faktor fakulti memainkan peranan dalam mempengaruhi prestasi pelajar dalam kursus Statistik. Walaupun pensyarah tidak menunjukkan kesan signifikan, dapatan ini boleh membuka ruang kepada penyelidikan lanjutan untuk mengenal pasti faktor lain seperti kaedah pengajaran, latar belakang pelajar atau motivasi pembelajaran yang mungkin menyumbang kepada perbezaan pencapaian akademik.

Perbincangan

Dapatan kajian menunjukkan bahawa terdapat perbezaan yang signifikan dalam pencapaian pelajar berdasarkan fakulti. Pelajar dari Fakulti Kejuruteraan Mekanikal mencatatkan markah yang lebih tinggi berbanding pelajar dari Fakulti Kejuruteraan Awam. Penemuan ini menyokong kajian Yusoff et al. (2017) dan Liu et al. (2024) yang menyatakan bahawa latar belakang akademik dan bidang pengkhususan pelajar boleh mempengaruhi cara mereka memahami serta mengaplikasikan konsep statistik. Perbezaan ini mungkin berpunca daripada pendedahan awal terhadap mata pelajaran berkaitan matematik, struktur kurikulum, atau budaya pembelajaran dalam fakulti masing-masing. Oleh itu, ia mencerminkan keperluan untuk menyemak semula kesesuaian pendekatan pengajaran Statistik antara fakulti, agar lebih sejajar dengan latar belakang dan keperluan pelajar.

Sebaliknya, keputusan menunjukkan bahawa faktor pensyarah tidak memberikan kesan yang signifikan terhadap pencapaian pelajar. Ini bercanggah dengan beberapa kajian terdahulu seperti yang dikemukakan oleh Chingos dan West (2012) serta Zhang et al. (2024) yang menekankan bahawa gaya pengajaran dan strategi pensyarah boleh memberi kesan terhadap prestasi pelajar. Kemungkinan besar, pensyarah yang terlibat dalam kajian ini telah menggunakan pendekatan pengajaran yang hampir seragam, memandangkan kandungan kursus yang sama dan garis panduan pengajaran yang ditetapkan secara institusi. Ini menunjukkan bahawa perbezaan prestasi pelajar lebih berkait rapat dengan latar belakang fakulti berbanding gaya pengajaran individu pensyarah.

Batasan Kajian

Walaupun kajian ini memberikan gambaran yang berguna tentang hubungan antara fakulti, pensyarah, dan prestasi pelajar dalam kursus Statistik, terdapat beberapa batasan yang perlu diambil kira:

1. Skop kajian terhad kepada satu institusi sahaja dan hanya melibatkan satu kursus, iaitu Statistik, yang mengehadkan keupayaan untuk membuat generalisasi kepada populasi pelajar yang lebih luas.

2. Saiz sampel yang tidak seimbang antara kumpulan pelajar bagi setiap fakulti boleh mempengaruhi kekuatan statistik serta sensitiviti ujian ANOVA yang dijalankan.

3. Kajian ini hanya meneliti faktor fakulti dan pensyarah, tanpa mengambil kira faktor luaran seperti motivasi pelajar, minat terhadap subjek, kemahiran asas matematik, atau penggunaan sumber pembelajaran tambahan yang juga mungkin mempengaruhi pencapaian pelajar.

Kesimpulan

Secara keseluruhannya, kajian ini mendapati bahawa pencapaian akademik pelajar dalam kursus Statistik berbeza secara signifikan mengikut fakulti, manakala faktor pensyarah tidak memberikan perbezaan yang signifikan. Penemuan ini menekankan bahawa latar belakang akademik dan kontekstual pelajar berdasarkan fakulti merupakan faktor penting yang perlu diberi perhatian dalam merancang strategi pengajaran. Sehubungan itu, disarankan agar intervensi pengajaran atau pendekatan sokongan akademik difokuskan kepada fakulti yang mencatatkan pencapaian yang lebih rendah, agar jurang prestasi antara fakulti dapat dikurangkan. Kajian lanjutan boleh dijalankan bagi meneliti faktor-faktor lain seperti strategi pembelajaran pelajar, beban kerja kursus, atau tahap motivasi yang mungkin turut mempengaruhi pencapaian dalam kursus Statistik.

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BEYOND CRONBACH'S ALPHA: RETHINKING RELIABILITY ANALYSIS IN THE AGE OF DIGITAL LEARNING

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ABSTRACT

Cronbach's alpha has been widely used to measure internal consistency in educational research due to its simplicity and ease of interpretation. However, its assumptions, such as tau equivalence, unidimensionality, and equal item contribution, are often violated in modern digital learning environments. This paper examines the limitations of Cronbach's alpha and presents alternative approaches that better suit technology enhanced assessments, namely McDonald's omega, Generalizability Theory, and Item Response Theory. A practical framework is proposed to guide the selection of reliability methods based on assessment characteristics. Examples from quizzes, reflective writing, and gamified simulations illustrate how these methods address specific psychometric challenges in digital contexts. The study shows that aligning reliability techniques with assessment design improves measurement accuracy, supports adaptive feedback, and enhances transparency in reporting. It concludes that adopting modern reliability approaches and investing in methodological training are essential for creating fair and valid digital assessment practices in education.

Keywords: Cronbach's alpha, McDonald's omega, Generalizability Theory, Item Response Theory, Digital learning assessment

Introduction

Reliability testing has long played a foundational role in educational research, underpinning the psychometric integrity of instruments used to assess learning outcomes, cognitive abilities, and affective constructs. Central to these efforts is the need to determine the consistency and precision of measurement tools, ensuring that observed scores reliably reflect the constructs they are intended to capture. Among the many indices developed to assess internal consistency, Cronbach's alpha (α) remains the most widely adopted. Since its introduction, α has become the de facto standard in education and psychology for estimating the reliability of scales composed of multiple items, particularly Likert-type survey instruments and standardized assessments.

Cronbach's alpha owes its popularity to its simplicity, ease of computation, and interpretability. However, over time, extensive theoretical and empirical scrutiny has revealed significant limitations in its assumptions and applicability. A presumes tau-equivalence, one-dimensionality, and uncorrelated errors across items conditions rarely met in real-world educational contexts (Zinbarg, Revelle, Yovel, & Li, 2005; Dunn, Baguley, & Brunsden, 2014). While researchers often rely on α due to convention or software defaults, its misuse can lead to misestimate reliability coefficients and misinformed conclusions about the quality of measurement instruments.

These concerns become even more pronounced in the context of digital learning environments. The rise of e-learning platforms, interactive simulations, gamified assessments, and complex data-driven learning analytics introduces new challenges for traditional reliability frameworks. Digital assessments often incorporate heterogeneous item types (e.g., video-based prompts, open-ended reflections, embedded quizzes), platform-dependent interactivity, and dynamic feedback mechanisms. Such features inherently violate key assumptions of α, calling into question its suitability for evaluating measurement precision in contemporary settings (Liu, Pek, & Maydeu-Olivares, 2024). As educational assessment evolves toward more diverse, adaptive, and data-rich formats, there is a pressing need to re-examine classical reliability approaches and explore alternatives better suited for the digital age.

This article explores the theoretical and practical limitations of Cronbach's alpha and evaluates more robust alternatives that better align with the evolving nature of digital learning environments. It aims to critically evaluate the continued reliance on Cronbach's alpha in educational research, particularly in the context of digital learning, and to propose more appropriate alternatives grounded in recent advancements in psychometric theory. Drawing upon recent literature, including comparative analyses of alpha and omega coefficients (Orcan, Celik, & Gungor, 2023), item response theory (Wang & Bao, 2010), and generalizability theory frameworks, this paper offers a structured synthesis of current reliability approaches and their applicability to various digital learning scenarios.

The article contributes by advancing a practical framework for selecting and applying reliability techniques tailored to specific digital data types, thereby enhancing the methodological robustness of assessment practices in modern educational contexts.

Literature Review

In the evolving landscape of digital learning, the reliability of assessment tools and measurement instruments has become a critical concern. The shift toward adaptive technologies, multimedia-rich content, and artificial intelligence in education has transformed how learning is delivered and assessed.

However, these innovations also challenge the adequacy of traditional reliability metrics, which were developed for static, unidimensional assessment formats. As digital learning environments become more complex, there is a growing need to reconsider the tools used to evaluate the consistency and dependability of educational measurements. This literature review critically examines both traditional and emerging approaches to reliability analysis, highlighting the limitations of legacy methods such as Cronbach's alpha, and exploring advanced alternatives better suited to the digital age.

Traditional Reliability Measures and Their Limitations

Cronbach's alpha remains one of the most widely used statistics for evaluating the internal consistency of measurement instruments, especially in educational, psychological, and biomedical research (Taber, 2018; Kotian et al., 2022). It provides an estimate of how closely related items in a scale are, serving as a proxy for reliability. Despite its widespread application, several researchers have highlighted critical limitations that question its continued relevance in increasingly complex and dynamic research contexts. A primary limitation of Cronbach's alpha is its reliance on the assumptions of tau-equivalence and unidimensionality conditions that are often violated in real-world applications (Sijtsma, 2009).

Furthermore, alpha is highly sensitive to the distribution of items, with skewed or non-normal data producing misleading estimates (Christmann, 2006). Its inability to account for the internal structure of multidimensional constructs also makes it inadequate for modern digital learning environments where assessments are diverse and interactive (Kumar,2024). Moreover, Cronbach's alpha is frequently misinterpreted. Researchers often over-rely on it as the sole indicator of reliability, overlooking more appropriate or nuanced alternatives. This reliance can compromise the validity of research findings, particularly in digital education, where traditional test characteristics may not apply. For instance, static assessments fail to capture the dynamic nature of sensor-based, AI-driven, or adaptive learning systems.

Additionally, traditional reliability measures such as test-retest or split-half methods do not adequately address the complexity of big data, machine learning, and real-time assessments in digital platforms. As Eagan (2020) and Rosli(2021) state, conventional coding reliability approaches in educational analysis can produce high Type I error rates, underscoring the need for more sophisticated and adaptive techniques.

Emerging and Alternative Approaches to Reliability

Given the pressing need for more robust reliability metrics, a range of emerging methods has been proposed to address the shortcomings of traditional approaches. These methods better align with the evolving demands of digital learning environments.

(1) McDonald's Omega (ω)

McDonald's Omega (ω) has gained traction as a superior alternative to Cronbach's alpha. Unlike alpha, Omega does not assume tau-equivalence and is derived from factor analytic models that allow for congeneric measures items that assess the same construct but with varying factor loadings and error variances (Hancock, 2020). This makes ω more flexible and applicable to a wider range of data sets.

Simulation studies have shown that while α tends to slightly underestimate reliability, ω provides a more accurate estimate, especially in large samples (Malkewitz,2023). Omega offers a more accurate estimate of the proportion of score variance attributable to the common factor, making it particularly useful in settings where item variances differ. ω generally performs better than α in handling missing data, providing more consistent reliability estimates (Malkewitz,2023). Its applicability in non-uniform item structures, common in multimedia and gamified assessments that makes it ideal for digital learning environments (Hancock & An, 2020). ω has been successfully applied in diverse fields, from psychological assessments to educational measurements, demonstrating its versatility and robustness (Yupari,2023 ; Wang, 2024)

(2) Generalizability Theory (G-Theory)

Generalizability Theory provides a powerful framework for identifying and quantifying multiple sources of measurement error. G-theory assumes that any measurement situation has multiple sources of variation and error. Analysis of variance (ANOVA) methods is used to disentangle these sources, providing a more detailed understanding of measurement error compared to classical test theory (Vispoel, 2025). It extends classical test theory by considering facets such as raters, items, tasks, occasions, and even digital platforms. This is particularly relevant for digital assessments involving peer evaluations, interactive media, or multi-platform delivery.

G-Theory enables researchers to design assessments that minimize error and optimize reliability across conditions. According to Vispoel (2025), G-theory supports both univariate and multivariate designs, allowing researchers to assess score consistency and measurement error at different levels of score aggregation. Its application across different fields demonstrates its versatility and effectiveness in enhancing the reliability and validity of measurement (Clayson,2021).

(3) Item Response Theory (IRT) – Based Reliability

Item Response Theory (IRT)-based reliability is a modern, model-based approach to measuring the precision and consistency of a test or scale, especially when items vary in difficulty, discrimination, and format. It provides item-level metrics such as difficulty and discrimination, allowing researchers to estimate reliability across different levels of ability or score ranges (Embretson & Reise, 2000). This is especially useful in adaptive digital testing, where each learner may encounter a different subset of items.

IRT-based reliability goes beyond static estimates, capturing measurement precision tailored to individual learner profiles. IRT provides more precise reliability estimates by considering the properties of individual items and their interaction with the latent trait being measured (Milanzi,2015). IRT helps in developing and validating instruments for assessing psychological construct and health-related quality of life (Cui,2025)

Rethinking Reliability Assessment in the Digital

The emergence of advanced technologies such as machine learning and artificial intelligence has redefined the methodologies used in reliability assessment. These innovations have enabled more dynamic, adaptive, and responsive forms of measurement, allowing reliability to be evaluated in real time with high precision and minimal human intervention (Teixeira, 2024). Digital learning platforms are now capable of automatically adapting to shifting learner behaviours, data patterns, and system parameters—features essential for personalized and adaptive education. Moreover, adaptive learning systems employ intelligent algorithms to tailor learning content and strategies according to individual student behaviours and characteristics (Cai, 2024).

Modern digital environments also support sophisticated tools for calculating, simulating, and visualizing advanced reliability coefficients beyond traditional static indices. Learning management systems like Moodle and Blackboard offer integrated analytic capabilities that not only streamline data collection but also improve the efficiency and transparency of reliability estimation, contributing to scalable and sustainable educational practices (Gavrus, 2025).

Despite these advancements, traditional reliability approaches such as test-retest and alternate-form methods still hold relevance, particularly in evaluating the temporal stability of assessments. However, their application must be reconsidered within the context of modern, technology-enhanced learning. For instance, when assessing stability in an adaptive learning system, test-retest procedures must account for fluctuating item exposure, personalized content sequencing, and diverse learner interaction pathways. As suggested by Wyse (2021), a retest interval of just over three weeks strikes a balance between preserving reliability and accommodating natural learner development, making it a useful guideline even in digital contexts.

Challenges in Digital Learning Contexts

The evolution of digital learning environments has redefined the structure and delivery of educational assessments. As education shifts further into virtual and hybrid spaces, the challenges associated with measuring reliability through traditional psychometric tools, such as Cronbach's alpha, become increasingly evident. The digital learning context introduces a series of complexities that directly challenge the assumptions and limitations of conventional reliability analysis.

Variety of Assessment Types

Unlike traditional classroom-based assessments, digital learning integrates a wide spectrum of assessment formats including e-quizzes, simulations, reflective discussion forums, and gamified tasks. These modalities are often designed to assess a range of competencies cognitive, metacognitive, affective, and even social engagement using diverse approaches.

This heterogeneity in format disrupts the uniformity typically required by classical test theory (CTT), where reliability measures such as Cronbach's alpha assume homogeneity in item structure and function. When items vary significantly in form and cognitive demand, interpreting internal consistency becomes problematic, leading to misleading or oversimplified reliability estimates. Green (2015) stated that, when items are multidimensional, measures like Cronbach's alpha can yield high but misleading reliability coefficients

Use of Non-Uniform Items

In digital learning, items are not limited to traditional multiple-choice or Likert-type scales. Assessments frequently involve multimedia elements (e.g., video or audio prompts), drag-and-drop interfaces, or open-ended written reflections. These non-uniform item types carry different response structures, scoring schemes, and interaction modalities. As a result, assumptions such as equal item contribution and linearity, which are central to Cronbach's alpha, are violated.

Open-ended responses, for instance, may be scored subjectively or via AI-based rubrics, which introduces another layer of variability. The inclusion of multimedia in assessments can influence response accuracy and perceived difficulty, a phenomenon known as the Multimedia Effect in Testing (Arts et al., 2024). This diversity in item structure calls for more nuanced reliability approaches that can handle multidimensionality and heterogeneity within digital instruments.

Dependence on Platforms, Algorithms, and Digital Data Analytics

Digital assessments rely heavily on underlying platforms and algorithms that govern content delivery, data logging, adaptive testing, and scoring. While these systems enhance personalization and interactivity, they also introduce new sources of error variance. For example, a platform's recommendation algorithm may expose learners to different item sets based on prior responses, creating inconsistencies in test experience across participants.

Similarly, platform-based analytics used for formative feedback may confound the measurement process if the feedback loop affects subsequent item responses. These platform-dependent variances are not accounted for by traditional reliability coefficients, which assume a static and uniform assessment experience.

Difficulty Maintaining Assumptions Like Equal Item Contribution

Cronbach's alpha relies on the assumption that all items in a scale contribute equally to the latent construct being measured. In digital learning, however, this assumption is difficult to uphold. Digital learning environments often involve a variety of activities and assessments, such as synchronous and asynchronous sessions, interactive activities, and digital resources, which may not equally contribute to the overall construct being measured (Fuster,2025). For example, in a gamified task, certain levels or scenarios may have greater impact on learner engagement or performance than others.

Similarly, in a reflective discussion forum, some prompts may elicit richer responses than others, depending on the learner's context or prior knowledge. This unequal item contribution undermines the conceptual foundation of internal consistency and calls for alternative reliability indices that can accommodate hierarchical or weighted item structures.

Alternative Reliability Analysis Methods

Considering the limitations associated with Cronbach's alpha, particularly in settings that violate assumptions of tau-equivalence and one-dimensionality, several alternative methods have emerged as more theoretically sound and empirically appropriate for assessing reliability in modern digital learning environments. These alternatives namely McDonald's omega, Generalizability Theory (G-Theory), and Item Response Theory (IRT) provide greater flexibility in handling multidimensional constructs, heterogeneous item formats, and complex data sources, which are increasingly prevalent in digital educational assessments.

Omega Coefficient

McDonald's omega (ω) has gained prominence as a more robust measure of internal consistency, especially in scales where items exhibit varying factor loadings or multidimensional structure. Unlike α, which assumes equal item contributions (tau-equivalence), ω accounts for the actual loadings of each item on a latent factor, thereby providing a more accurate estimate of true score variance (Zinbarg et al., 2005; Dunn et al., 2014). This makes ω particularly suitable for digital learning instruments, such as multimedia-based surveys or performance tasks, where item characteristics often differ in complexity and cognitive demand. Simulation studies by Orcan, Celik, and Gungor (2023) further demonstrate that ω yields more stable reliability estimates under conditions of low item homogeneity or limited sample size, both of which are common in digital pilot evaluations. Nevertheless, ω still relies on a factor analytic model and assumes correct model specification; as such, its performance is sensitive to mis-specified factor structures, which may occur in exploratory assessments with minimal theoretical underpinning.

Generalizability Theory (G-Theory)

Generalizability Theory extends classical test theory by modelling multiple sources of measurement error simultaneously. Unlike α or ω, which yield a single reliability index, G-Theory decomposes variance into multiple facets such as items, raters, tasks, or occasions enabling researchers to estimate generalizability coefficients across complex designs. This approach is particularly beneficial in digital contexts where assessments often involve multifaceted interactions, such as combinations of auto-graded quizzes, peer-assessed discussions, and reflective journal entries. For example, Liu, Pek, and

Maydeu-Olivares (2024) highlighted the ability of G-Theory to capture contextual variance arising from different modes of item delivery, such as synchronous versus asynchronous digital formats. While G-Theory provides a highly nuanced picture of score dependability, it requires larger sample sizes and carefully structured study designs to estimate variance components accurately, which may pose practical constraints in small-scale classroom settings.

Item Response Theory (IRT)

Item Response Theory offers an entirely different paradigm by modelling the probability of item responses as a function of underlying latent traits. Its flexibility in addressing item characteristics such as discrimination, difficulty, and guessing makes it particularly well-suited for adaptive digital assessments and log-based evaluations. In adaptive environments, IRT models especially the 2PL and 3PL models enable real-time tailoring of items based on learner performance, enhancing both engagement and measurement precision (Wang & Bao, 2010). Additionally, IRT has been employed to model user interaction patterns via clickstream data, capturing response times, navigation paths, and keystroke dynamics as behavioural indicators of cognitive processes. However, IRT-based reliability coefficients require sophisticated estimation procedures and large item pools with pre-calibrated parameters, which may not always be feasible in emerging educational technology applications or low-resource environments.

Collectively, these methods represent a methodological shift toward more context-sensitive and theoretically grounded approaches to reliability assessment in education. Each offers distinct advantages depending on the nature of the instrument and digital data environment. Omega is suitable for multidimensional constructs with variable item loadings, G-Theory excels in multifaceted assessment designs, and IRT provides precision and adaptability in dynamic testing contexts. However, none are universally optimal, and each requires specific assumptions, data structures, and technical expertise. Accordingly, the selection of reliability methods must be informed not only by statistical considerations but also by the epistemological and practical demands of digital education.

Proposed Practical Framework

This article proposes a practical framework to guide the selection of appropriate reliability analysis methods for digital learning assessments. As assessment formats continue to diversify, including objective quizzes, reflective writing, and gamified tasks, relying solely on Cronbach's Alpha is no longer sufficient. Aligning the psychometric method with the specific characteristics of the assessment enhances the validity, precision, and interpretability of results. A simplified visual (see Figure 1) supports this approach by mapping common assessment types to their recommended reliability methods (Orçan, 2023; Njeri, Rop, & Too, 2023).

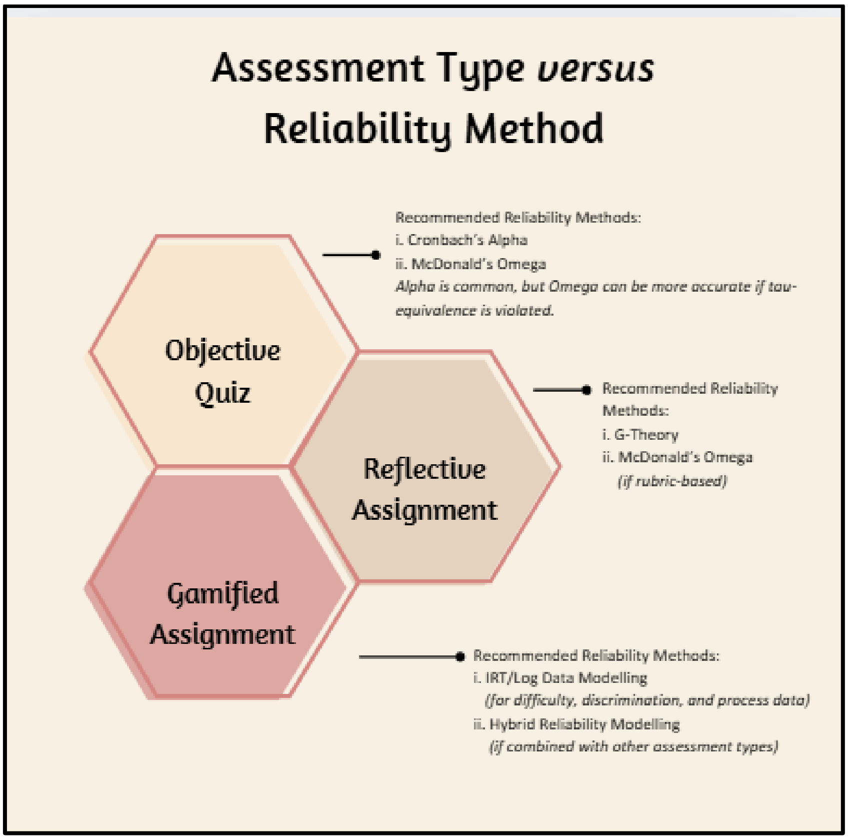

Figure 1. Proposed Framework for Selecting Reliability Methods in Digital Learning Assessments

Objective quizzes are typically analysed using Cronbach's Alpha because of its accessibility and popularity. However, Cronbach's Alpha assumes tau-equivalence, meaning that all items contribute equally to the total score. In many real-world cases, this assumption is violated. McDonald's Omega provides a more accurate estimate of internal consistency in such situations by incorporating item loadings derived from factor analysis (Revelle & Condon, 2019; Stensen, Wendt, Wacker, & Esser, 2022). For reflective assessments such as journals and essays, variability in scoring is often introduced by differences among raters or scoring conditions. Generalizability Theory accounts for multiple sources of variance in these complex settings, making it a more appropriate method for estimating score reliability (Atılgan, 2019; Shavelson & Webb, 1991). Assessments that involve gamified or adaptive tasks generate interaction data that go beyond right or wrong responses. Item Response Theory is especially useful in modelling item characteristics such as difficulty and discrimination in these contexts. Furthermore, digital learning environments produce log data that can be analysed through behavioural modelling techniques like time-on-task and action-sequence analysis, offering additional insights into the consistency and reliability of learner behaviours (Bell, Ferrell, & Ward, 2024; Tempelaar, Rienties, & Giesbers, 2015). For assessments that combine multiple types of items or tasks, a hybrid approach is recommended. This might involve using McDonald's Omega for the objective component, Generalizability Theory for reflective responses, and IRT or log-data modelling for interactive parts, followed by a composite reliability estimate that accounts for all components (Van der Linden, 2016; Bell et al., 2024).

To illustrate this framework, consider a digital engineering course in which students complete three types of assessments: a ten-item multiple-choice quiz, a reflective journal, and a simulation-based system design task. The multiple-choice quiz was analysed using Cronbach's Alpha, which yielded a reliability coefficient of 0.82. A confirmatory analysis using McDonald's Omega produced a comparable value, supporting the consistency of the instrument. Reflective journals scored by two raters were analysed using Generalizability Theory, resulting in a generalizability coefficient of 0.75 and showing that only 10 percent of the score variance was attributable to rater effects (Atılgan, 2019). The simulation assessment was evaluated using a two-parameter IRT model, which identified two items with low discrimination values, prompting revision. Additional log data were used to track time and interaction patterns, revealing meaningful trends that correlated with performance levels (Tempelaar et al., 2015). This case demonstrates the value of applying targeted reliability methods that suit the structure of each assessment type.

Discussion and Implications

Shifting from Cronbach's alpha to modern reliability methods has important implications for digital learning. While alpha remains common, it often underestimates reliability when assumptions like equal item contribution are violated. Omega provides a more accurate alternative by accounting for factor structure, making it more suitable for diverse and complex digital assessment formats (McNeish, 2018; Revelle & Zinbarg, 2009). This shift urges researchers and instructional designers to adopt accessible tools such as *psych*, *GeneralizIT*, and *mirt*, while platforms like OpenMx and easystats support more advanced modelling workflows (Makowski et al., 2022). Incorporating these methods not only improves assessment quality and personalized feedback but also promotes greater transparency in reporting measurement accuracy. Institutions that invest in methodological training and psychometric literacy will be better equipped to create fair, valid, and data-informed digital learning environments (Andersson et al., 2022).

Conclusion

In the era of digital learning, the continued reliance on Cronbach's alpha as the primary measure of reliability is increasingly untenable. While Cronbach's alpha has served as a valuable tool for decades, its restrictive assumptions, particularly tau equivalence, unidimensionality, and equal item contribution, are frequently violated in modern technology enhanced assessments. The complexity of digital learning environments, encompassing diverse item formats, platform dependencies, adaptive algorithms, and multidimensional constructs, demands more flexible and context sensitive approaches.

McDonald's omega, Generalizability Theory, and Item Response Theory each offer distinct advantages for different assessment scenarios, enabling more accurate and nuanced measurement of score dependability. By aligning reliability analysis methods with the structural and functional characteristics of digital assessments, researchers can ensure higher psychometric precision, stronger validity, and more actionable insights. This shift requires both methodological awareness and institutional investment in psychometric literacy. Ultimately, adopting a tailored multi method reliability framework will support the creation of fairer, more transparent, and data driven educational environments that keep pace with the rapidly evolving digital landscape.

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SOCIAL AND BEHAVIORAL FACTORS INFLUENCING E-WASTE RECYCLING PRACTICES IN MALAYSIA

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ABSTRACT

Electronic waste (e-waste) is a rapidly growing environmental challenge in Malaysia, driven by digitalization, rising incomes, and shorter product lifecycles. Despite established recycling infrastructure, formal collection rates remain low. This conceptual paper explores the social and behavioral factors influencing e-waste recycling participation, drawing on existing literature. Social determinants include cultural norms, peer influence, community engagement, public education, and socioeconomic status, which shape collective attitudes toward recycling. Behavioral factors, such as individual attitudes, habits, perceived convenience, trust in recycling systems, awareness, and economic incentives, directly affect participation rates. These influences operate interactively, highlighting the need for integrated strategies that combine accessible infrastructure, targeted education, incentive schemes, and community norm-building. The paper proposes a conceptual model to guide future research and policymaking, with the aim of bridging the gap between policy targets and actual recycling behavior, contributing to Malaysia's transition toward sustainable e-waste management.

Keywords: e-waste recycling, Malaysia, social behavior, sustainability, waste management

Introduction

Electronic waste (e-waste) refers to all items of electrical and electronic equipment (EEE) and their components discarded without the intent of reuse (ITU, 2024). Globally, e-waste has emerged as the fastest-growing solid waste stream, with the *Global E-waste Monitor* estimating a record 62 million tons generated in 2022. In Malaysia, the problem is acute: approximately 411,000 tons of e-waste, equivalent to 12 kg per capita, were produced in the same year, yet only a small fraction was recovered through formal channels (Tommy, 2024). The trend is driven by rapid digitalization, rising incomes, and shorter product life cycles, which together create an escalating environmental and public health challenge.

E-waste contains valuable secondary resources such as gold, copper, and rare-earth metals, but also hazardous substances like lead, mercury, and cadmium. Informal or improper disposal allows these toxics to leach into soil and water, posing threats to both ecosystems and human health, while valuable materials are lost to the linear economy (Yiswaree, 2025). Recognizing this challenge, Malaysia's *12th Malaysia Plan* targets a household waste recycling rate, including e-waste, of 40 per cent (Yiswaree, 2025). Yet, while the country has over 50 licensed recovery facilities, the success of such policies depends heavily on social and behavioral engagement, particularly whether households are willing and able to separate, store, and return obsolete devices (Muhammad, 2025).

Despite official campaigns and the availability of Department of Environment (DoE) drop-off points, participation remains very low. In 2021, formal collection channels managed only 2,459 tons of household e-waste, less than one per cent of the estimated volume (Yiswaree, 2025). Surveys reveal that just five per cent of consumers use approved disposal methods, and adoption of tools like the MyEwaste locator app has been minimal. Much of the research on Malaysia's e-waste problem has focused on technical and regulatory solutions, leaving socio-cultural and behavioral factors relatively underexplored, despite their central importance in shaping public participation.

The existing literature underscores the importance of awareness, knowledge, and social norms in driving recycling behavior. Rodzi et al. (2023) highlight that awareness, knowledge, and risk perception significantly influence household recycling habits, while Akhtar et al. (2014) confirm a positive relationship between understanding e-waste issues and favorable recycling attitudes. Social influences also play a decisive role. Mokhtar and Shamsuddin (2024) reveal that social norms and perceived behavioral control influence recycling practices among Malaysian online shoppers, while Noor et al. (2023) show that peer behaviors and community initiatives shape individuals' intentions to recycle. Yusoff and Asmuni (2021) similarly emphasize the importance of community participation in effective waste management.

Convenience is another critical determinant. Puzzo and Prati (2024) found that the accessibility and proximity of recycling facilities directly affect willingness to participate, while Hussin et al. (2023) argue that established collection systems encourage community involvement. Finally, intrinsic motivations, rooted in environmental consciousness and personal values, are central to recycling intention. Nadarajan et al. (2023) reveal that individuals with strong sustainability values are more committed to e-waste recycling, a finding echoed by Mohamad et al. (2022), who demonstrate the predictive power of environmental attitudes through the Extended Theory of Planned Behavior. Together, these studies illustrate that Malaysia's e-waste recycling landscape is shaped by a dynamic interplay of knowledge, social norms, perceived convenience, and intrinsic motivations, reinforcing the need for strategies that address both structural and behavioral dimensions.

Social Factors Affecting E-Waste Recycling

Social factors, encompassing cultural norms, peer influence, community engagement, and socioeconomic conditions, play a decisive role in shaping e-waste recycling behaviors. In Malaysia, cultural attitudes toward waste disposal often prioritize convenience over environmental responsibility, with many households still discarding obsolete electronics alongside general waste. While such habits persist, peer influence and community norms can positively shift behavior, as individuals are more likely to recycle when they observe friends, neighbors, or respected community figures engaging in responsible disposal. Public education campaigns, particularly those delivered through schools, local councils, and religious institutions, have proven effective in reframing recycling as a civic duty. Convenience emerges as a particularly influential factor. Research by Puzzo and Prati (2024) demonstrates that accessible and user-friendly collection points, whether through proximity, strategic placement, or ease of use, significantly increase recycling participation. Similarly, Nowakowski et al. (2021) highlight that providing appropriate disposal options, such as dedicated containers for small e-waste items, reduces the perceived effort and encourages proper recycling practices.

Psychological and social dynamics further shape recycling intentions. Drawing on the Theory of Planned Behavior, Soomro et al. (2022) and Bhutto et al. (2023) show that individual attitudes, subjective norms, and perceived behavioral control strongly influence willingness to recycle. Communities where recycling is seen as the norm often witness collective action, a point echoed by Zhao (2023), who stresses that consumer perceptions can determine the success of broader recycling strategies.

Awareness and knowledge of e-waste hazards and disposal methods are also critical. Studies by Nuwematsiko et al. (2021) reveal that low awareness among vulnerable populations hinders recycling, while incentive-based programs, such as mobile phone take-back schemes in the UK, both educate and motivate consumers (Owusu-Twum et al., 2022). Educational initiatives that address not only the dangers of improper disposal but also the practical steps for participation are vital (Munir & Daud, 2024).

Cultural beliefs and socioeconomic status further influence attitudes toward recycling. Delcea et al. (2020) and Yu & Mangmeechai (2023) note that perceptions of e-waste value, shaped by cultural understandings of material worth, can either encourage or deter responsible disposal. Tailored campaigns that address specific cultural contexts are therefore essential, particularly in communities with low baseline awareness. Governmental support and policy frameworks underpin these social dimensions. As Azlan et al. (2021) argue, strong enforcement, systematic policy design, and collaboration among stakeholders are necessary to promote participation. Incentives, whether financial benefits for consumers and businesses or reduced costs for recycling, can further boost engagement (Fadhullah et al., 2022).

In the Malaysian context, generational differences also emerge as relevant. Millennials and younger consumers, influenced by normative social pressures (Bhutto et al., 2023; Noor et al., 2023), often align their recycling behavior with societal expectations. However, despite growing awareness of e-waste hazards, many Malaysians still lack knowledge of the practical steps required to recycle effectively (Mohamad et al., 2022). Moral obligation, or feelings of guilt for not recycling, can motivate action, but insufficient guidance from authorities often leads to inaction (Nasir & Yaacob, 2022).

Socioeconomic disparities further complicate participation, as lower-income groups may face barriers to accessing formal recycling services (Deshpande et al., 2024).

Behavioral Factors Affecting E-Waste Recycling

Behavioral factors, encompassing individual attitudes, habits, perceived convenience, and trust in recycling systems, are central to shaping participation in e-waste recycling. Positive attitudes toward recycling, often rooted in environmental concern and awareness of health risks, can significantly motivate individuals to engage in proper disposal practices. Conversely, entrenched habits, such as storing unused electronics indefinitely or discarding them with general waste, act as substantial barriers. In this context, convenience is a decisive element: when recycling facilities are readily accessible, well-located, and simple to use, participation increases substantially (Mohamad et al., 2022; Nadarajan et al., 2023). Structural arrangements that reduce the time and effort required to recycle, such as strategically placed collection points, have been shown to be powerful enablers of sustainable behavior.

Emotional and psychological motivations also influence recycling intentions. Feelings of guilt for not recycling, combined with a sense of moral obligation, often encourage individuals to act (Allison et al., 2022; Swanson & Ferrari, 2022). Personal norms and values (particularly those aligned with environmental stewardship) strongly predict positive recycling intentions (Yu & Mangmeechai, 2023; Ang et al., 2023). Social influences play a complementary role: when recycling is seen as socially endorsed, by peers, family members, or community networks, individuals are more likely to adopt similar practices (Swanson & Ferrari, 2022; Kassim et al., 2023). The Theory of Planned Behavior supports this perspective, highlighting how subjective norms interact with attitudes and perceived behavioral control to shape intentions (Kassim et al., 2023; Bhutto et al., 2023).

Perceived behavioral control, or confidence in one's ability to recycle effectively, is another strong determinant. When individuals believe they have the necessary knowledge, skills, and access to facilities, they are more inclined to participate. Educational initiatives that build this confidence, by providing clear instructions and demystifying recycling procedures, can significantly improve engagement rates (Leng & Arif, 2022). Conversely, when recycling processes are seen as complicated, inconvenient, or time-consuming, willingness to participate diminishes (Yuriev et al., 2020; Yu et al., 2021).

Awareness of environmental issues and knowledge of proper recycling methods are critical enablers of behavioral change. Studies show that while many people understand that e-waste poses risks, fewer know the correct procedures for safe disposal (Abdul et al., 2023; Mokhtar et al., 2024). Targeted public education campaigns that combine hazard awareness with practical guidance can help close this gap (Delcea et al., 2020). Without this combination, even well-intentioned individuals may fail to act effectively.

Economic incentives can also serve as powerful behavioral triggers. Financial rewards, discounts, or buy-back programs provide tangible motivation for recycling, reinforcing sustainable behavior and encouraging repeat participation (Mohamad et al., 2022; Siddiqua et al., 2022). When such incentives are paired with supportive infrastructure and community engagement, their impact is magnified, creating a positive feedback loop that normalizes recycling within society (Sabbir et al., 2023).

Conclusion

Malaysia's e-waste challenge is not solely a matter of technology or infrastructure but is deeply rooted in social and behavioral dimensions. Awareness, social norms, and cultural values shape the willingness to engage, while convenience, trust, and personal motivation determine the consistency of participation. Policies that integrate these factors, through targeted education, community engagement, and user-friendly collection systems, are more likely to succeed in bridging the gap between policy goals and public action. Future research should empirically test integrated models that capture the interplay between social and behavioral influences, ensuring that strategies are not only technically sound but also socially resonant and behaviorally sustainable.

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APPLICATION OF THE RUNGE-KUTTA FOURTH ORDER (RK4) AND RUNGE-KUTTA FIFTH ORDER (RK5) IN DYNAMIC SYSTEMS: A FOCUS ON ELECTRICAL CIRCUIT ANALYSIS

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Abstract

This study examines the application of the Runge–Kutta Fourth Order (RK4) and Fifth Order (RK5) numerical methods in modelling dynamic electrical systems, focusing on series and parallel RLC circuits. Both approaches are widely recognized for solving ordinary differential equations (ODEs) with accuracy and efficiency, making them valuable when analytical solutions are difficult to obtain. The research compares the performance of RK4 and RK5 in simulating transient and steady-state behaviours under different damping conditions, including underdamped, overdamped, and critically damped cases. Mathematica was used as the computational platform to evaluate each method in terms of accuracy, stability, and computational cost. Findings show that RK4 offers a practical balance between simplicity and performance, making it suitable for general circuit analysis. In contrast, RK5 demonstrates superior precision, especially in scenarios where high accuracy is essential. By applying both methods to different circuit configurations, the study provides a well-rounded understanding of their capabilities and limitations in real-world applications. Overall, the results highlight the trade-offs between RK4 and RK5, offering engineers, researchers, and students clearer guidance in selecting the most suitable method. Choosing the appropriate approach enhances both the accuracy and efficiency of electrical circuit modelling.

Keywords*:* RK4, RK5, Mathematica, Circuit analysis

Introduction

Numerical methods play a vital role in solving ordinary differential equations (ODEs), particularly when obtaining exact analytical solutions is challenging or impractical. In electrical engineering, these techniques are essential for analyzing the time-dependent behavior of circuits, especially during sudden changes or transient events. While Euler's method, one of the earliest approaches to solving differential equations, remains a foundation for modern numerical techniques (Euler, 1768; Burden & Faires, 2011; Sauer, 2018). It often lacks the accuracy required for complex or high-precision systems (Chen et al., 2024).

Runge–Kutta methods, particularly the fourth-order (RK4) and fifth-order (RK5) variants, provide significantly improved accuracy and stability. By estimating slopes at multiple points within each time step, these methods are well-suited for studying real-time circuit responses (Ashgi et al., 2021; Ezhilarasi, 2023). The several current studies apply RK4 and RK5 to compare booth method in

RLC circuits (Godswill *et al.* (2025) and also implementing Runge-Kutta RK4 vs RK5 in RLC Transient Responses (Kafle *et al.* (2021). Although both methods are widely used, detailed comparative studies remain limited. Using Mathematica as the computational platform, this research evaluates the accuracy and efficiency of each method, aiming to offer practical guidance for engineers in selecting the most appropriate approach—particularly for nonlinear circuits or systems with rapidly changing signals (Shaikh et al., 2022; Ying et al., 2023).

Methodology

Equation (1) is the formula of the Runge-Kutta fourth-order method given by (Shaikh et al., 2022b) as below:

$$y'' = f(x, y) \tag{1}$$

$y(x_0) = y_0$ and $y'(x_0) = y'_0$

$$y_{i+1} = y_i + \frac{1}{6}(R1 + 2(R2 + R3) + R4) + O(h^5)$$

where,

$$R1 = hf(x_n, y_n)$$

$$R2 = hf\left(x_n + \frac{1}{2}h, y_n + \frac{1}{2}R1\right)$$

$$R3 = hf\left(x_n + \frac{1}{2}h, y_n + \frac{1}{2}R2\right)$$

$$R4 = hf(x_n + h, y_n + R3)$$

h represents the step size and $\boldsymbol{y_i}$ are the values of the dependent variables at the current step. R1, R3, and R4 are intermediate calculations based on the derivative function.

There exist several RK5 formulations, like equation (2), each suited for different applications. Some are given by the RK5 formula (Kafle et al., 2021).

$$y_{i+1} = y_i + \frac{h}{90}(7k_1 + 32k_3 + 32k_5 + 7k_6) \quad (2)$$

where,

$$t_{n+1} = t_n + h$$

$$k_1 = hf(t_n, y_n)$$

$$k_2 = f\left(t_n + \frac{h}{4}, y_n + \frac{h}{4}k_1\right)$$

$$k_3 = f\left(t_n + \frac{h}{4}, y_n + \frac{h}{8}k_1 + \frac{h}{8}k_2\right)$$

$$k_4 = f\left(t_n + \frac{h}{2}, y_n + \frac{h}{2}k_2 + hk_3\right)$$

$$k_5 = f\left(t_n + \frac{3h}{4}, y_n + \frac{3h}{16}k_1 + \frac{9h}{16}k_4\right)$$

$$k_6 = f\left(t_n + h, y_n - \frac{3h}{7}k_1 + \frac{2h}{7}k_2 + \frac{12h}{7}k_3 - \frac{12h}{7}k_4 + \frac{8h}{7}k_5\right)$$

Also, the RK5 formula constructed by Kazeem Iyanda et al. (2021) as equation (3):

$$Y_{i+1} = Y_i + \frac{1}{192}(23k_1 + 125k_3 - 81k_5 + 125k_6) \quad (3)$$

where,

$$k_1 = hf(t_i, Y_i)$$

$$k_2 = f\left(t_i + \frac{h}{3}, Y_i + \frac{k_1}{3}\right)$$

$$k_3 = f\left(t_i + \frac{2h}{5}, Y_i + \frac{1}{25}(4k_1 + 6k_2)\right)$$

$$k_4 = f\left(t_i + h, Y_i + \frac{1}{4}(k_1 - 12k_2 + 15k_3)\right)$$

$$k_5 = f\left(t_i + \frac{2h}{3}, Y_i + \frac{1}{81}(6k_1 + 90k_2 - 50k_3 + 8k_4)\right)$$

$$k_6 = f\left(t_i + \frac{4h}{5}, Y_i + \frac{1}{75}(6k_1 + 36k_2 + 10k_3 + 8k_4)\right)$$

h is the step size, $\boldsymbol{x_n}$ are the values of the independent variables and $\boldsymbol{y_n}$ are the values of the dependent variables. k1, k3, k4, k5, and k6 are intermediate calculations based on the derivative function. This requires the use of numerical techniques to solve the governing differential equations of the circuit. Parameters for the circuit are given as resistance (R), inductance (L), and capacitance (C).

Classification of circuit response:

The damping factor (ξ)using equation (4):

$$\xi = \frac{R}{2}\sqrt{\frac{C}{L}} \tag{4}$$

Classify the system's response based on the damping force:

$\xi > 1$: Overdamped

$\xi = 1$:Critically damped

$\xi < 1$: Underdamped

This classification is crucial as it determines the nature of the transient response, ranging from convergence to steady state in overdamped systems to oscillatory behaviour in systems

Absolute error is calculated using the formula in equation (5) from (Shaikh et al., 2022):

$$|V_A - V_E| \tag{5}$$

$$V_A = 12 - [12\cos(8660.25t) + 6.39\sin(8660.25t)]e^{-S000t}$$

Results and Discussion

Figure 1 displays the voltage-time response of a series RLC circuit under underdamped conditions. The graph shows that the voltage oscillates with decreasing amplitude over time, which is typical of an underdamped system. Both the RK4 and RK5 methods in this study successfully capture this oscillatory behaviour.

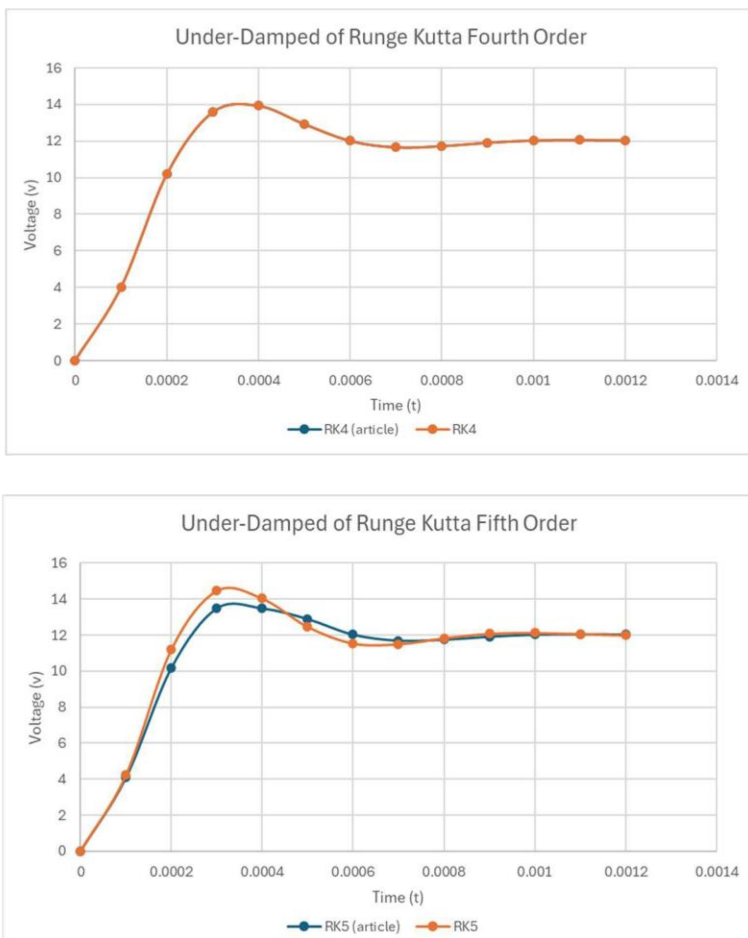

Figure 1: Voltage-Time Response of the Underdamped RLC Series Circuit

Table 1 shows the absolute error analysis for the underdamped RLC parallel circuit over a short simulation period from t=0.0000 to t=0.0012 seconds. The exact solution is compared against the RK4 and RK5 numerical methods at each time step to evaluate their accuracy.

t	Exact Solution	Abs Error	
		RK4	RK5
0.0000	0	0	0
0.0001	4.0828	0.44349	0.1447
0.0002	10.1925	1.03632	1.0215
0.0003	13.4920	0.0869	0.9744
0.0004	13.8375	0.0952	0.1951
0.0005	12.8952	0.0401	0.4289
0.0006	12.0276	0.0153	0.4899
0.0007	11.6923	0.0350	0.1972
0.0008	11.7481	0.0240	0.0778
0.0009	11.9152	0.00452	0.01588
0.0010	12.0260	0.00718	0.0934
0.0011	12.0517	0.00829	0.0033
0.0012	12.0310	0.00387	0.0389

Table 1: Error Analysis of RK4 and RK5 of RLC Series Circuit (Case I: Underdamped)

Figure 2 illustrates a visual comparison, which plots the voltage response of Euler, RK3, BRK5, RK4, and RK5 against time. The graph clearly shows that the RK5 curve remains closer to the reference (BRK5) throughout, indicating higher fidelity and better error control.

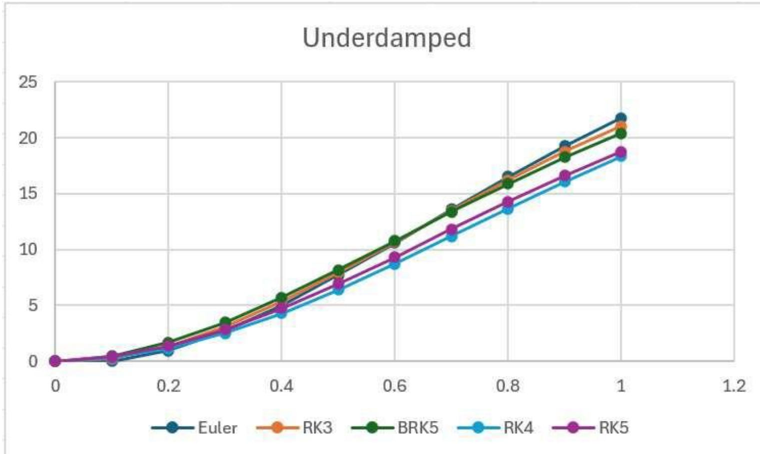

Figure 2: Voltage-Time Response of the Underdamped RLC Parallel Circuit.

Table 2 presents the absolute error analysis for the RLC parallel circuit under underdamped conditions (Case II). The errors were calculated by comparing the RK4 and RK5 results with the exact analytical solution over the time interval t=0 to t=1.0 seconds.

t	Exact Solution	Abs Error	
		RK4	RK5
0.0	0	0	0
0.1	0.73755	0.44349	0.34137
0.2	2.18195	1.03632	0.81197
0.3	4.15289	1.65848	1.30695
0.4	6.48369	2.21999	1.75112
0.5	9.02491	2.66072	2.09789
0.6	11.64659	2.94854	2.32655
0.7	14.23940	3.07625	2.43851
0.8	16.71490	3.05767	2.45295
0.9	19.00490	2.92302	2.40189
1.0	21.06029	2.71405	2.32534

Table 2 Absolute Error Analysis of RK4 and RK5 of RLC Parallel Circuit (Case II: Underdamped).

Conclusion

This study successfully applied and evaluated the Runge–Kutta Fourth Order (RK4) and Fifth Order (RK5) methods in solving differential equations that model the dynamic behavior of electrical circuits, with a focus on RLC configurations. Through simulations of transient and steady-state responses under underdamped, critically damped, and overdamped conditions, the results confirmed that both RK4 and RK5 are reliable and effective tools for circuit analysis.

RK4 emerged as a computationally efficient method, delivering accurate results with lower complexity—making it particularly suitable for real-time simulations and simpler circuit models. In contrast, RK5 consistently provided higher accuracy, proving advantageous in scenarios with rapid transients, stringent precision requirements, or nonlinear system dynamics. Despite its higher computational cost, RK5 demonstrated the ability to minimize absolute error over extended time intervals.

Overall, the findings highlight that RK4 is well-suited for fast, less resource-intensive applications, while RK5 is the method of choice for high-accuracy modeling of complex or sensitive electrical systems. This comparative insight can guide engineers and researchers in selecting the most appropriate approach based on the trade-off between computational efficiency and precision.

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EFFECT OF GRAPHICA3D ON STUDENTS' VISUALIZATION AND SKETCHING OF 3D GRAPHS IN MULTIVARIABLE CALCULUS

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ABSTRACT

Developing skills in visualizing, interpreting, and sketching three-dimensional (3D) graphs is essential for learning multiple integrals, a key topic in multivariable calculus. However, many students struggle with these skills, creating barriers to understanding and solving related problems. While dynamic mathematics software like GeoGebra can support visualization, existing teaching materials often lack structured integration of technology to strengthen 3D graph learning. To address this gap, an interactive module, Graphica3D, was developed. The module combines explanatory notes on 3D graphs with embedded GeoGebra applets that enable interactive visualization. This study evaluated the effectiveness of the Graphica3D module using a pre–post test design. Participants were 44 engineering students enrolled in Further Calculus for Engineers at UiTM Cawangan Pulau Pinang. Data were analyzed using a non-parametric test, namely ANOVA-type statistics and results showed significant improvements in students' ability to visualize and sketch 3D graphs. Moreover, no interaction between test performance (pre vs. post) and gender was observed, suggesting that the module benefits students equitably. These findings demonstrate that Graphica3D is a valuable supplementary tool for enhancing spatial visualization in multivariable calculus and for supporting inclusive teaching practices in higher education mathematics.

Keywords: 3-dimensional graphs, GeoGebra, interactive learning, multiple integrals, multivariable calculus

Introduction

Multivariable calculus is a compulsory subject in science and engineering degree programs, and one of its key topics is multiple integrals. These integrals involve integrating functions of more than two variables over two-dimensional (2D) or three-dimensional (3D) regions. Before evaluating a multiple integral, students must first understand the region of integration to determine the limits of integration, which requires accurate interpretation of 3D graphs (Milenkovic et al., 2023).

However, many students face difficulties in developing the skills to visualize, interpret, and sketch 3D graphs represented by algebraic equations. They often struggle to connect algebraic equations with their corresponding geometric representations (Gemechu et al., 2021). This difficulty has been identified as a significant barrier to learning and problem-solving in multiple integrals (Kashefi et al., 2010; Listiana et al., 2022), particularly among students from non-mathematics programs (Milenkovic et al., 2023).

To address this issue, dynamic mathematics software has been increasingly adopted to support visualization in calculus learning. Software such as MATLAB, Mathematica, Maple, and GeoGebra provide interactive environments that allow students to explore mathematical objects independently (Milenković & Vučićević, 2024). Among these, GeoGebra has gained wide adoption in mathematics education due to its open-source nature and versatile applications in geometry, algebra, and calculus (Hohenwarter et al., 2008; Ziatdinov & Valles Jr., 2022). GeoGebra can also be seamlessly integrated into teaching materials.

Building on this potential, we developed Graphica3D, an interactive module with embedded GeoGebra applets designed to help students visualize, interpret, and sketch 3D graphs. Initial survey results from engineering students enrolled in multivariable calculus course at UiTM Cawangan Pulau Pinang (UiTMCPP) indicated that Graphica3D was perceived as an effective supplementary learning tool that enhanced their visualization and sketching skills (Saad et al., 2025, 2024).

While these findings highlight students' positive perceptions, further investigation is needed to determine the module's impact on learning outcomes. Therefore, the present study aims to evaluate students' improvement in sketching 3D graphs after using the Graphica3D module. The module was implemented in the Further Calculus for Engineers course, and students' sketching performance was assessed before and after its use. Specifically, this study examines whether there is a statistically significant difference between pre-test and post-test scores, as well as whether gender differences influence students' performance.

The research questions guiding this study are:

1. Do students' skills in sketching 3D graphs improve from pre-test to post-test?
2. Do gender differences influence students' scores in sketching 3D graphs?
3. Is there an interaction between test performance (pre-test and post-test) and gender?

Methodology

The Graphica3D module, developed as a digital flipbook, was designed to address students' challenges in visualizing and understanding 3D graphs. It incorporates interactive 3D visualizations supported by GeoGebra applets, along with explanatory notes on common 3D surfaces such as planes, cones, cylinders, paraboloids, spheres, and hemispheres. Figure 1 presents sample pages from the Graphica3D module.

Figure 1: Graphica3D module

A pre–post study design was employed to measure students' improvement in sketching 3D graphs after using the Graphica3D module. Students' sketches were collected both before and after using the module. The same set of six algebraic equations (Table 1) was used in the pre-test and post-test, and students were instructed to sketch the corresponding 3D graphs.

Table 1: Algebraic Equations for Pre- and Post-Tests

No	Algebraic Equations
1	$y = x + 1, x = -1$
2	$y = 2 - \sqrt{x^2 + z^2}$
3	$x = y^2 + z^2 - 3$
4	$x^2 + z^2 = 16$
5	$y = -\sqrt{4 - x^2 - z^2}$
6	$z = -\sqrt{4 - x^2 - y^2}$

A total of 44 students participated in the study, comprising 23 females and 21 males from three engineering programs at UiTMCPP: Civil Engineering, Chemical Engineering, and Electrical Engineering. For the pre-test, students were asked to sketch 3D graphs of six algebraic equations (Table 1) prior to the introduction of the module. After completing the pre-test, students were introduced to the

Graphica3D module and instructed to review it. One week later, they completed the post-test by sketching graphs of the same equations.

Each sketch was evaluated using a scoring rubric with three criteria: (i) axes orientation, (ii) basic shape accuracy, and (iii) correct representation of mathematical features such as symmetry, intercepts, and curves. For each student, total scores were computed for both pre-test and post-test. Descriptive statistics (mean and standard deviation) were calculated for both sets of scores.

To address the research questions, a non-parametric test, the ANOVA-type statistic (ATS) (Brunner & Puri, 2001), was used as an alternative to mixed ANOVA (two-way ANOVA with repeated measures), given that the data did not meet the normality assumption. The ATS was appropriate for this study because it allows examination of interactions between gender (male, female) and test at two different times (pre-test, post-test). Data analysis was conducted using the nparLD package in R (Noguchi et al., 2012).

Results

The effectiveness of the Graphica3D module in enhancing students' ability to visualize and sketch 3D graphs was evaluated using a pre–post study design. Students' scores were analyzed with the non-parametric ANOVA-type statistic (ATS) to examine the effects of test (pre vs. post), gender, and their interaction.

Table 2 presents the means and standard deviations (SD) of test scores. The overall mean pre-test score was 14.48 (SD = 8.40), while the post-test mean increased to 26.18 (SD = 8.85). For female students, the mean pre-test score was 13.30 (SD = 8.62) and the post-test mean was 24.48 (SD = 10.55). Male students scored slightly higher, with a pre-test mean of 15.76 (SD = 8.17) and a post-test mean of 28.05 (SD = 6.25).

Table 2: Descriptive Statistics of Pre- and Post-Test Scores by Gender

Test	Gender	Mean	Std. Deviation	n
Pre	Female	13.30	8.62	23
	Male	15.76	8.17	21
	Total	14.48	8.40	44
Post	Female	24.48	10.55	23
	Male	28.05	6.25	21
	Total	26.18	8.85	44

Results of the ATS are shown in Table 3. A significant main effect was found for test, $F = 144.49$, p-value $< 10^{-33}$, indicating that post-test scores were significantly higher than pre-test scores at the 0.05 significance level. Gender had no significant effect on test scores, $F = 1.40$, p-value = 0.237, suggesting no overall performance difference between male and female students. The interaction between test and gender was also not significant, $F = 0.40$, p-value = 0.527, indicating that the improvement from pre-test to post-test was consistent across genders. Figure 2 provides a graphical illustration of the interaction effect. The parallel lines confirm the absence of a significant interaction between test and gender on students' test performance.

Table 3: ATS Results for Test Occasion (Pre vs Post), Gender, and Interaction Effects

Source	**df**	**F**	**p-value**
Test	1	144.4877	$<10^{-33}$
Gender	1	1.3983	0.2370
Test * Gender	1	0.3999	0.5271

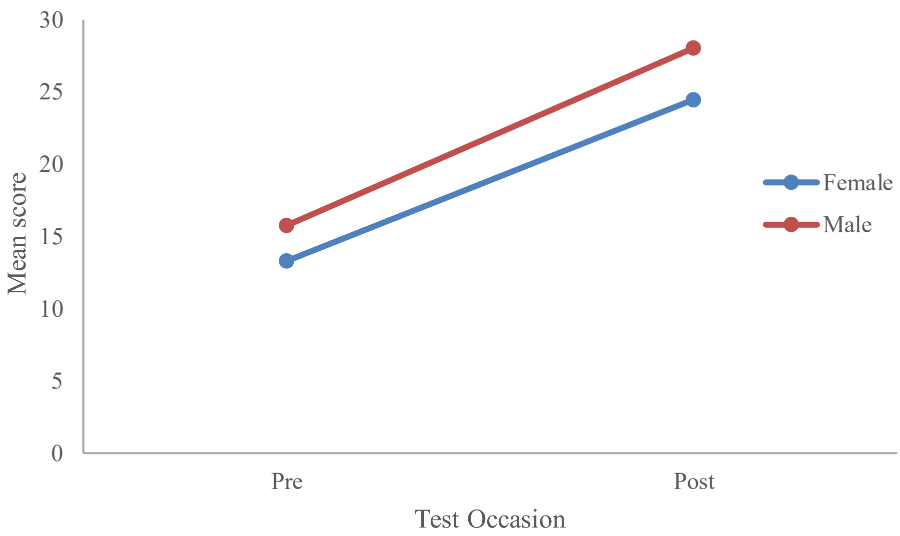

Figure 2: Interaction Effect of Pre- and Post-Test Scores by Gender

Discussion

This study examined whether interactive teaching materials, specifically the Graphica3D module, could help students improve their spatial skills in visualizing, interpreting, and sketching 3D graphs. The descriptive statistics revealed an overall mean gain of 11.71 points from pre-test to post-test. This improvement was further confirmed by the non-parametric ATS test, which showed a statistically significant difference between pre-test and post-test performance. These results indicate that the

Graphica3D module effectively enhances students' visualization and sketching skills, which are essential for understanding multiple integrals. These findings are consistent with previous research showing that dynamic mathematics software such as GeoGebra supports deeper learning of multiple integrals compared to traditional methods (Listiana et al., 2022; Milenković et al., 2024; Septian et al., 2021).

With regard to gender differences, descriptive statistics indicated that male students scored slightly higher than female students on both tests, with mean gain of 12.29 and 11.18, respectively. However, the ATS test revealed no statistically significant gender difference. This suggests that both male and female students developed comparable visualization and sketching skills. Previous studies have reported mixed findings in this area. For example, Gamage and Charles-Ogan (2019) and Akpan et al. (2022) concluded that gender does not influence mathematics performance when using GeoGebra, emphasizing that male and female students possess similar cognitive abilities to learn geometry effectively. In contrast, Adelabu et al. (2019) reported that female students outperformed male students in mathematics when GeoGebra was integrated into instruction. Research directly comparing male and female performance in multivariable calculus learning with dynamic mathematics software remains limited.

Lastly, the investigation of interaction effects between pre-test and post-test and gender revealed no significant interaction. This means that both male and female students benefited similarly from the Graphica3D module. Overall, these results complement prior research on GeoGebra-assisted learning and extend the evidence by demonstrating that the Graphica3D module is equally effective for both male and female students.

Conclusion

This study evaluated the effectiveness of the Graphica3D module as a supplementary learning tool in multiple integrals, a key topic in multivariable calculus. Results showed that students demonstrated significant improvements in their ability to visualize and sketch 3D graphs after using the module.

These findings highlight the value of integrating technology-based modules such as Graphica3D into the teaching and learning of multivariable calculus. By enhancing students' ability to visualize and sketch 3D graphs, the module not only strengthens conceptual understanding but also helps overcome a key barrier to learning multiple integrals. Importantly, the results indicate that the Graphica3D module provides equitable learning benefits across genders, supporting inclusive teaching practices in higher education mathematics.

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HARNESSING CANVA INFOGRAPHICS TO ENHANCE ENGAGEMENT IN ONLINE LEARNING

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ABSTRACT

The rapid shift toward online learning has intensified the challenge of sustaining student engagement and ensuring meaningful comprehension. Traditional lecture slides and text-heavy resources often fail to capture learners' attention, resulting in reduced motivation and cognitive overload. Visual learning strategies, particularly infographics, have shown promise in simplifying complex concepts and supporting retention. This study explores the integration of Canva-designed infographics into higher education online courses. Infographics were developed to represent key course concepts and shared with students through learning management systems and synchronous online lectures. Informal feedback and instructor observations indicated that the visuals enhanced clarity, improved recall, and increased participation during discussions. Students reported that Canva-based infographics made learning materials more engaging and easier to understand compared to conventional slides. While challenges such as design time and balancing visual appeal with accuracy were noted, the findings suggest that Canva provides educators with an accessible tool to foster engagement in digital classrooms. Future work should employ systematic evaluations, such as pre- and post-tests or large-scale surveys, to measure the direct impact on learning outcomes.

Keywords: Canva, infographics, online learning, student engagement, visual learning

Introduction

The rapid adoption of online learning in higher education, accelerated by the COVID-19 pandemic and the digital transformation of education, has reshaped how students and educators interact with course materials. While online platforms offer flexibility and wider accessibility, they also present significant challenges, particularly in maintaining student engagement and ensuring comprehension of complex subject matter. In fields such as mathematics and engineering, where abstract theories and technical problem-solving are central, the risk of student disengagement is even higher (Fabian et al., 2022).

Traditional online teaching methods often rely heavily on text-based lecture slides, lengthy notes, or extended video recordings. Although these formats deliver content, they are not always effective in sustaining attention or supporting long-term retention (Mayer, 2009). Students may become passive recipients of information rather than active participants in the learning process. Thus, there is a need for instructional innovations that not only transmit knowledge but also enhance motivation, reduce cognitive load, and facilitate deeper understanding.

One promising approach is the use of visual learning tools, particularly infographics. Infographics provide a concise, visually appealing medium for presenting complex ideas, combining text, images, icons, and diagrams into a structured format (Smiciklas, 2012). In recent years, digital tools such as Canva have enabled educators to design professional-quality infographics with minimal technical expertise. This accessibility makes Canva an attractive option for lecturers seeking to integrate visual strategies into their teaching practices.

At Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang, educators have been exploring technology-enhanced teaching innovations to improve student learning experiences. Building upon earlier work, such as the award-winning Bridging Calculus and Engineering Practice: An Instructional Video Series recognized at SUSED2025, this study focuses on the integration of Canva-designed infographics as a complementary tool to enhance engagement in online learning environments.

The aim of this paper is to document the process of designing and integrating Canva infographics in higher education courses, reflect on observed outcomes in terms of student engagement and comprehension, and discuss the opportunities and challenges encountered in practice.

Literature Review

2.1 Student Engagement in Online Learning

Engagement has been identified as a critical factor for successful online learning outcomes (Redmond et al., 2018). Engagement can be understood across behavioral, emotional, and cognitive dimensions. In digital classrooms, sustaining engagement is difficult due to distractions, reduced face-to-face interactions, and the limitations of screen-based communication (Martin & Bolliger, 2018). Innovative instructional strategies are therefore needed to foster active participation and motivation.

Visual Learning and Cognitive Theory

Visual learning has long been recognized as an effective pedagogical approach. According to Mayer's Cognitive Theory of Multimedia Learning (2009), students learn better from a combination of words and visuals than from words alone. Infographics align with this principle by integrating visuals, structure, and concise text, thereby reducing cognitive load while enhancing retention (Lyra et al., 2016).

Infographics in Higher Education

Recent studies have highlighted the effectiveness of infographics in higher education. Ibrahim (2020) reported that infographic-based materials improved comprehension of technical content among engineering students. Similarly, Alrwele (2017) found that infographics increased motivation and participation in science courses. These findings suggest that infographics can serve as both instructional aids and learning resources for students to independently review.

Canva as a Tool for Educators

Canva, a web-based design platform, provides educators with user-friendly templates and customization options for creating visually compelling educational resources. Research indicates that Canva supports non-designers in producing high-quality visuals for teaching and assessment (Bouchrika, 2022). Its collaborative features also enable co-creation of infographics, allowing students to engage in content design as an active learning strategy.

Positioning This Study

While the potential of infographics is well-documented, there is limited literature that specifically examines their integration through Canva in online higher education contexts in Malaysia. This paper contributes to filling that gap by presenting a case of practice-based reflection from UiTM Cawangan Pulau Pinang. It focuses on how Canva infographics were designed, integrated into teaching, and perceived to enhance clarity, engagement, and retention.

Methodology

This study employed a practice-based reflective approach rather than a formal empirical design. The purpose was to document and reflect on the integration of Canva-designed infographics in online teaching at Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang. The methodology consisted of three main stages:

Design of Infographics

Canva was selected as the primary tool due to its accessibility, wide range of templates, and ease of use for non-designers. Infographics were created to represent core concepts from mathematics and computing courses, focusing on topics that students typically found abstract or challenging. Each infographic combined key formulas, diagrams, and step-by-step explanations in a visually structured format.

Integration into Online Learning

The infographics were integrated into both synchronous and asynchronous learning contexts:

- Synchronous delivery: Infographics were embedded in lecture slides and presented during live online classes.

- Asynchronous support: Infographics were uploaded to the Learning Management System (LMS) and shared as downloadable resources, allowing students to review content at their own pace.

Informal Feedback and Reflection

Instead of structured surveys, informal student feedback was gathered through classroom discussions and chat responses during online sessions. Educators also engaged in reflective observation, noting student reactions, participation levels, and patterns of engagement when infographics were used compared to conventional slides. This reflective practice provided qualitative insights into the effectiveness and limitations of Canva-designed infographics in enhancing online learning engagement.

Finding and Discussion

Improved Clarity of Content

Students reported that the infographics simplified complex ideas into more manageable forms. For example, abstract calculus concepts were easier to follow when presented visually alongside brief textual explanations. This aligns with Mayer's (2009) multimedia learning theory, which emphasizes dual-channel processing of information.

Increased Student Engagement

During live online classes, educators observed greater student participation when infographics were used. Questions in the chat box increased, and students frequently requested copies of the visuals for later review. This suggests that Canva-based infographics not only sustained attention but also stimulated interaction.

Enhanced Retention and Recall

When tested informally through problem-solving activities, students demonstrated improved recall of formulas and procedures previously represented in infographics. These finding echoes prior studies (Ibrahim, 2020; Alrwele, 2017) showing the positive effect of infographics on comprehension and memory.

Challenges in Implementation

Despite the benefits, several challenges were identified:

- Design Time: Creating effective infographics required additional preparation compared to standard lecture slides.

- Balance Between Visual Appeal and Accuracy: Ensuring that the infographic was attractive without oversimplifying content was a recurring difficulty.
- Digital Overload: Some students expressed concern about receiving too many visual materials, suggesting the need for balance with other formats.

Link to Previous Innovation Work

This project builds on the team's earlier innovation, Bridging Calculus and Engineering Practice: An Instructional Video Series, which won a bronze medal at SUSED2025. While the video series emphasized contextual applications of calculus in engineering, the Canva infographic initiative focused on concise visual summaries to support online comprehension. Together, these innovations reflect UiTM educators' ongoing commitment to bridging theory and practice through technology-enhanced teaching.

Conclusion and Future Directions

The integration of Canva-designed infographics into online higher education courses at UiTM Cawangan Pulau Pinang demonstrated strong potential for enhancing engagement and comprehension. Infographics provided a visually structured medium that improved clarity, increased student participation, and supported content retention. Although no formal data collection was conducted, reflective observations and informal feedback indicated that students found the approach valuable compared to conventional teaching materials.

Nevertheless, challenges such as the time investment for design and the need to balance aesthetics with accuracy must be acknowledged. The findings suggest that Canva is a practical, accessible tool that can empower educators to create engaging digital resources without requiring advanced design skills.

Future work should involve systematic evaluations, such as pre- and post-tests, structured student surveys, or comparative studies across multiple cohorts, to measure the measurable impact of infographics on learning outcomes. By combining Canva infographics with other innovations, such as instructional videos and gamification, educators can develop diverse strategies to meet the evolving needs of digital learners.

Acknowledgement

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with a Bronze Medal. This recognition has inspired the continuation of efforts to explore innovative digital tools, such as Canva, to enhance student engagement in online learning.

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KEFAHAMAN SIMBOL MATEMATIK DAN PENYELESAIAN MASALAH DALAM KALKULUS LANJUTAN

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ABSTRAK

Kalkulus lanjutan merupakan kursus asas dalam program Kejuruteraan di peringkat ijazah sarjana muda yang menuntut pelajar menguasai kemahiran prosedural dan kefahaman konseptual. Simbol matematik seperti kamiran berganda (∬), kamiran tertutup (∮), notasi vektor ($\vec{\ }$), parameterisasi dan siri tak terhingga (Σ) berfungsi sebagai bahasa formal dalam menggambarkan konsep kompleks. Walau bagaimanapun, ramai pelajar cenderung melihat simbol sebagai arahan mekanikal tanpa memahami makna sebenar, sekali gus menjejaskan prestasi dalam penyelesaian masalah berbentuk konseptual dan aplikasi dunia sebenar. Kajian ini melibatkan 40 orang pelajar ijazah sarjana muda Kejuruteraan di UiTM Cawangan Pulau Pinang. Reka bentuk kajian berbentuk kuantitatif dengan pendekatan korelasi, menggunakan dua instrumen iaitu ujian literasi simbol kalkulus lanjutan dan ujian penyelesaian masalah berasaskan prosedural, konseptual serta aplikasi. Analisis deskriptif dan korelasi Pearson menunjukkan tahap kefahaman simbol pelajar berada pada tahap sederhana. Prestasi pelajar dalam menyelesaikan soalan berbentuk penyelesaian masalah berprosedur lebih baik berbanding soalan berbentuk aplikasi. Kajian ini membuktikan adanya hubungan signifikan antara kefahaman simbol matematik dan keupayaan penyelesaian masalah, sekali gus menegaskan kepentingan literasi simbol dalam pengajaran kalkulus lanjutan.
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Katakunci: *Simbol, kefahaman, Kalkulus lanjutan, simbol matematik*

Pengenalan

Kalkulus lanjutan merupakan kursus teras dalam pengajian kejuruteraan yang menuntut penguasaan bukan sahaja dari aspek prosedural, tetapi juga kefahaman mendalam terhadap simbol dan notasi matematik. Simbol seperti ∫ (kamiran), lim (had) dan pelbagai notasi pembezaan berperanan sebagai bahasa formal dalam menghubungkan konsep abstrak dengan aplikasi dunia sebenar. Namun, kajian menunjukkan ramai pelajar masih berdepan kesukaran dalam mentafsir makna simbol secara konseptual, sekali gus menjejaskan keupayaan mereka menyelesaikan masalah yang lebih kompleks (Tall, 2013; Kidron, 2018a).

Dalam konteks pendidikan tinggi di Malaysia, khususnya di UiTM Cawangan Pulau Pinang, ramai pelajar kejuruteraan hanya menguasai formula dan prosedur pengiraan tanpa memahami makna simbol yang lebih mendalam. Contohnya, simbol kamiran sering dianggap sekadar proses pengiraan, sedangkan secara konseptual ia mewakili jumlah terkumpul. Kelemahan ini menyebabkan pelajar bergantung pada hafalan semata-mata dan gagal menguasai konsep dengan menyeluruh.

Beberapa sarjana menegaskan bahawa kefahaman simbol merupakan asas penting dalam pemikiran matematik kerana simbol berfungsi sebagai jambatan antara bahasa formal dengan aplikasi

(Arcavi, 1994; Pierce & Stacey, 2010). Salah tafsir simbol telah dikenalpasti sebagai punca utama kesilapan pelajar dalam kalkulus, bukannya kelemahan pengiraan semata-mata (Trigueros & Oktaç, 2009; Park, 2019). Hal ini menunjukkan bahawa tahap kefahaman simbol boleh memberi kesan langsung kepada prestasi penyelesaian masalah pelajar.

Berdasarkan isu tersebut, kajian ini dijalankan untuk meneliti hubungan antara kefahaman simbol matematik dengan keupayaan penyelesaian masalah kalkulus lanjutan dalam kalangan pelajar kejuruteraan di UiTM Cawangan Pulau Pinang. Kajian ini diharap dapat memberikan bukti empirikal mengenai peranan simbol matematik dalam meningkatkan kompetensi pelajar, sekali gus menyumbang kepada literatur pendidikan matematik yang menekankan kepentingan literasi simbol dalam pengajaran dan pembelajaran.

Kajian Literatur

Dalam pendidikan matematik, simbol memainkan peranan sebagai medium utama komunikasi antara konsep abstrak dan penyelesaian praktikal. Bagi pelajar kejuruteraan, kalkulus lanjutan merupakan kursus yang bukan sahaja menguji keupayaan pengiraan tetapi juga menuntut kefahaman terhadap simbol dan notasi matematik yang kompleks. Contohnya, simbol kamiran $\int$ tidak sekadar menandakan proses pengiraan luas di bawah lengkung, sebaliknya membawa makna konseptual tentang pengumpulan nilai yang berterusan. Begitu juga notasi had $\lim_{x \to a} f(x)$, yang sering disalah tafsir oleh pelajar sebagai sekadar penggantian nombor, sedangkan ia merujuk kepada idea nilai menghampiri (limit process).

Pelbagai laporan pengajaran mendapati bahawa kegagalan pelajar memahami makna simbol ini sering menghalang keupayaan mereka untuk menyelesaikan masalah bukan rutin yang memerlukan penaakulan konseptual. Menurut Tall (2013), salah satu cabaran utama dalam pembelajaran kalkulus adalah peralihan daripada pemahaman aritmetik kepada pemikiran formal yang memerlukan penguasaan simbol. Tanpa pemahaman ini, pelajar cenderung untuk bergantung kepada prosedur mekanikal semata-mata.

Di Malaysia, pensyarah universiti melaporkan fenomena yang sama. Walaupun pelajar mampu menggunakan formula kalkulus dalam latihan rutin, mereka menghadapi kesukaran apabila soalan berbentuk aplikasi sebenar atau apabila simbol dipersembahkan dalam bentuk berbeza daripada contoh yang biasa. Keadaan ini membuktikan bahawa kefahaman simbolik masih merupakan isu kritikal yang perlu ditangani dalam pengajaran kalkulus.

Kajian-kajian lepas telah memberikan penekanan terhadap beberapa aspek berkaitan kefahaman simbol matematik dan hubungannya dengan penyelesaian masalah. Arcavi (1994) memperkenalkan konsep *symbol sense* iaitu keupayaan pelajar untuk mentafsir, menghubungkan dan memanipulasi simbol secara fleksibel. Pelajar yang memiliki *symbol sense* dilaporkan lebih berjaya dalam menyelesaikan masalah matematik berbanding mereka yang hanya bergantung pada hafalan prosedur.

Selain itu, Pierce dan Stacey (2010) menekankan bahawa salah faham terhadap simbol algebra adalah punca utama kepada kesulitan dalam kalkulus, kerana kalkulus dibina atas asas pemahaman fungsi dan notasi simbolik. Kajian mereka menunjukkan bahawa pelajar sering melihat simbol sebagai “huruf” yang statik, tanpa mengaitkannya dengan makna dinamik.

Kajian oleh Kidron (2018b) pula mendapati bahawa pelajar universiti menghadapi cabaran dalam memahami simbol pembezaan dan kamiran. Mereka sering menganggap notasi seperti dy/dx sebagai formula operasi semata-mata, sedangkan simbol tersebut mewakili hubungan konsep antara pemboleh ubah. Hal ini mengakibatkan kesilapan dalam penyelesaian masalah yang lebih kompleks, terutamanya dalam aplikasi kejuruteraan.

Tambahan pula, Trigueros dan Oktaç (2009) meneliti konsep fungsi dalam kalkulus dan mendapati bahawa kelemahan pelajar dalam memahami fungsi sebagai objek matematik berkait rapat dengan kesukaran mereka mentafsir simbol. Ini menunjukkan bahawa kefahaman simbol bukan sahaja isu teknikal, tetapi juga isu epistemologi yang berkait dengan cara pelajar membina makna dalam matematik. Berdasarkan kajian-kajian ini, jelas bahawa isu kefahaman simbol matematik bukanlah fenomena terpencil, sebaliknya merupakan cabaran global yang turut memberi kesan besar kepada pelajar di Malaysia.

Permasalahan dan Objektif

Walaupun kalkulus lanjutan merupakan komponen penting dalam pendidikan kejuruteraan, tahap penguasaan pelajar terhadap subjek ini masih rendah, khususnya apabila melibatkan soalan yang menuntut kefahaman mendalam terhadap simbol matematik. Pelbagai kajian mendapati bahawa pelajar boleh menghafal rumus serta melakukan manipulasi prosedur, tetapi gagal apabila simbol digunakan dalam konteks yang berbeza atau lebih abstrak (Arcavi, 1994; Kidron, 2018). Situasi ini jelas kelihatan dalam kalangan pelajar ijazah sarjana muda di UiTM Cawangan Pulau Pinang, yang sering bergelut dengan simbol kamiran, pembezaan, serta had (*limit*) apabila ia dikaitkan dengan masalah dunia sebenar.

Tambahan pula, kebanyakan pendekatan pengajaran masih bersifat mekanikal dan menekankan pengiraan rutin tanpa memberi penekanan kepada makna simbolik di sebaliknya (Pierce & Stacey, 2010). Keadaan ini menyebabkan pelajar tidak mengembangkan *symbol sense* yang membolehkan mereka menafsir, menghubungkan dan memanipulasi simbol secara fleksibel. Kekurangan kajian dalam konteks tempatan mengenai hubungan langsung antara kefahaman simbol matematik dan penyelesaian masalah kalkulus lanjutan menimbulkan satu jurang ilmu yang perlu diisi.

Berdasarkan permasalahan kajian yang telah dikenalpasti, kajian ini bertujuan untuk menganalisis tahap kefahaman simbol matematik dalam kalangan pelajar ijazah sarjana muda dalam bidang kejuruteraan di UiTM Cawangan Pulau Pinang serta menilai keupayaan mereka dalam menyelesaikan masalah kalkulus lanjutan berasaskan tahap kefahaman simbol yang dimiliki. Selain itu, kajian ini juga berhasrat untuk mengenal pasti hubungan antara kefahaman simbol matematik dan keupayaan penyelesaian masalah dalam kalkulus lanjutan bagi menentukan sejauh mana penguasaan simbol memberi kesan terhadap prestasi akademik pelajar. Seterusnya, kajian ini berusaha untuk mencadangkan pendekatan pedagogi yang lebih berkesan dalam meningkatkan kefahaman simbol matematik, sekali gus memperkukuhkan kemahiran penyelesaian masalah pelajar kejuruteraan.

Metodologi

Kajian ini menggunakan reka bentuk kuantitatif deskriptif-korelasi, dengan tujuan menilai tahap kefahaman simbol matematik serta menganalisis hubungan antara kefahaman tersebut dengan keupayaan penyelesaian masalah kalkulus lanjutan. Sampel kajian terdiri daripada 40 orang pelajar ijazah sarjana muda dalam bidang kejuruteraan di UiTM Cawangan Pulau Pinang yang mengambil kursus kalkulus lanjutan. Pemilihan sampel dibuat menggunakan kaedah persampelan bertujuan (*purposive sampling*), kerana kumpulan ini dianggap mewakili populasi pelajar yang terdedah kepada cabaran penggunaan simbol matematik dalam pembelajaran kalkulus.

Instrumen kajian dibangunkan dalam dua komponen utama:

1. Ujian Kefahaman Simbol Matematik – terdiri daripada soalan berbentuk aneka pilihan dan struktur ringkas yang menilai kebolehan pelajar mengenal pasti, mentafsir dan menggunakan simbol matematik.
2. Ujian Penyelesaian Masalah Kalkulus Lanjutan – terdiri daripada soalan penyelesaian masalah berbentuk subjektif yang memerlukan pelajar mengaplikasikan kefahaman simbol untuk menyelesaikan persoalan kalkulus.

Data dianalisis menggunakan kaedah statistik deskriptif seperti min, sisihan piawai dan peratusan untuk mengenal pasti tahap purata kefahaman simbol dan keupayaan penyelesaian masalah pelajar. Analisis lanjut dijalankan dengan menggunakan korelasi Pearson untuk menilai kekuatan dan arah hubungan antara kefahaman simbol matematik dan prestasi penyelesaian masalah kalkulus. Keseluruhannya, metodologi kajian ini dirangka bagi memastikan proses pengumpulan dan penganalisisan data dapat memberikan gambaran yang jelas tentang hubungan antara kefahaman simbol matematik dan keupayaan penyelesaian masalah kalkulus lanjutan. Dengan reka bentuk yang sistematik dan instrumen yang komprehensif, kajian ini berpotensi menyumbang kepada penambahbaikan strategi pengajaran matematik di peringkat pengajian tinggi, khususnya dalam kalangan pelajar kejuruteraan.

Hasil dan Dapatan

Analisis awal menunjukkan tahap kefahaman simbol matematik dalam kalangan pelajar kejuruteraan adalah pada tahap sederhana. Skor min bagi ujian kefahaman simbol matematik ialah 62.5%, manakala skor min bagi ujian penyelesaian masalah kalkulus lanjutan ialah 58.7%. Hal ini memberi gambaran bahawa terdapat sebahagian pelajar yang masih keliru dengan penggunaan simbol pembezaan, kamiran, had dan notasi sigma.

Jadual 1: Tahap Kefahaman Simbol Matematik dan Penyelesaian Masalah

Tahap	**Kefahaman Simbol Matematik (%)**	**Penyelesaian Masalah Kalkulus (%)**
Tinggi (≥75%)	10% (4 pelajar)	8% (3 pelajar)
Sederhana (50–74%)	65% (26 pelajar)	60% (24 pelajar)
Rendah (<50%)	25% (10 pelajar)	32% (13 pelajar)

Majoriti pelajar berada pada tahap sederhana dalam kedua-dua aspek, namun lebih ramai pelajar mencatatkan skor rendah dalam penyelesaian masalah berbanding kefahaman simbol.

Hasil ujian korelasi Pearson menunjukkan terdapat hubungan yang signifikan dan positif antara kefahaman simbol matematik dengan keupayaan penyelesaian masalah dalam kalkulus lanjutan, dengan nilai $r = 0.68$, $p < 0.01$. Ini bermakna semakin tinggi kefahaman simbol matematik pelajar, semakin tinggi juga keupayaan mereka menyelesaikan masalah kalkulus lanjutan. Berdasarkan interpretasi pekali korelasi oleh Cohen (1988), nilai $r = 0.68$ menunjukkan hubungan yang kuat dan positif antara kedua-dua pemboleh ubah.

Jadual 2: Keputusan Korelasi Pearson

Pemboleh Ubah	**r**	**Sig. (p)**
Kefahaman Simbol & Penyelesaian Masalah	0.68	0.001 **

Pekali Penentuan turut dijalankan dan menunjukkan bahawa kefahaman simbol menyumbang sebanyak 46% ($R^2 = 0.46$) varians dalam keupayaan penyelesaian masalah. Ini membuktikan bahawa kefahaman simbol merupakan faktor penting yang mempengaruhi keupayaan pelajar dalam menyelesaikan masalah kalkulus lanjutan.

Perbincangan

Dapatan kajian ini menunjukkan bahawa tahap kefahaman simbol matematik dan keupayaan penyelesaian masalah kalkulus lanjutan pelajar berada pada tahap sederhana. Penemuan ini sejajar dengan kajian terkini oleh Kidron (2018) yang menegaskan bahawa simbol matematik sering menjadi sumber kekeliruan kerana pelajar gagal membezakan antara makna konseptual dan prosedural sesuatu simbol. Sebagai contoh, simbol ∫ bukan sahaja merujuk kepada proses pengiraan tetapi juga konsep luas di bawah lengkung. Kekeliruan sebegini membuktikan bahawa kesukaran pelajar bukan semata-mata pada prosedur tetapi juga pada pemahaman konseptual.

Kajian ini turut mendapati wujud hubungan signifikan yang kuat ($r = 0.68$, $p < 0.01$) antara kefahaman simbol dan keupayaan penyelesaian masalah. Penemuan ini selari dengan konsep *symbol sense* yang dibincangkan dalam kajian semasa, iaitu keupayaan pelajar mentafsir dan menghubungkan simbol secara fleksibel bagi menyokong penyelesaian masalah matematik (Nurjannah, 2024; Alkhateeb & Anagreh, 2020). Pelajar dengan *symbol sense* yang baik lebih mudah menstruktur strategi penyelesaian dan seterusnya meningkatkan prestasi dalam kalkulus lanjutan.

Tambahan pula, analisis regresi menunjukkan kefahaman simbol menyumbang 46% varians keupayaan penyelesaian masalah, namun masih terdapat 54% faktor lain seperti kemahiran penaakulan, strategi penyelesaian dan sikap pelajar yang turut mempengaruhi pencapaian. Hasil ini seiring dengan penemuan Messias (2024) dan Rupnow (2023) yang menekankan kepentingan *concept image* dan *concept definition* dalam memahami simbol serta aplikasi matematik yang kompleks. Oleh itu, pengajaran perlu menekankan bukan sahaja prosedur tetapi juga makna konseptual melalui strategi seperti visualisasi, peta konsep dan aplikasi kontekstual.

Kesimpulan

Kajian ini meneliti hubungan antara kefahaman simbol matematik dan keupayaan penyelesaian masalah kalkulus lanjutan melibatkan 40 pelajar Ijazah Sarjana Muda Kejuruteraan di UiTM Cawangan Pulau Pinang. Hasil analisis menunjukkan tahap kefahaman simbol berada pada aras sederhana namun mempunyai hubungan signifikan yang kuat dengan keupayaan penyelesaian masalah ($r = 0.68$, $p < 0.01$). Dapatan ini mengesahkan bahawa semakin tinggi penguasaan simbol, semakin baik prestasi pelajar dalam menyelesaikan masalah kalkulus lanjutan.

Penemuan ini menegaskan bahawa kefahaman simbol matematik bukan sahaja bersifat prosedural tetapi turut melibatkan pemahaman konseptual yang mendalam, selari dengan konsep *symbol sense* (Kidron, 2018b; Alkhateeb & Anagreh, 2020). Walau bagaimanapun, analisis regresi juga menunjukkan bahawa hanya 46% varians keupayaan penyelesaian dapat dijelaskan oleh kefahaman simbol, manakala selebihnya dipengaruhi faktor lain seperti kemahiran penaakulan, sikap dan pendekatan pengajaran.

Secara keseluruhan, kajian ini menekankan bahawa pengajaran matematik perlu memberi penekanan kepada pemahaman simbol secara konseptual melalui pendekatan kontekstual, visua, dan interaktif. Kajian lanjutan disarankan untuk melibatkan sampel yang lebih luas dan menggunakan kaedah kualitatif bagi memahami pengalaman pelajar secara lebih mendalam. Usaha ini diharap dapat meningkatkan kualiti pembelajaran kalkulus, sekali gus melahirkan graduan kejuruteraan yang lebih kompeten dan berdaya saing.

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UNDERSTANDING LEARNING STYLE: VISUAL, AUDITORY, READING/WRITING, AND KINESTHETIC (VARK) IN MATHEMATICS LEARNING

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ABSTRACT

Understanding students' preferred learning styles is crucial in enhancing teaching and learning effectiveness, especially in subjects that are often perceived as challenging, such as mathematics. The VARK model, comprising Visual, Auditory, Reading/Writing, and Kinesthetic modalities, offers a framework for identifying how students best process and retain information. In the context of university mathematics, the VARK approach can help explain differences in student performance, engagement, and problem-solving strategies. Visual learners may benefit from graphs, diagrams, and symbolic representations, while auditory learners respond well to discussions and verbal explanations. Reading/Writing learners are more comfortable with textbooks, problem sets, and formal proofs, whereas kinesthetic learners prefer hands-on activities, real-world applications, and interactive problem-solving. In this study, 30 engineering students were given questions to evaluate their learning style. Results show that most students have Kinesthetic and Visual learning styles. Recognizing these diverse preferences allows educators to design more inclusive and adaptive instructional strategies, blending multiple modalities to address varied student needs. Ultimately, integrating the VARK model into mathematics education can foster deeper conceptual understanding, improve learning outcomes, and support lifelong learning among university students.

Keywords: learning styles, mathematics, VARK, engineering students, instructional strategies

Introduction

Mathematics is widely regarded as one of the most essential yet challenging subjects in higher education. University students, regardless of their field of study, often encounter mathematics as part of their core curriculum, particularly in engineering, science, technology, and business-related programs. However, many students perceive mathematics as abstract, difficult, and intimidating, leading to anxiety and low performance. This challenge is not solely a matter of ability but is often influenced by the way students receive, process, and apply mathematical knowledge. Understanding how students learn, therefore, is a critical step toward improving teaching effectiveness and fostering deeper engagement with mathematical concepts.

The VARK model of learning styles, introduced by Fleming and Mills (1992), provides a framework to categorize learners based on their preferred sensory modality: Visual, Auditory, Reading/Writing, and Kinesthetic. Each learning style influences how students absorb and retain new information, as well as how they approach problem-solving in mathematics. For instance, visual learners may benefit from diagrams, graphs, and symbolic representations, while auditory learners may prefer lectures, discussions, and verbal explanations. Similarly, reading/writing learners thrive with textbooks, worked examples, and notes, while kinesthetic learners grasp mathematical concepts more effectively through real-world applications, experiments, and hands-on tasks. Recognizing these differences in learning preferences can shed light on why some students struggle with mathematics when traditional teaching methods are heavily skewed toward one style.

Given the diversity of student populations at universities, adopting a one-size-fits-all approach to mathematics instruction is no longer sufficient. Incorporating VARK-informed strategies allows educators to design more inclusive learning environments that accommodate multiple learning preferences. This integration not only enhances comprehension and performance but also encourages students to engage more actively with mathematics, thereby reducing anxiety and fostering positive attitudes toward the subject. Exploring the connection between VARK learning styles and mathematics learning at the university level is therefore essential to improving teaching practices, supporting student success, and preparing learners with the problem-solving skills required for lifelong learning in their academic and professional careers.

Literature Review

Learning styles have long been a topic of interest in higher education research, with the VARK model emerging as one of the most widely used frameworks for understanding how students learn. Fleming and Mills (1992) introduced the VARK model to classify learners into four categories: Visual, Auditory, Reading/Writing, and Kinesthetic. Numerous studies have demonstrated that students have diverse preferences for processing information, and these preferences can influence their learning outcomes, motivation, and attitudes toward specific subjects. While some students demonstrate a single dominant learning style, many are multimodal, meaning they use a combination of VARK modalities depending on the learning context. Recognizing this diversity provides educators with insights into designing instructional strategies that are inclusive and effective.

In the context of mathematics, learning styles play a particularly important role because the subject requires the integration of abstract reasoning, symbolic representation, and problem-solving skills. Visual learners often find diagrams, flowcharts, and spatial representations useful in understanding mathematical concepts, while auditory learners benefit from verbal explanations, classroom discussions, and peer collaboration. Reading/Writing learners are generally more comfortable with lecture notes, textbooks, and problem sets, whereas kinesthetic learners prefer hands-on approaches, such as applying mathematics to real-life scenarios or engaging in interactive simulations. Studies by Hawk and Shah (2007) and Surjono (2015) highlight that when mathematics instruction is closely aligned with students' learning preferences, their comprehension and performance improve significantly. Conversely, a mismatch between teaching strategies and learning styles may contribute to poor engagement and mathematics anxiety.

Recent research further emphasizes the value of multimodal teaching approaches in mathematics education. Leite, Svinicki, and Shi (2010) found that students who were exposed to multiple learning modalities developed greater flexibility in approaching mathematical problems, ultimately enhancing both their understanding and long-term retention. Moreover, adopting VARK-informed strategies has been shown to reduce learning barriers for students who struggle with mathematics by offering alternative pathways for comprehension. For example, incorporating visual graphs with step-by-step written explanations, alongside verbal discussions and real-world applications, ensures that students with different preferences can access and engage with the material. Literature suggests that integrating VARK into mathematics instruction at the university level is not only beneficial but necessary for addressing the diverse learning needs of modern students.

Methodology

This study adopts a descriptive survey design. A sample of 30 engineering students from UiTM Pulau Pinang enrolled in undergraduate mathematics-related courses was selected. The VARK questionnaire (Fleming & Baume, 2006) was administered to identify individual learning preferences. Data were analyzed using descriptive statistics to give view on their learning styles.

The VARK model, developed by Fleming and Mills (1992), is one of the most widely recognized frameworks for understanding individual differences in learning preferences. The acronym stands for Visual, Auditory, Reading/Writing, and Kinesthetic, representing four sensory modalities through which students commonly absorb, process, and retain information. Unlike rigid categorizations, VARK emphasizes that learners may rely on a single dominant mode or adopt a multimodal approach, using different preferences in different contexts. This flexibility makes VARK particularly useful for educators, as it highlights the need for instructional strategies that incorporate multiple teaching methods to meet diverse learner needs. Table 1 shows the description of VARK.

Table 1. Description of VARK Learning Styles

Learning style	Description
Visual	Learners process information best when it is presented graphically or symbolically. They respond well to diagrams, flowcharts, graphs, and spatial representations that make abstract ideas more concrete. In mathematics, visual learners benefit from seeing problems illustrated step by step, such as through geometric diagrams or visual models of algebraic functions.
Auditory	Learners prefer listening and speaking as their primary means of learning. They thrive in environments where discussions, explanations, and verbal problem-solving are emphasized. In mathematics, this could include engaging in group discussions about solutions, listening to explanations of problem-solving strategies, or verbally explaining steps to peers.
Reading/Writing	Learners prefer textual materials such as lecture notes, textbooks, and written problem sets. These learners often excel in mathematics when they are provided with detailed worked examples, written proofs, and step-by-step instructions. Their strength lies in organizing knowledge through lists, definitions, and summaries.
Kinesthetic	Learners learn best by doing, experimenting, and experiencing. They prefer practical, hands-on tasks that connect abstract ideas to real-world contexts. In mathematics, kinesthetic learners are more engaged when they can apply mathematical concepts to real-life problems, conduct simulations, or manipulate physical objects to represent abstract principles, such as using geometric tools or interactive digital software.

In this study, the students were evaluated on only three questions from VARK questionnaire to give insight into their learning styles. Table 2 shows the related questions and the learning styles based on the answers.

Table 2. Questions for learning styles evaluation

No.	Question	Answer	Learning style
1	A website has a video showing how to make a special graph or chart. There is a person speaking, some lists and words describing what to do and some diagrams. I would learn most from:	seeing the diagrams.	Visual
		listening.	Auditory
		reading the words.	Reading/Writing
		watching the actions.	Kinesthetic
2	When I am learning I:	I like to talk things through.	Auditory
		see patterns in things.	Visual
		use examples and applications.	Kinesthetic
		read books, articles and handouts.	Reading/Writing
3	I prefer a presenter or a teacher who uses:	demonstrations, models or practical sessions.	Kinesthetic
		question and answer, talk, group discussion, or guest speakers.	Auditory
		handouts, books, or readings.	Reading/Writing
		diagrams, charts, maps or graphs.	Visual

Findings and Discussion

Preliminary findings suggest that a majority of students display multimodal learning preferences, with combinations of visual and kinesthetic being most common Table 3. Students who identified strongly as visual learners demonstrated better performance in geometry and graph-related problems, while auditory learners performed well in collaborative tutorials. Reading/writing learners excelled in algebraic manipulations and theoretical proofs, whereas kinesthetic learners showed strength in applied mathematics and modeling tasks. The results support the argument that understanding and accommodating VARK preferences can reduce learning barriers in mathematics and promote more effective engagement Figure 1 to 3.

Table 3. Result from questions based on learning style in percentage

Question	Visual	Auditory	Reading/Writing	Kinesthetic
1	25%	0	8.3%	66.7%
2	12.5%	4.2%	0	83.3%
3	8.3%	25%	8.4%	58.3%

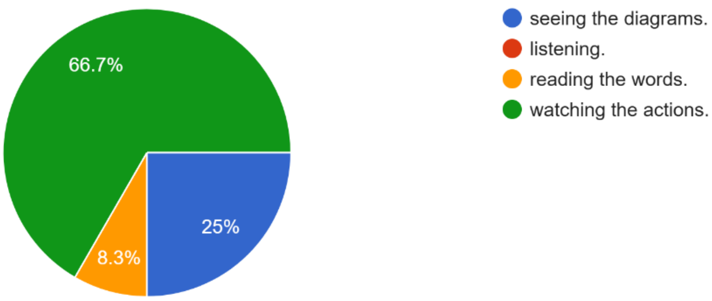

Figure 1. Result from question 1

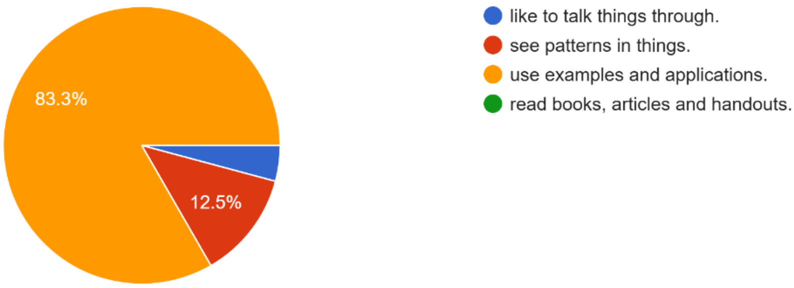

Figure 2. Result from question 2

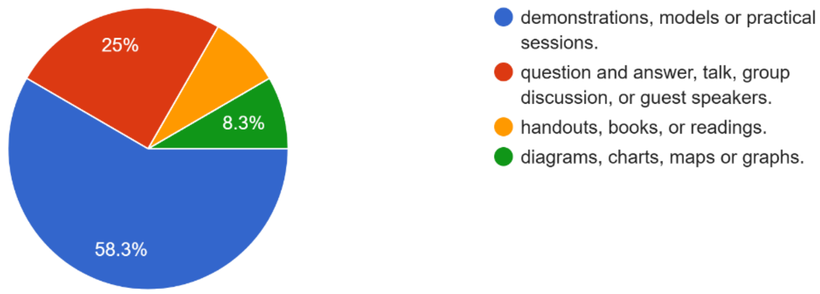

Figure 3. Result from question 3

Conclusion

The VARK model provides valuable insight into how university students learn mathematics. Recognizing and accommodating learning preferences can help educators design more inclusive and effective teaching methods. While students may have dominant learning styles, most benefit from multimodal approaches that combine Visual, Auditory, Reading/Writing, and Kinesthetic elements. By applying VARK-informed strategies, mathematics educators can enhance students' conceptual understanding, performance, and lifelong learning skills.

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BRIDGING THE GENERATIONAL GAP: A STUDY INTO LECTURERS' AND STUDENTS' CLASSROOM EXPERIENCES

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ABSTRACT

This paper studies the generational gap between lecturers and students in higher education through narrative inquiry. In many universities, Generation X and Millennial lecturers teach classrooms filled predominantly with Generation Y students. These generational differences influence teaching and learning practices, communication styles, and approaches to technology. Rather than relying on quantitative measures, this study adopts a qualitative narrative approach to capture the lived experiences of both lecturers and students. Stories will be collected through interviews, focus group discussions, and reflective journals, allowing participants to describe their perspectives on classroom interactions. The analysis will identify themes such as technology as both a bridge and a barrier, tensions between authority and facilitation, and moments of connection and misconnection across generations. Findings show that while generational differences can create misunderstandings, they also open opportunities for deeper engagement and mutual learning. The study concludes that bridging generational gaps in higher education requires valuing diverse teaching identities, integrating technology thoughtfully, and fostering inclusive approaches that meet students' evolving needs.

Keywords: generational gap, narrative inquiry, Gen X, Gen Y, Millennials

Introduction

Higher education classrooms today serve as an intersection of multiple generations, where on one side are the lecturers, often from Generation X (born between 1965 and 1980) and Millennials (born between 1981 and 1996), while on the other side are the students, most of whom belong to Generation Y. The differences in age and generational experiences affect more than just demographics but also the teaching methods, learning preferences, communication styles, and the way technology is used in the classroom.

Exploring the classroom based on narrative inquiry allows us to understand these generational differences not through numbers or statistics, but through real stories. Narratives reveal how both lecturers and students experience, how they perceive one another, and how moments of connection or misconnection unfold in real learning environments. The aim of this study is to explore how Gen X and Millennial lecturers narrate their teaching experiences with Gen Y students, how Gen Y students perceive their lecturers, and what kinds of stories emerge about challenges and opportunities in these inter generational encounters.

Problem Statement

The generational gap between lecturers and students in higher education presents both challenges and opportunities in the teaching and learning process. Lecturers, primarily from Generation X and the Millennial generation, often employ pedagogical practices shaped by their own formative experiences. On the other hand, current students mostly belong to Generation Y which frequently described as digital natives (Lahuerta-Otero et al., 2019). These differences influence classroom expectations, communication styles, and approaches to technology. For instance, Generation X lecturers are often associated with structured, pragmatic methods, while Millennial lecturers tend to prefer collaborative and technology-driven approaches (Seemiller & Grace, 2019). Meanwhile, Generation Y students expect interactive, flexible, and technology-supported learning environments. These mismatched expectations can create tension, misunderstandings, and gaps in classroom engagement. Despite the importance of this issue, limited qualitative research has focused on how both lecturers and students narrate and make sense of these inter-generational encounters (Clandinin & Connelly, 2000). Addressing this gap is critical in fostering inclusive teaching strategies that embrace generational diversity.

Research Objectives

This study aims to:

1. Explore how Generation X and Millennial lecturers narrate their teaching experiences with Generation Y students.
2. Examine how Generation Y students perceive their classroom interactions with lecturers from different generations.
3. Identify the challenges within inter generational classroom encounters.
4. Investigate the role of technology, authority, and facilitation in shaping points of connection and misconnection between lecturers and students.

Literature Review

Generational theory suggests that people from the same age cohort share certain values, habits, and worldviews shaped by the events and conditions of their formative years (Moisescu & Gică, 2020). In education, this translates into significant differences in how various generations view authority, independence, collaboration, and the use of technology.

Generation X lecturers are often characterized as practical, independent, and shaped by a pre-digital learning environment. They may prefer structured, disciplined approaches in teaching and expect students to take responsibility for their own learning. In contrast, Millennial lecturers, who are closer in age to their students, are typically seen as more collaborative and tech-savvy. They are often comfortable with digital platforms, online learning tools, and interactive approaches that engage students more directly (Seemiller & Grace, 2019).

Generation Y students, who dominate current higher education settings, are considered digital natives where they have grown up with technology and often expect learning to be interactive, flexible, and supported by digital tools. They value immediate feedback (Raslie, Pit & Ting, 2016), active participation, and practical applications of what they learn (Carter, 2008). These generational dynamics can lead to tension, but also to opportunities for richer teaching and learning when approached thoughtfully.

Narrative inquiry has been widely used in education to capture the lived stories of teachers and students. According to Clandinin and Connelly (2000), stories are focus on how people make sense of their experiences. By focusing on personal experiences, narrative inquiry allows researchers to uncover how individuals interpret events, challenges, and relationships in ways that statistics cannot. For the present study, narrative inquiry provides the opportunity to explore how generational differences in higher education are experienced and told by both lecturers and students.

Methodology

This research adopts a qualitative narrative inquiry approach. The goal is not to measure the generational gap in numerical terms but to understand the lecturers' and students' experiences and interpret it based on their personal stories.

The participants included a group of ten lecturers from both Generation X and the Millennial generation, along with fifteen undergraduate students representing Generation Y. A purposive sampling method was used to ensure that participants come from different academic disciplines, to allow diverse classroom experiences. Data was collected through in-depth interviews with lecturers and focus group discussions with students. These methods gave space for participants to share their stories in their own words, providing insight into how they perceive and navigate generational differences in the classroom.

The narratives was analyzed using thematic analysis. This involves identifying recurring storyline and themes across participants' accounts (Riessman, 2008). Likely themes may include the role of technology in teaching and learning, the tension between authority and facilitation, and moments of connection or misconnection between students and lecturers. Ethical considerations was the center of the study, which included informed consent, confidentiality, and the respectful handling of participants' stories.

Findings and Discussion

Intuitive inquiry prioritizes the actual experiences of participants and thus provides more insights into this study. Even the perspectives of Generation X and Millennial lecturers is distinct, they were united by the same problem which is adaptation fatigue. Gen X lecturers often described their experiences as professional responsibility and earned authority, expressing an intuitive sense that their foundational training was being challenged by a new learning culture. Their Millennial counterparts whom act as generational intermediaries, felt a more internal conflict, intuitively sensing a tension between their desire for a collaborative, democratic classroom and the institutional pressure to maintain traditional standards of rigor and discipline, leaving them feeling caught between two worlds.

The perceptions of Generation Y students provided a crucial reflection to the lecturers' experiences. Their interpretation of what constitutes authentic teaching varied significantly. They frequently naturally perceived many Gen X lecturers' expert-led, disciplined style as a sign of disengagement and a lack of interest in their personal development. In contrast, while they leaned towards the relatable and accessible style of Millennial lecturers, some students intuitively questioned the depth of their expertise, worrying that a focus on facilitation might affect the knowledge transmission.

The first challenge focused on technology as both a bridge and a barrier. Millennial lecturers use digital tools effectively, making learning more engaging and accessible. Students also shared experiences where some Gen X lecturers are less comfortable with technology. However, students did understand and recognize the value of Gen X lecturers' emphasis on critical thinking and discipline, which complements their reliance on digital learning.

The second challenge involves authority versus facilitation. Gen X lecturers express difficulties in maintaining authority in classrooms where students expect collaborative and participatory learning. Meanwhile, Millennial lecturers face challenges in balancing a more relaxed, facilitative teaching style with the need to maintain professional boundaries. These contrasting narratives highlighted how generational values shaped teaching identities and student expectations.

The third challenge relates to moments of connection and misconnection where students and lecturers shared stories of misunderstandings concerning different expectations about feedback speed, participation and classroom etiquette. At the same time, both groups recounted positive experiences where generational differences taught them to develop mutual respect and meaningful connections.

These stories reveal that generational diversity in the classroom can be a source of both tension and opportunity, depending on how the situation is handled.

Lastly, the findings suggest that technology, authority, and facilitation play intertwined roles in shaping the classroom dynamic between lecturers and students. On one hand, technology provides a common ground, enabling interactive learning tools and online platforms that encourage collaboration and engagement. However, generational differences in digital articulateness sometimes create moments of disconnection, with students expecting immediate apprehension and interactivity while some lecturers prioritize traditional pedagogical methods. Authority emerged as another point of tension where students increasingly value democratic and ideological learning environments. On the contrary, Gen X lecturers often perceive that there is a need to maintain hierarchical boundaries to preserve discipline and academic rigorousness. Facilitation, therefore, becomes the mediating factor where Millenial lecturers prefer to adopt flexible, student-centered strategies and tend to transform authority into guidance rather than control thus enabling a more meaningful exchange of perspectives. The interplay of these elements highlights that bridging the generational gap requires balancing respect for authority with openness to technological innovation and facilitative teaching practices.

Conclusion

The generational gap between Gen X and Millennial lecturers and Gen Y students represents more than a difference in age where it reflects broader shifts in culture, technology, and pedagogy. Through narrative inquiry, this study highlighted the real experiences of both lecturers and students which offers insight into how generational perspectives shape teaching and learning in higher education.

The findings contribute to understanding classroom dynamics but also offer practical implications. Universities may use these insights to design professional development for lecturers while promoting the thoughtful use of technology, and encourage approaches that honor both traditional teaching values and contemporary student expectations. Ultimately, bridging the generational gap is not about erasing differences, but about valuing them as opportunities to build more inclusive and dynamic learning environments.

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DATA ANALYTICS FOR ELECTRIC VEHICLE SPECIFICATIONS AND PRICES

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ABSTRACT

The worldwide surge in Electric Vehicle adoption underscores the importance of not only production and sales but also the characteristics that shape consumer choices, such as price, battery capacity, range, charging time, and performance. While macro-level data reveals the overall market trajectory, micro-level analysis of vehicle specifications provides insight into how product attributes and pricing influence adoption across regions. This study examines the Electric Vehicle Specifications and Price dataset, which comprises both macro- and micro-level data, to be evaluated using data analytics in Python. The study emphasises the establishment of protocols for data management quality before doing any descriptive analysis.

Keywords: electric vehicle; data analytics, macro-level, micro-level, data quality

Introduction

Electric vehicles are a fast-expanding area of the automotive industry, with significant importance in sustainability, innovation, and customer interest. The EV now have shifted from niche to mainstream, driven by rapidly decrease cost, better emission policies, and extending model variation in the market. EV sales exceed 17 million in 2024 worldwide, accounting for 20 percent of all new cars; China remained the epicenter, with almost 11 million EV sold which nearly two-thirds of global sales (ahay38,2025). Analysts expect momentum to continue in 2025, with 22 million EVs projected worldwide as battery costs fall and more affordable model arrive (IEA, 2025).

Beyond sales, the supply side has scaled dramatically within 2024 production reached almost 17.3 million EV and 70 percent of which were built in China. Capacity build-out in batteries is running ahead of demand, with 2025 cell manufacturing capacity estimated in the multi-terawatt-hour range, indicating continued cost pressure and availability (IEA, 2025).

Asia anchors today's EV market, with China's share hovering around 50 percent of new car sales in 2024, while Europe averaged roughly one in four in early 2025, and the United States grew, albeit more slowly than the previous year. Focusing in Southeast Asia, adaptation is accelerating from a low base as governments roll out incentives and charging networks. As ASEAN uptake rises year-on-year, Thailand currently leads the region's transition.

Malaysia is entering a phase of faster adoption, supported by tax incentives and a growing model line-up. EV as BEV penetration remains modest but rising, with BEVs accounting for almost 3.4 percent of new car sales in 1H 2025, a sharp increase from 2024 levels (Lye, 2025). Policymakers target 10,000 public charging points under the Low Carbon Mobility Blueprint. As of October 2024, about 3,354 chargers had been installed, and authorities continue to emphasize network expansion to sustain uptake (Shahrilmd, 2025; *PLANMalaysia - MEVnet*, 2025).

This study employs the Electrical Vehicle Specifications and Price dataset (Fatih İlhan, 2023), which compiles detailed information on EV models worldwide. By analyzing specifications (e.g., battery size, range, acceleration, top speed) alongside price data, we gain a better understanding of the trade-offs consumers face and identify trends that differ globally across Asia and within Malaysia's emerging markets. Such granular analysis can reveal whether high upfront costs or lower costs drive adoption, and how these factors align with Malaysia's policy targets and infrastructure readiness.

Problem Statements

Despite the rapid growth of EV worldwide, adoption rate remains uneven across regions and market segments. While global data highlights rising sales volumes, less attention is given to micro-level factors such as price, battery capacity, range and performance that directly influence consumer adoption.

In Asia, focusing on Malaysia, EV penetration is still modest compared to global leaders like China and Europe. High upfront costs, limited model variety, and concerns over charging infrastructure are often known as barriers. However, there is limited empirical research of quantitatively links EV specifications and pricing to adoption trends in Malaysia context. This lack of insight leads to poor incentives and market strategies by policymakers and industries that align to consumer preferences and technological readiness. // write para to align the problem with summary of dataset.

Data Management Towards Quality Data

Data quality management is important to ensure it is useful for business purposes in term of accuracy, completeness, validity, uniqueness, timeliness and consistency. This empowers the business for decision making, understand spending, enhance customer experiences and drive business growth. Hence, several careful steps were taken to process the dataset of EV for better analysis and followed as elaborated in the next subsection.

Data Definition Installing and Important Libraries

The code begins by installing and importing necessary libraries, including pandas for data manipulation, matplotlib.pyplot, and seaborn for data visualization. Figure 1 shows process of loads the electric vehicle dataset (EV_cars.csv) into a DataFrame called df_ev. The column Price.DE., which most likely shows vehicle prices in Euros, is converted to Malaysian Ringgit (RM) at an exchange rate of around 4.7. Finally, the columns name is changed from Price.DE. to RM for clarity and consistency in the local context.

```
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns
df_ev = pd.read_csv('EV_cars.csv')
df_ev['Price.DE.'] = df_ev['Price.DE.']*4.7
df_ev.rename(columns={'Price.DE.': 'RM'}, inplace=True)
```

Figure 1: Process of importing important libraries for excessing the dataset as data frame

The next initial preparation after the data was loaded and to get prepared for quality assessments were profiling the data, parsing and standardization to make sure all the data is standard across all records such as ‘Tesla Model 3’ vs ‘tesla model 3”, generalization or also known as cleansing null content, marching and check for inconsistent and misspelling,

Data Quality Assessment

1. Format check

The coding in Figure 2 describes output that include a notice for each column that indicates whether there are any formatting concerns. If a column contains entries that cannot be translated to numerical values, it will show the number of problematic entries that require attention. Columns with no difficulties will simply indicate that there are no formatting concerns. This makes it easier to identify columns that need extra inquiry or cleaning, resulting in more effective error detection and data analysis.

```
for col in df_ev.select_dtypes(include='object'):
    cleaned = pd.to_numeric(df_ev[col].str.replace(',', '').str.replace(' ', ''), errors='coerce')

    num_errors = cleaned.isna().sum()

    if 0 < num_errors < len(df_ev):
        print(f" Possible formatting errors in column '{col}': {num_errors} entries could not be converted to numeric.")
    else:
        print(f" No formatting issues in column '{col}'.")
```

```
No formatting issues in column 'Car_name'.
No formatting issues in column 'Car_name_link'.
No formatting issues in column 'Speed_Flag'.
```

Figure 2: *Process of Handling Formatting Issues*

2. Completeness checks

For the purposes of continuous data quality monitoring, completeness was verified by evaluating the following columns: Car_name, Efficiency, Fast_charge, RM, and Range. These fields are essential for conducting accurate analyses of electric vehicles. In Figure 3, a script was used to calculate the number of missing values in each of these columns, along with the total number of rows containing at least one missing value across these key attributes. This approach helps to identify incomplete records that could impact analysis or require human validation. Only a summary of missing data is displayed to streamline auditing and support targeted evaluation.

```
# List of essential columns
essential_cols = ['Car_name', 'Efficiency', 'Fast_charge', 'RM', 'Range']

# Check for missing values in these columns
missing_values = df_ev[essential_cols].isnull().sum()

# Display the results
print("Missing values in essential columns:")
print(missing_values)

# Check if there are any rows with missing values in these essential columns
rows_with_missing = df_ev[essential_cols].isnull().any(axis=1).sum()

print(f"\nTotal rows with missing values in essential columns: {rows_with_missing}")
```

```
Missing values in essential columns:
Car_name       0
Efficiency     0
Fast_charge    0
RM             0
Range          0
dtype: int64

Total rows with missing values in essential columns: 0
```

Figure 3: *Detecting Missing Values Through Completeness Checks*

3. Reasonableness checks

As part of the reasonable checks for ensuring data validity, two key evaluations were performed. First, in Figure 4 shows vehicle entries priced between RM 290,000 and RM 400,000 were filtered to identify high-end models that may require verification for pricing accuracy; second in Figure 5, a correlation analysis between Battery size and Range was performed to validate the logical relationship that larger batteries typically support longer driving distances. These tests guarantee that individual values fit within expected bounds and that associated features follow consistent patterns, which contributes to the dataset's overall integrity.

```
# Check for price values within the range (RM 290,000 to RM 400,000)
outliers = df_ev[(df_ev['RM'] >= 290000) & (df_ev['RM'] <= 400000)]

# Display the rows with outlier prices in a DataFrame format
outliers
```

	Battery	Car_name	Car_name_link	Efficiency	Fast_charge	RM	Range	Top_speed	acceleration..0.100.	Speed_Flag
6	71.0	BMW IX XDRIVE40	https://ev-database.org/car/1472/BMW-iX-xDrive40	197	480.0	363310.0	360	200	6.1	OK
14	75.0	TESLA MODEL Y PERFORMANCE	https://ev-database.org/car/1183/Tesla-Model-Y...	181	640.0	299234.9	415	250	3.7	OK
18	74.0	BMW IX3	https://ev-database.org/car/1535/BMW-iX3	192	520.0	316310.0	385	180	6.8	OK
21	85.4	BYD HAN	https://ev-database.org/car/1784/BYD-HAN	180	450.0	332783.5	475	180	3.9	OK
26	81.2	BMW I5 EDRIVE40 SEDAN	https://ev-database.org/car/1906/BMW-i5-eDrive...	171	710.0	329940.0	475	193	6.0	OK
27	80.7	BMW I4 M50	https://ev-database.org/car/1519/BMW-i4-M50	179	700.0	332760.0	450	225	3.9	OK
46	96.0	KIA EV9 99.8 KWH AWD	https://ev-database.org/car/1835/Kia-EV9-998-k...	226	740.0	359503.0	425	200	6.0	OK
51	86.4	BYD TANG	https://ev-database.org/car/1783/BYD-TANG	240	330.0	335580.0	360	180	4.6	OK
55	74.0	KIA EV6 GT	https://ev-database.org/car/1471/Kia-EV6-GT	206	940.0	343053.0	360	260	3.5	OK

Figure 4: *Price Range for Electric Vehicles*

```
print(df_ev[['Battery', 'Range']].corr())
```

```
          Battery     Range
Battery  1.000000  0.881937
Range    0.881937  1.000000
```

Figure 5: *Battery size and Range Analysis*

4. Limit Checks

To execute limit checks as part of data validation, two conditions were used to identify entries that may exceed usual performance bounds for electric vehicles. First, in Figure 6, the dataset was filtered to find EVs with a driving range more than 600 km, which could indicate exceptional performance or probable data entry errors. Second in Figure 7, acceleration values (ranging from 0 to 100 km/h) were calculated, and any records with values less than 1 second or greater than 15 seconds were noted. These limitations assist keep acceleration numbers within realistic expectations. Both filters produce simplified outputs that include only important columns for targeted human inspection and verification of extreme or potentially inaccurate values.

```
# Filter the DataFrame for cars with a range greater than 600 km
result = df_ev[df_ev['Range'] > 600][['Car_name', 'Range']]

# Display the result as a DataFrame
result
```

	Car_name	Range
67	Lucid Air Dream Edition R	685
86	Mercedes EQS 450+	635
131	Lucid Air Grand Touring	665
147	Lucid Air Dream Edition P	665
226	Mercedes EQS 450 4MATIC	610

Figure 6: *Cars with a Range Greater than 600 km*

```
df_ev[(df_ev['acceleration..0.100.'] < 1) | (df_ev['acceleration..0.100.'] > 15)]
```

	Battery	Car_name	Car_name_link	Efficiency	Fast_charge	Price.DE.	Range	Top_speed	acceleration..0.100.	Brand
25	25.0	Dacia Spring Electric 45	https://ev-database.org/car/1705/Dacia-Spring-...	152	180.0	22550.0	165	125	19.1	Dacia

Figure 7: *Acceleration Calculation 1s or Greater Than 15s*

5. Review of the data to identify outlier

The purpose of reviewing the data to identify outliers is to detect any data points that significantly differ from the rest of the dataset, which may indicate errors, rare cases, or exceptional values. In the context of electric vehicle data, identifying outliers in top speed can help analysts spot cars that are unusually fast or slow compared to the majority. The data is then sorted in descending order based on the. Top_speed column, allowing the user to quickly identify vehicles with exceptionally high or low speeds. The output displays the car names alongside their respective top speeds, highlighting models such as the Maserati GranTurismo Folgore with a top speed of 320 km/h and the Tesla Model S Plaid at 282 km/h, which represent the upper extreme. Conversely, vehicles like the Dacia Spring Electric 45, with a top speed of just 125 km/h, represent the lower extreme. Figure 8 visualize inspection aids in spotting potential outliers within the dataset, which may require further statistical analysis or consideration during data pre-processing.

```
# Load the dataset
df_ev = pd.read_csv('EV_cars.csv')

# Sort by top speed to check for unusually high or low values
print(df[['Car_name', 'Top_speed']].sort_values(by='Top_speed', ascending=False))
```

```
                          Car_name  Top_speed
215      Maserati GranTurismo Folgore       320
17                 Tesla Model S Plaid       282
131           Lucid Air Grand Touring       270
147          Lucid Air Dream Edition P       270
67           Lucid Air Dream Edition R       270
..                                 ...       ...
334      Toyota PROACE Shuttle L 50 kWh       130
336    Citroen e-SpaceTourer XL 75 kWh       130
359            Fiat E-Ulysse L3 50 kWh       130
122   Dacia Spring Electric 65 Extreme       125
25            Dacia Spring Electric 45       125

[360 rows x 2 columns]
```

Figure 8: *Review of The Data to Identify Outliers*

6. Assessment of data by subject area experts

Assessment of data by subject area experts refers to the process of having professionals who are knowledgeable in a specific field review and validate the dataset used for analysis. These experts evaluate whether the data is accurate, complete, consistent, and relevant for the intended purpose. The output shown the result of a filter applied to identify electric vehicles (EVs) with battery capacities less than 20 kWh. After performing the necessary data cleaning and conversion, the script checks for EVs that meet this condition. However, Figure 9 indicates the output displays an empty data frame, which means that no vehicles in the dataset have battery capacities below 20 kWh.

```
df_ev.columns = df_ev.columns.str.strip()

# Convert to numeric
df_ev['Battery'] = pd.to_numeric(df_ev['Battery'], errors='coerce')

# Identify small battery capacity
small_battery_ev = df_ev[df_ev['Battery'] < 20]

print("EVs with battery capacity < 20 kWh:")
print(small_battery_ev[['Car_name', 'Battery']])
```

```
EVs with battery capacity < 20 kWh:
Empty DataFrame
Columns: [Car_name, Battery]
Index: []
```

Figure 9: *Assessment of Data by Subject Area Experts*

7. Missing values

Missing values refer to the absence of data in one or more fields of a dataset. In the context of data analysis, missing values can occur for many reasons, such as human error during data entry, equipment malfunctions during data collection, or inconsistencies in data formats when merging datasets. These gaps in the data can affect the quality of analysis and the accuracy of machine learning models if not properly addressed. Figure 10 shows the count of missing values for each column then it will filter the column that have missing values.

```
# Load the data
df_ev = pd.read_csv("EV_cars.csv")

# Strip spaces in column names (optional good practice)
df_ev.columns = df_ev.columns.str.strip()

# Count missing values in each column
missing_counts = df_ev.isnull().sum()

# Filter columns with missing values
missing_columns = missing_counts[missing_counts > 0]

print("Columns with missing values:")
print(missing_columns)
```

```
Columns with missing values:
Fast_charge     2
Price.DE.      51
dtype: int64
```

Figure10: *Detecting Column with Missing Values*

8. Smoothing noisy data

Smoothing noisy data is a crucial pre-processing step in data analysis that involves reducing random variations or fluctuations, often referred to as "noise," in order to highlight the underlying patterns or trends within the dataset. By doing this in Figure 11, it shows the smoothed battery capacity using a moving average.

```
# Load data
df_ev = pd.read_csv("EV_cars.csv")
df_ev.columns = df_ev.columns.str.strip()

# Convert to numeric (in case there are errors or strings)
df_ev['Battery'] = pd.to_numeric(df_ev['Battery'], errors='coerce')

# Apply a 3-point moving average
df_ev['BatteryCapacity_Smoothed'] = df_ev['Battery'].rolling(window=3).mean()

# Show a few rows
print(df_ev[['Battery', 'BatteryCapacity_Smoothed']].head(10))
```

```
   Battery  BatteryCapacity_Smoothed
0     75.0                       NaN
1     57.5                       NaN
2     60.5                 64.333333
3     61.7                 59.900000
4     75.0                 65.733333
5     57.5                 64.733333
6     71.0                 67.833333
7     64.0                 64.166667
8     44.0                 59.666667
9     82.5                 63.500000
```

Figure11: *Analysis of Smooth Noisy Data of Battery Capacity*

9. Identify and remove outlier

First in Figure 12, extra spaces in column names are stripped for consistency. Then in Figure 13, it filters the dataset to find these unusually high or low EV prices and prints the names and RM prices of the outlier vehicles. In the output, cars like the BMW i7 xDrive60 and Audi e-tron GT RS are identified as having prices outside the normal range. This process is essential in identifying pricing anomalies that could affect data analysis or decision-making.

```python
import pandas as pd

# Read CSV and clean column names
df_ev = pd.read_csv('EV_cars.csv')
df_ev.columns = df_ev.columns.str.strip()

# Convert Euro to RM and rename column
df_ev['Price.DE.'] = pd.to_numeric(df_ev['Price.DE.'], errors='coerce')
df_ev['RM'] = df_ev['Price.DE.'] * 4.7
df_ev.drop(columns='Price.DE.', inplace=True)

# IQR calculation
Q1 = df_ev['RM'].quantile(0.25)
Q3 = df_ev['RM'].quantile(0.75)
IQR = Q3 - Q1

# Bounds
lower_bound = Q1 - 1.5 * IQR
upper_bound = Q3 + 1.5 * IQR

# Detect outliers
price_outliers = df_ev[(df_ev['RM'] < lower_bound) | (df_ev['RM'] > upper_bound)]

# Display
print("EVs with unusually high or low prices (in RM):")
print(price_outliers[['Car_name', 'RM']])
```

Figure12: *Identify Price Outliers*

```
EVs with unusually high or low prices (in RM):
                                  Car_name          RM
31                        BMW i7 xDrive60    657530.0
48                      Audi e-tron GT RS    686435.0
67               Lucid Air Dream Edition R  1024600.0
107                    Tesla Model X Plaid   545059.0
116                             BMW iX M60   639670.0
125              Mercedes EQS SUV 580 4MATIC 636539.8
131                   Lucid Air Grand Touring 747300.0
147              Lucid Air Dream Edition P  1024600.0
170                         Lotus Eletre R   709653.0
183                       Lucid Air Touring  606300.0
192                  Mercedes EQS 580 4MATIC 666013.5
205                        BMW i7 eDrive50   543790.0
207                     Porsche Taycan GTS   657558.2
210                     BMW i7 M70 xDrive    854460.0
231                 Porsche Taycan Turbo S   929378.0
254              Mercedes EQS AMG 53 4MATIC+ 728542.3
262              Mercedes EQS SUV 500 4MATIC 585361.5
268                  Mercedes EQS 500 4MATIC 589276.6
269                  Porsche Taycan 4S Plus  564380.7
273              Mercedes EQS SUV 450 4MATIC 538662.3
286           Mercedes EQE SUV AMG 43 4MATIC 587124.0
289                       Porsche Taycan 4S  538427.3
296          Mercedes EQE SUV AMG 53 4MATIC+ 655358.6
306                    Porsche Taycan Turbo  772774.0
311          Porsche Taycan 4S Cross Turismo 563595.8
324         Porsche Taycan GTS Sport Turismo 662032.6
325       Porsche Taycan Turbo Cross Turismo 779485.6
329     Porsche Taycan Turbo S Cross Turismo 936089.6
335     Porsche Taycan Turbo S Sport Turismo 933852.4
341     Porsche Taycan 4S Plus Sport Turismo 564380.7
344          Porsche Taycan 4S Sport Turismo 538427.3
349       Porsche Taycan Turbo Sport Turismo 777248.4
```

Figure13: *The Output of EV's With High or Low Prices*

10. Resolve inconsistencies

The output displays in Figure 14 shows the cleaned dataset after missing values in the Range and Top_speed columns were removed. The code fills in any missing values with the mean of each column, which is a popular imputation strategy for ensuring data completeness. Alternatively, rows with missing values in these columns could be removed. The cleaned dataset, as stated by the head() method, demonstrates that no NaN values exist in the Range and Top_speed columns. Each row now has detailed information on various EV models, including battery capacity, car name, efficiency, quick charging capability, and acceleration. This pre-processing phase prepares the dataset for subsequent analysis or modeling. Furthermore, the method corrects errors in the dataset to maintain uniformity and accuracy.

```
# Fill missing values with the mean (for numerical columns like Range or Top_speed)
df_ev['Range'] = df_ev['Range'].fillna(df_ev['Range'].mean())
df_ev['Top_speed'] = df_ev['Top_speed'].fillna(df_ev['Top_speed'].mean())
# Alternatively, drop rows with missing values in specific columns
df_ev = df_ev.dropna(subset=['Range', 'Top_speed'])
# Print the cleaned dataset
print(df_ev.head())
```

```
   Battery                           Car_name  \
0     75.0  Tesla Model Y Long Range Dual Motor
1     57.5                       Tesla Model 3
2     60.5                          BYD ATTO 3
3     61.7              MG MG4 Electric 64 kWh
4     75.0  Tesla Model 3 Long Range Dual Motor

                                   Car_name_link  Efficiency  Fast_charge  \
0  https://ev-database.org/car/1619/Tesla-Model-Y...         172        670.0
1     https://ev-database.org/car/1991/Tesla-Model-3         137        700.0
2        https://ev-database.org/car/1782/BYD-ATTO-3         183        370.0
3  https://ev-database.org/car/1708/MG-MG4-Electr...         171        630.0
4  https://ev-database.org/car/1992/Tesla-Model-3...         149        780.0

   Range  Top_speed  acceleration..0.100.          RM
0    435        217                   5.0  1303685.53
1    420        201                   6.1  1020999.80
2    330        160                   7.3   985766.25
3    360        160                   7.9   883379.10
4    505        201                   4.4  1219809.80
```

Figure14: *Resolving Inconsistencies of The Data*

Result of Comprehensive Visualization

This bar chart in Figure 15 displays the top ten electric vehicle (EV) brands with the most model listings in the dataset. To do this, we first extracted the brand name from the Car_name column by extracting the first word (for example, "Tesla" from "Tesla Model 3"). We then counted how many EV models each brand provides and chose the top ten brands based on model count. The horizontal bar chart clearly shows which brands are most prevalent in the EV market, according to the dataset. For example, if Tesla is at the top, it means that it has the most diverse EV line-up among the entries. This type of analysis helps us understand brand dominance and market diversity in the EV business.

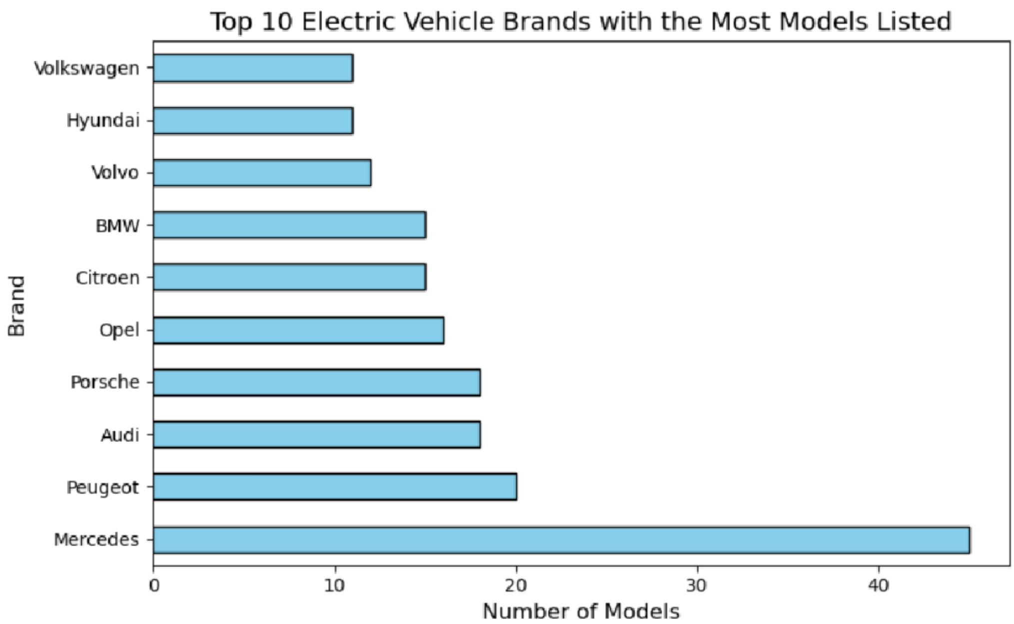

Figure15: *Bar Chart of Top 10 Electric Vehicle Brands with the Most Models Listed*

The pie chart in Figure 16 illustrates the distribution of electric vehicles based on their 0-100 km/h acceleration times, which are categorized into four speed ranges: 0-5 seconds, 5-10 seconds, 10-15 seconds, and 15-20 seconds. To create this graph, we divided the vehicles into bins based on their acceleration from 0 to 100 km/h, using the acceleration column from 0.100. Each bin represents a performance category, and the chart depicts the percentage of vehicles in each group.

The generated visualisation demonstrates how performance varies among the EVs in the dataset. For example, suppose a substantial percentage of the chart falls in the "5-10 sec" category. In that case, it means that most EVs have a moderate acceleration time, which is common in both consumer and mid-range performance models.

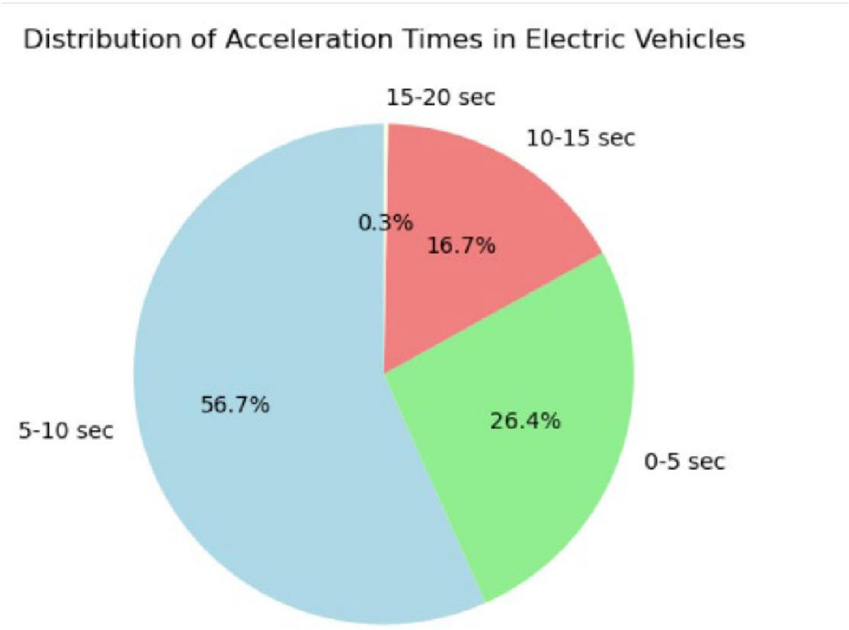

Figure 16: *Pie Chart of Distribution of Acceleration Times in Electric Vehicles*

The distribution of top speeds (in km/h) for electric vehicles in the dataset is displayed in the histogram in Figure 17. The cars maximum speed is shown by the x-axis, while the number of vehicles falling within each speed range is displayed by the y-axis. To visualise the general distribution form, we enabled the kernel density estimate (KDE) line and used Seaborns 15-bin histplot function to arrange the speeds into intervals.

The graphic shows us which EV models have the most common speed ranges. A peak in the histogram between 150 and 200 km/h, for instance, indicates that the majority of the EVs in the dataset are built to run in that range. The KDE line offers a smooth curve that illustrates the overall distribution of the data.

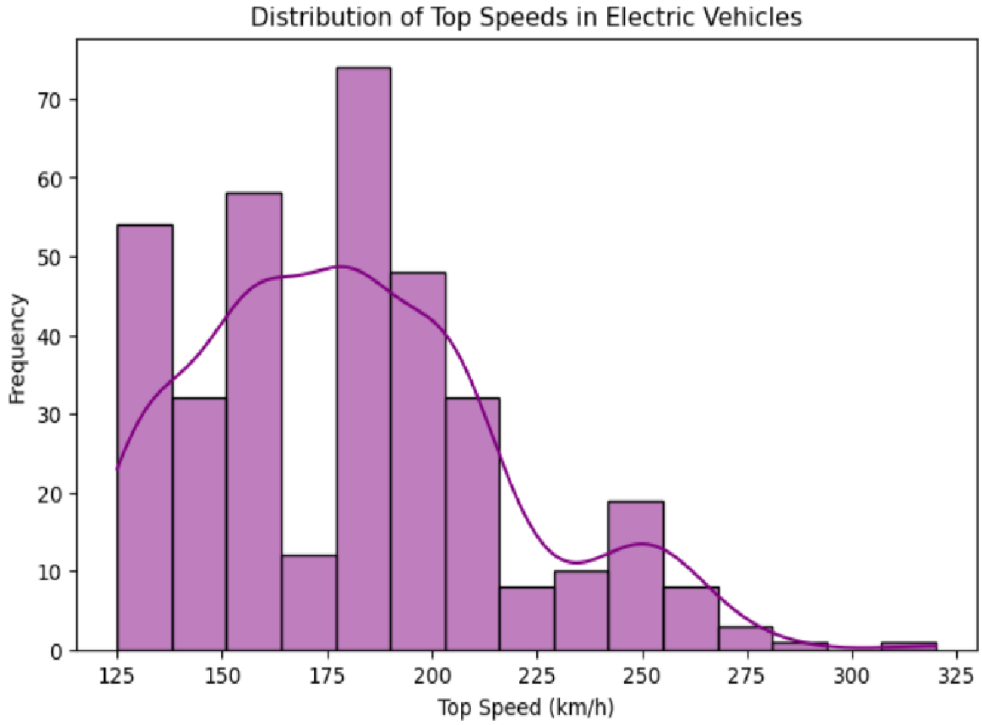

Figure 17: *Histogram of Distribution of Top Speeds in Electric Vehicles*

The top 10 brands of electric vehicles are listed in the bar chart in Figure 18, ranked by their average car pricing in Malaysian Ringgit (RM). Each brand's average price was determined by taking the mean of the RM price values and applying the groupby() function to the Brand column.

Which EV brands fall into the premium or luxury market sector can be determined with the aid of the chart. While the brands not displayed here (with lower averages) might prioritise affordability, those with higher average pricing are probably offering automobiles with additional features or high performance.

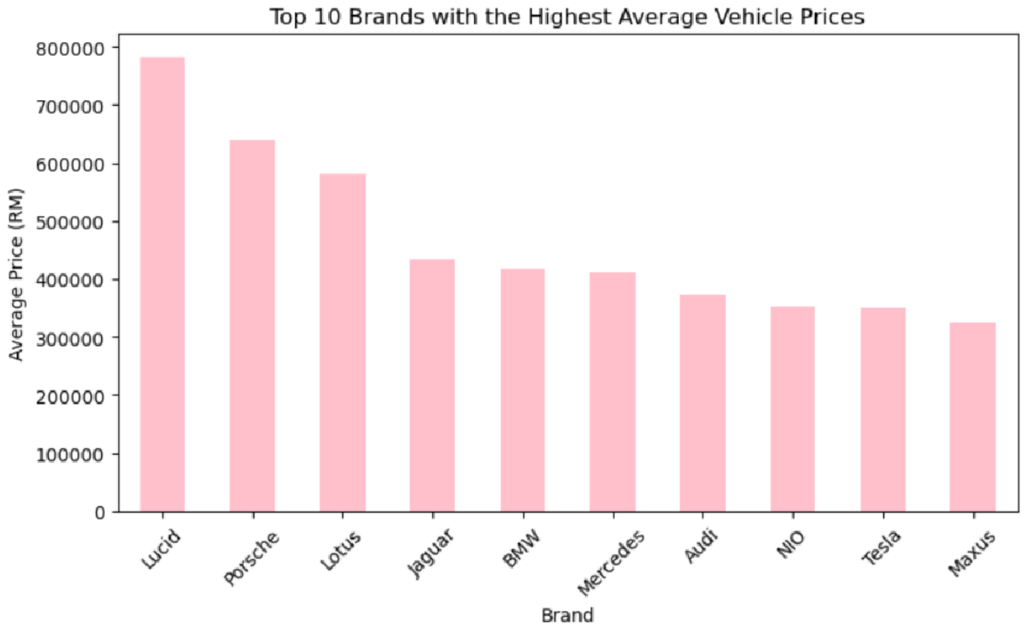

Figure 18: *Bar Chart of Top 10 Brands with the Highest Average Vehicle Prices*

The code in Figure 19 is designed to produce a bar chart that displays the proportion of electric vehicles that support fast charging versus those that do not. The number of vehicles that support fast charging is represented by a green bar, while the number of vehicles that do not is represented by a red bar. The number of cars in each category is shown by the height of each bar.

```
plt.figure(figsize=(6, 4))
plt.bar(['Supports Fast Charging', 'Does Not Support'], [fast_charge_support, no_fast_charge], color=['green', 'red'])
plt.title('Electric Vehicles Fast Charging Support')
plt.ylabel('Number of Vehicles')
plt.tight_layout()
plt.show()
```

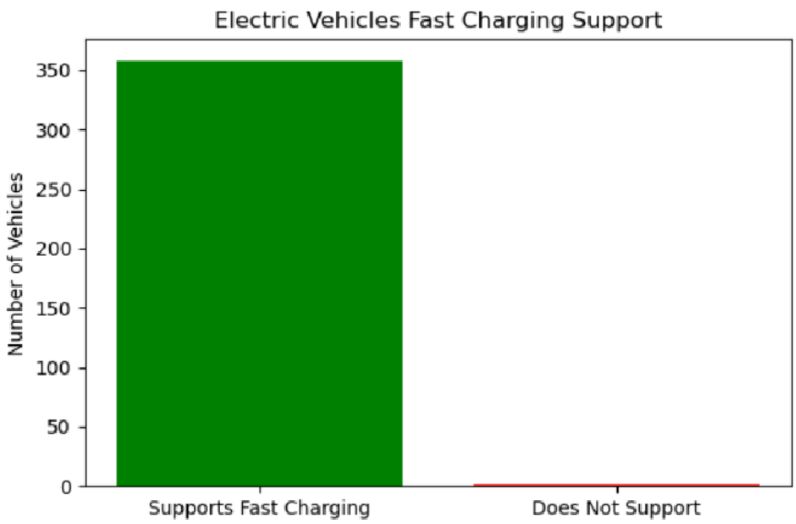

Figure 19: *Bar Chart of Electric Vehicles Fast Charging Support*

Conclusion

The descriptive analysis elaborated in the previous section, along with data management for quality evaluation, illustrates the extensive process of transforming raw data into high-quality data before analysis, ensuring substantial validity. In the subsequent attempt, the data will undergo further analysis using predictive analytics, which utilises machine learning techniques, as well as prescriptive analytics employing optimisation algorithms and simulation.

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