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THE COMPARISON OF INNOSAT ATTITUDE CONTROL PERFORMANCE WITH THE IMPACT OF PERTURBATION USING A VARIETY OF CONTROLLERS

Fadzilah binti Hashim[1*], Ida Safinar binti Aziz[1], Sharipah binti Daud[1], Nurul Hidayah binti Zainol[2], Siti Maryam binti Sharun[3], Mohd Yusof bin Mashor[4]

[1]Electrical Engineering Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim-HiTech, Kedah, Malaysia

[2]Engineering Mini-Circuits Technologies Malaysia Sdn. Bhd. Bayan Lepas Industrial Zone, 11900 Penang, Malaysia

[3]Universiti Sultan Zainal Abidin, Gong Badak Campus, Kuala Terengganu, 21300, Malaysia

[4]FKTEN, Universiti Malaysia Perlis, 02600 Ulu Pauh Main Campus, Arau, Perlis, Malaysia

*Corresponding author e-mail address: fadzilah.hashim@ptsb.edu.my

Abstract

The development of space technology has increasingly become a benchmark for assessing a country's technological advancement. One of the challenges faced in satellite operations is the potential shift in a satellite's position due to various external factors during its orbit. The Malaysian Innovative Satellite (InnoSAT), a nanosatellite system, addresses this issue by focusing on control mechanisms designed to maintain stability. InnoSAT systems are subject to multiple perturbations, including noise, delays, varying gain, and external disturbances. To ensure these real-world conditions are accurately reflected, researchers conducted several simulations that incorporated these perturbations. The attitude control for InnoSAT was initially designed using the state-space approach. The performance of the proposed control strategies was then evaluated and compared. To assess and select the most effective controller for future applications, the Mean Square Error (MSE) was calculated for Roll (ϕ), Pitch (θ), and Yaw (ψ) axis responses under noise influence. Results indicate that the Model Predictive Control (MPC)-based controllers, specifically MPC-Lead and MPC-PDLead which outperformed the PID-Lead controller in terms of MSE across all axes. Notably, both MPC-based controllers achieved steady-state conditions with fewer perturbations compared to the PID-Lead controller.
Keywords: InnoSAT; MPC; Perturbation.

1. Introduction

In recent years, small satellites have gained increasing popularity due to their affordability in terms of size, design, development, and power efficiency. This has made satellite-based research and applications more cost-effective and accessible. Rapid advancements in technology have further enabled the widespread use of small satellites for both research and everyday applications. Among the smallest types of microsatellites are nanosatellites and picosatellites. Miniature satellites can be categorized into various groups based on their size and weight. To promote interest in satellite development among Malaysian universities, the National Space Agency (ANGKASA) developed the Innovative Satellite (InnoSAT), a nanosatellite designed for educational and research purposes (Hashim et al., 2015).

Attitude Control Systems (ACS) are critical for ensuring the success of satellite missions and overall operational stability. Extensive research over the years has led to a variety of solutions for the satellite attitude control problem (Dastjerdi et al., 2018; Petersen et al., 2017; Song et al., 2018; Hazza et al., 2021; Al-Darraji et al., 2021). Satellite orientation can be controlled using several approaches, including Proportional-Integral-Derivative (PID) controllers (Dastjerdi et al., 2018; Fiori et al., 2018), Linear Matrix Inequality (LMI) methods (Fazlyab et al., 2017), Linear Quadratic Regulators (LQR) (Hashim et al., 2015), gain scheduling and linear parameter-varying techniques, and Model Predictive Control (MPC) strategies (Petersen et al., 2017; Sopasakis et al., 2015; Zidek et al., 2021). To further improve attitude control performance, artificial intelligence (AI) techniques such as neural networks (Song et al., 2018; Long et al., 2020) and fuzzy logic (Hazza et al., 2021; Navabi et al., 2020) have also been explored. Building on previous studies of lead and MPC controllers (Prakash et al., 2017; Al-Darraji et al., 2021), researchers have developed simulations to evaluate the effectiveness of combined control strategies, including PID-Lead, MPC-Lead, and MPC-PDLead controllers. The PDLead controller improves phase margin more effectively than traditional PD or PID controllers, which means better stability and faster response. It adds a phase at the right frequency to make the system more robust. Unlike PID, it avoids reducing stability due to the integral term. Overall, PDLead is useful when you need better control of system stability and speed.

2. Methodology

2.1 Equations of InnoSAT dynamics

The transfer function needs to be converted into state space. This transfer function is represented by Roll (ϕ), Pitch (θ), and Yaw (ψ), such as in (1), (2), and (3) (Hashim et al., 2015).

$$\phi_{(s)} = \frac{s^2+0.3051s+0.2040}{s^4+1.1050s^2+0.1650} \quad (1)$$

$$\theta_{(s)} = \frac{1}{s^2-7.1138\times10^{-3}} \quad (2)$$

$$\psi_{(s)} = \frac{s^2-0.3051s+0.8088}{s^4+1.1050s^2+0.1650} \quad (3)$$

By (4) and (5) below, the general form of state-space is presented.

$$x_{k+1} = Ax_k + Bu_k + w_k \quad (4)$$

$$y_k = Cx_k + Du_k + v_k \quad (5)$$

A is the "state (or system) matrix," B is the "input matrix," C is the "output matrix," D is the "feedforward matrix," where x is the "state vector," y is the "output vector," u is the "input (or control) vector," and (in cases where the system model does not have a direct feedforward, D is the zero matrix). The equations (4) and (5) are also amended to include the state noise, w_k, and measurement noise, v_k.

2.2 Experimental setup

InnoSAT attitude controllers based on gap analysis are designed, developed, and compared in several steps. First, the state space technique is used to create and construct InnoSAT attitude controllers. Next, the performance of the suggested controllers for InnoSAT attitude control is compared. Additionally, this study comprised simulations under several operating parameters, including step input for disturbance, measurement noise, one sample time delay, and varying

gain, which are displayed in Figure 1, where the input was set to +1.

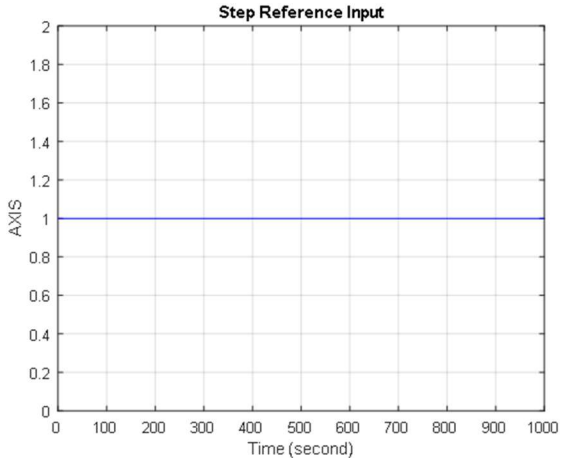


Fig. 1. Step input of normal condition from 0 sec to 1000 sec for ACS InnoSAT plant

Four types of perturbations, including noise, delay, varying gain, and disturbance, can have an impact on InnoSAT systems. The first perturbation is the measurement of noise. The measurement of noise illustrates the noise sensors produced by ADCS. The cumulative first non-singleton dimension of normally distributed pseudorandom numbers was applied as noise. The values were generated from the normal distribution of pseudorandom numbers, which has a mean of 0.2 and the standard deviation of 0.0094. Therefore, to noise ratio (SNR) is equal to the mean of the signal divided by the standard deviation of the noise is equal to 21.2766. Figure 3.20 shows the simulation for measurement noise that was added to the InnoSAT plant as part of the perturbation to simulate the active control method.

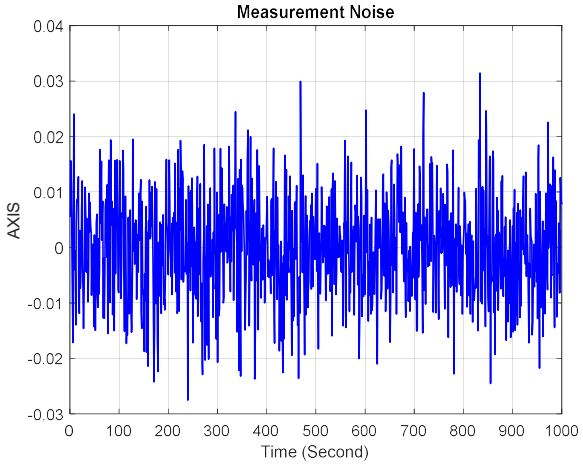


Fig. 2. Measurement of noise

Time delay is a measure of how long a perturbation might last while a signal is being transmitted. In this document, paperwork ƭ =1, and the time delay is defined as paperwork ƭ the entire time delay. It will take some time for the system to react to the incoming reference signal. To comprehend the true dynamic behaviour of the satellite system and its entire performance, including stability, a time delay is crucial in satellite attitude control. Additionally, plants with time delays often have feedback controls that are overcompensated and unreliable. Equation (6) illustrates how the state space approach was applied in this study to measure the time delay

utilizing the input for the Roll (ϕ), Pitch (θ), and Yaw (ψ) axes.

$$x_{k+1}=Ax_k+Bu_{k-\tau}+30.58T_{dx}+5 \quad (6)$$

The value of gain, K_o, varies from 1 to a maximum value of 1.25 and a minimum of 0.75, in a sinusoidal pattern. The varying gain emulated the changes of the InnoSAT parameter slowly with time. The simulation result in Equation (7) for varying gain based on a sinusoidal signal, where K_1 is set to be as shown in Figure 3.

$$K_o=K_1+0.25K_1 \sin(0.01k) \quad (7)$$

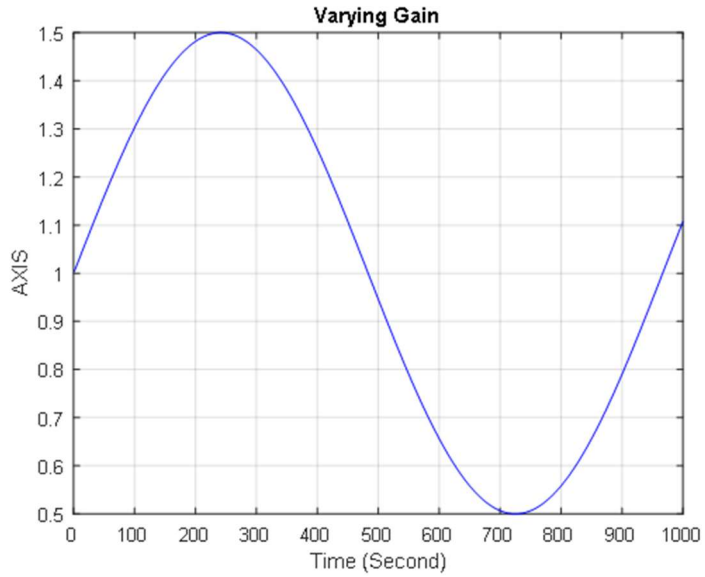


Fig. 3. Simulated varying gain for ACS InnSAT plant

Disturbances occurred due to Earth's gravity gradients and magnetic fields, as well as impact among particles. The step input disturbance is emulated by the external disturbance due to the solar wind, solar snap, and aerodynamic drag. Figure 4 shows the step input disturbance with a strength of 25% that was added to the InnoSAT plant at time 301s to 500s. The equation for the step input disturbance used in this research is shown in Equation (8):

$$u(k)= u(k)+disturbance \quad (8)$$

where u(k) is a discrete control signal produced by the controller

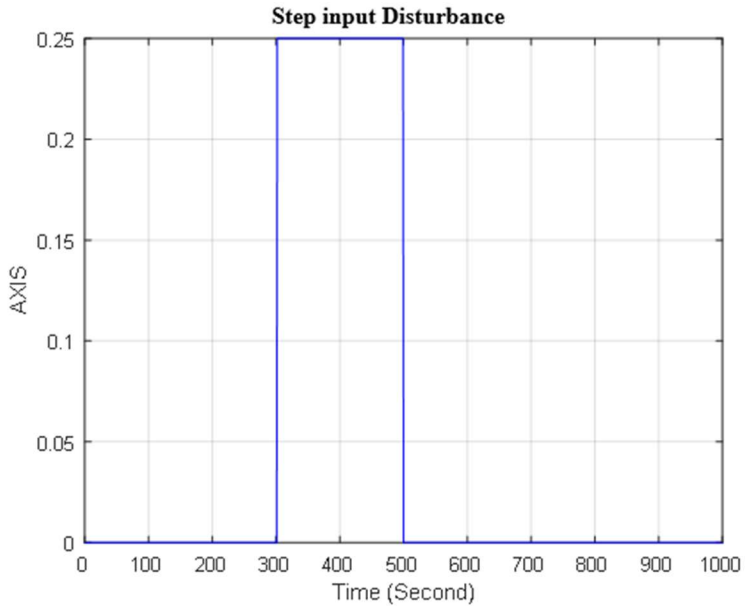


Fig. 4. Step input disturbance of 25% at 301sec to 500 sec

2.3 PID-Lead Controller Design

The term PID describes its three main components, a proportional control term (K_p), an integral control term (T_i,), and a differential control term (T_{dd}) which was derived by Åström (2002), then $G_{cPID}(s)$ can be written as:

The same thing happened as before to the PD-Lead controller, when $\frac{T_{dd}s}{1+(T_{dd}/N')\,s}$ is set as T'_d, then Equation (9) can be written as:

$$G_{cPID}(s)=K_p\left(1+\frac{1}{T_i s}+\frac{T_{dd}s}{1+(T_{dd}/N')\,s}\right) \quad (9)$$

The transfer function shown in Equation (8) is selected again and then multiplied with the PID controller to achieve PID-Lead Controller, as shown in Figure 5:

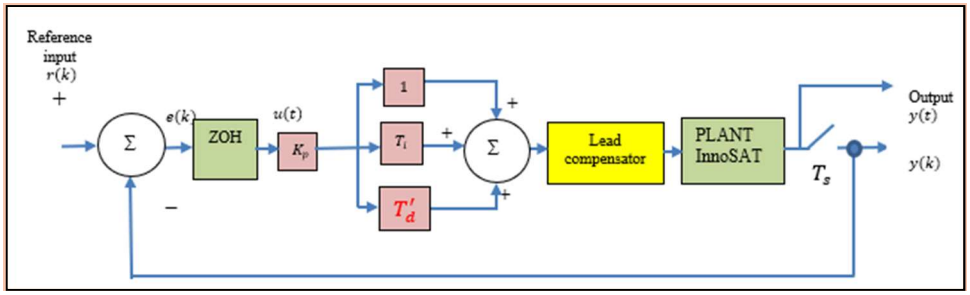


Fig. 5. Block Diagram of a PID-Lead Controller for InnoSAT Plant

To create new transfer functions of the Roll (ϕ), Pitch (θ), and Yaw (ψ) axes, two controllers are coupled in series with the InnoSAT plant. The plant is then transformed into a discrete form. Only when the PID controller has been adjusted using the rule of thumb can the transfer equation be found [2]. Equation (10) represents the overall form of the PID-Lead Controller in conjunction with the InnoSAT plant:

$$G_{PIDL}(s)=K_p\left(1+T_i s+\left(\frac{T_{dd}s}{1+(T_{dd}/N')s}\right)\right)\left(\frac{s+0.5}{s+5}\right) \quad (10)$$

The nonlinear InnoSAT plant is complicated to explain mathematically. However, it is known that sometimes it can be satisfactorily controlled by using a PID controller when the parameters are well-tuned. Three parameters that are used to establish the PID controller are K_p, $T_{i,}$ and T_{dd}. According to Equation (9), the K_p, T_i , and T_{dd} parameters are tuned by using the rule-of-thumb tuning method.

2.4 MPC-Lead Controller Design

This study connected the controllers by connecting a Lead Controller in series with the MPC to enhance the control signal. The purpose of using a Lead Controller is to help MPC improve the systems. It also helps to stabilize the impact of MPC on sudden changes in the heading variable, y(k). Additionally, the Lead Controller was used to mimic the insertion of a derivatives control term. It will increase the reaction's speed and bandwidth while reducing its overshoot. Figure 6 illustrates the series connection between the controller and MPC. The type of controller used in this investigation was the Lead Controller.

The InnoSAT plant's performance was met using the Lead Controller's chosen value for PID-Lead Controllers. The new transfer functions of the Roll (ϕ), Pitch (θ), and Yaw (ψ) axes were then created by discretizing equations (1), (2), and (3) of the InnoSAT plant using a 0.1-second sample period before being connected in series with the Lead Controller.

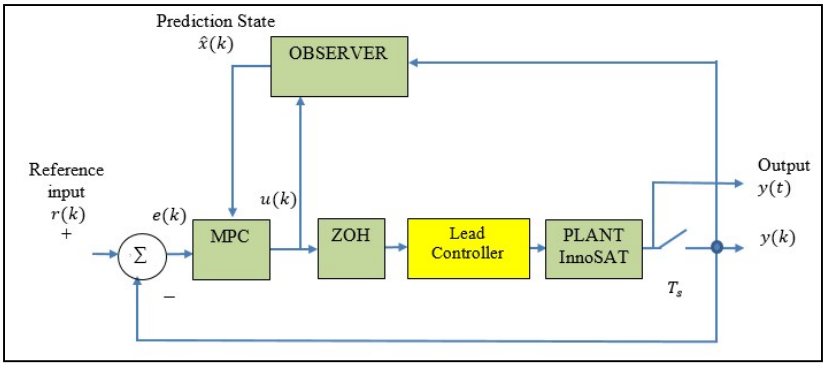


Fig. 6. Block Diagram of MPC-Lead Controller for the InnoSAT Plant

2.5 MPC-PDLead Controller Design

The MPC-based control methods were modified to achieve the necessary control performance in this investigation. The MPC-PDLead Controller, which was based on the MPC-Lead Controller, was created by adding the Lead Controller in series with the PD component. The design of the MPC-PDLead Controller is depicted in Figure 7.

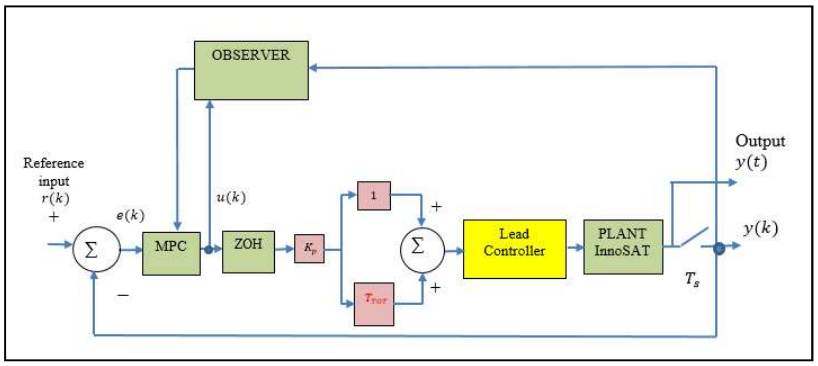


Fig. 7. Block Diagram of MPC-PDLead Controller for the InnoSAT Plant

3. Results and Discussion

Figure 8 denotes the step response of the Roll (ϕ) axis using PID-Lead, MPC-Lead, and MPC-PDLead Controllers for the InnoSAT plant in the presence of Disturbance, Noise, Varying Gains, and Delay, simultaneously. Figure 8 shows the outputs and errors for the outputs of each type of controller used. Overall, it was observed that the response output for all controllers used can overcome all the perturbations imposed. Although the error was found to be quite high at the initial stage with maximum overshoot, all controllers managed to converge to zero, gradually. After being subjected to a disturbance in the 30s, there was an increased error, but again managed to converge to zero. The same was true when the disturbance was removed in the 70s. The zoom-out shows the output of the Roll (ϕ) axis using PID-Lead, MPC-Lead, and MPC-PDLead controllers with all perturbations simultaneously at a time between t = 1s to t = 1000s. Based on the observation in Figure 8, during the initial time, MPC-Lead was the fastest controller with a very high maximum overshoot of 74.81% at 7s, followed by MPC-PDLead, 49.06% after 8s. The slowest controller was the PID-Lead with a maximum overshoot of 36.56% after 15s.

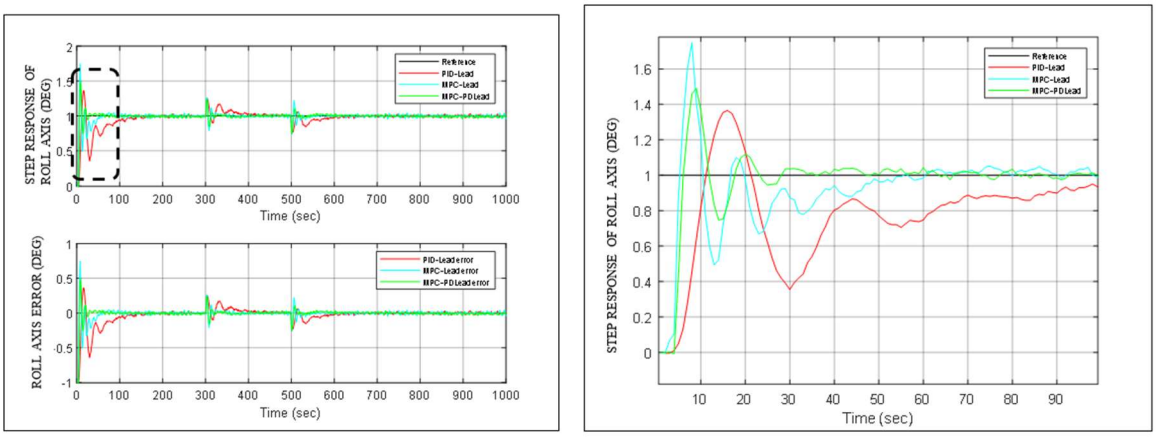


Fig. 8. Performance and zoom-out of comparison Step response of Roll (ϕ) axis using a variety of controllers (with simultaneous all Perturbations)

Figure 9 indicates the step response of the Pitch (θ) axis using PID-Lead, MPC-Lead, and MPC-PDLead Controllers for the InnoSAT plant in the presence of Disturbance, Noise, Varying Gains, and Delay, simultaneously. Figure 9 shows the outputs and errors for the outputs of each type of controller used. Overall, it was observed that the response output for all controllers could overcome all the imposed perturbations. However, when all the controllers were tested, PID-Lead, MPC-Lead, and MPC-PDLead controllers encountered % of overshoot exceeding 20%. Although

the error was found to be quite high at the initial stage with maximum overshoot, all controllers managed to converge to zero gradually. After being subjected to a disturbance at the 300s, there was an increased error but again managed to converge to zero.

The same was true when the disturbance was removed in the 500s. The zoom-out output presents of Pitch (θ) axis using PID-Lead, MPC-Lead, and MPC-PDLead controllers with all perturbations simultaneously at a time between t = 1s to t = 1000 s. Figure 9 presents the outputs and errors for the outputs of each type of controller used. Based on the observation in Figure 4.39, during the initial time, even though the MPC-Lead was the fastest controller. The maximum overshoot was also very high, 65.84% at 7s, followed by MPC-PDLead, 43.5% after 8s. The slowest was the PID-Lead Controller with a maximum overshoot of 49.38% after 25s.

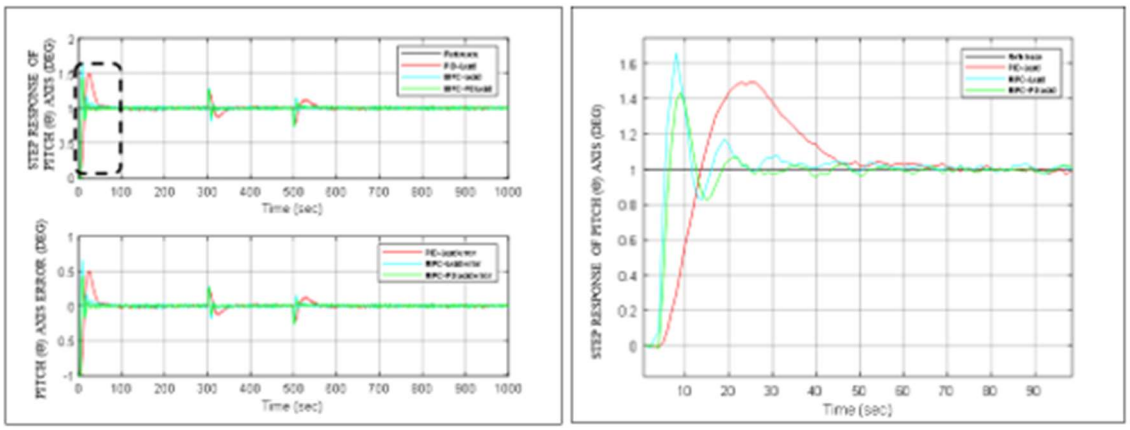


Fig. 9. Performance and zoom-out of comparison Step response of Pitch (θ) axis using a variety of controllers (with simultaneous all Perturbations)

Figure 10 shows the step response of the Yaw (ψ) axis for the InnoSAT plant using PID-Lead, MPC-Lead, and MPC-PDLead controllers under simultaneous disturbance, noise, varying gains, and delay. As seen in Figure 4.39, all controllers were able to handle these perturbations. Although the initial error was high with significant overshoot, all controllers gradually converged to zero. When a disturbance occurred at 300 seconds, the error increased but eventually settled back to zero, and the same happened when the disturbance was removed at 500 seconds.

The zoomed-out response from 1 to 1000 seconds (Figure 4.40) shows that MPC-Lead was the fastest controller but had the highest maximum overshoot of 77.77% at 7 seconds. MPC-PDLead followed with an overshoot of 47.66% at 8 seconds, while PID-Lead was the slowest, reaching a maximum overshoot of 56.72% at 16 seconds.

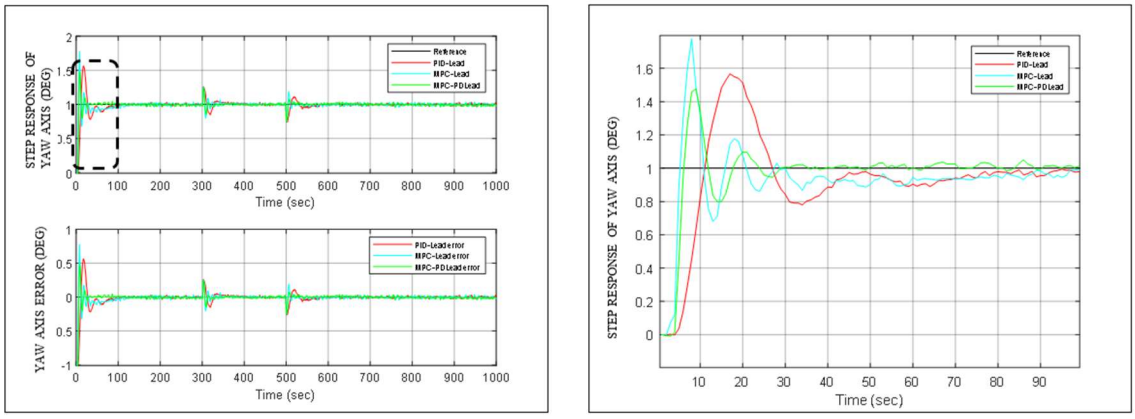


Fig. 10. Performance and zoom-out of comparison Step response of Yaw (ψ) axis using a variety of controllers (with simultaneous all Perturbations)

Table 1. MSE for PID-Lead, MPC-Lead and MPC-PDLead controllers with Disturbance, Noise, Varying Gain and Delay=1 simultaneously

Controllers	Mean Square Error (MSE)		
	Roll (ϕ) axis	Pitch (θ) axis	Yaw (ψ) axis
PID-Lead	1.2811×10^{-01}	1.1024×10^{-01}	9.6450×10^{-02}
MPC-Lead	6.5288×10^{-02}	5.1697×10^{-02}	5.7939×10^{-02}
MPC-PDLead	5.2748×10^{-02}	5.1287×10^{-02}	5.1564×10^{-02}

4. Conclusion

A shorter rising time for the system to reach ideal conditions with the least amount of overshoot and the capacity to function as effectively as feasible to resume regular operations in the event of any anticipated disturbance are indicators of a strong controller's performance. Utilizing the MPC-PDLead Controller, the PD-Lead Controller was utilized to get the necessary performance of the InnoSAT facility. Then, the discrete equations of (1), (2), and (3) were connected in series with PD-Lead Controller. This equation was converted to a discrete form the new transfer functions of Roll (ϕ), Pitch (θ), and Yaw (ψ) axes. Figures 8 through 10 present the output responses of Roll (ϕ), Pitch (θ), and Yaw (ψ) axes, and the mean squared error values are tabulated in Table 4.16. The initial condition of the MPC controller deviates from the 20% maximum overshoot. Referring to the Roll (ϕ), Pitch (θ), and Yaw (ψ) axes output responses of MSE with Disturbance, Noise, Varying Gains, and Delay=1, simultaneously in Table 1, after observing all three axes, the MPC-PDLead was identified to have the smallest mean square error value. Overall, based on the output response characteristics of all the tested controllers, it proved that the MPC-PDLead controller was the best among the proposed controllers. Integrating the InnoSAT design system into a Graphical User Interface (GUI) that enables a list of instructions to be issued in the simulation at any time is another potential enhancement for the simulation. Additionally, users can use the GUI to modify the simulation parameters' values and view simulation output progress statistics.

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FOOD PHOTOGRAPHY IN CULINARY ARTS: THE IMPACT OF VISUAL APPEAL ON CONSUMER BEHAVIOUR

Siti Fitrika Nora binti Shaari[1]*, Muhammad Farid bin Rozhan[2]

[1]Culinary Arts Unit, Langkawi Tourism Academy@Kolej Komuniti Langkawi, 07000 Langkawi, Kedah, Malaysia

[2]Recreational Tourism Unit, Langkawi Tourism Academy@Kolej Komuniti Langkawi, 07000 Langkawi, Kedah, Malaysia

Corresponding author e-mail address: fitrika@kklk.edu.my

Abstract

In the digital age, where visual culture dominates consumer interactions, the role of aesthetically pleasing food images has become increasingly significant in shaping consumer perceptions and behaviour. However, the specific ways in which elements of food photography influence consumer responses remain underexplored. This study, “Food Photography in Culinary Arts: The Impact of Visual Appeal on Consumer Behaviour,” aims to examine how the visual appeal of food photography affects consumer engagement, taste perception, and purchasing decisions. Using secondary data analysis, the research reviews existing literature, market reports, social media analytics, and marketing case studies to identify patterns and correlations between visual presentation such as image quality, colour scheme, plating, and context and consumer responses, while also considering demographic and cultural factors. The findings indicate that high quality, visually appealing food images significantly enhance consumer engagement and willingness to purchase, with vibrant colours, attractive plating, and contextual relevance contributing to positive perceptions. Furthermore, cultural and demographic differences were found to moderate these effects. The study concludes that visual appeal in food photography plays a strategic role in influencing consumer behaviour, offering valuable insights for culinary professionals, marketers, and photographers to optimize food presentation and drive consumer satisfaction and sales.
Keywords: Food Photography; Culinary Arts; Visual Appeal.

1. Introduction

In the digital age, visual communication has become a cornerstone of consumer engagement, particularly in the context of food marketing and the culinary arts (Fairchild, 2020; Spence et al., 2016). The rise of image-driven platforms such as Instagram, Pinterest, and TikTok has elevated the importance of visual content, transforming how consumers interact with food products (Choe & Kim, 2018; Pham & Avnet, 2021). No longer is food appreciated solely for its taste and aroma; instead, visual appeal has become an essential part of the overall dining experience. This phenomenon, often referred to as "eating with the eyes," underscores the significant influence of food photography in shaping consumer behaviour. In today's competitive culinary landscape, where consumer decisions are increasingly informed by digital content, high-quality food imagery can determine the success or failure of a product or establishment.

Food photography plays an important and multifaceted role in the culinary and hospitality industries. It functions not only as a medium of artistic expression but also as a powerful marketing tool that can spark desire, evoke emotions, and influence purchasing behavior. The visual presentation of food, whether on a restaurant menu, a social media platform, or an e-commerce site, directly shapes consumer perceptions. Recent marketing research shows that visually appealing images can significantly increase user engagement, strengthen brand image, and build customer loyalty. Elements such as color contrast, plating techniques, lighting, texture, and composition contribute to the psychological and emotional reactions of viewers. These visual cues can convey freshness, quality, indulgence, or healthfulness, which shape expectations and influence consumer choices.

The integration of visual appeal into food-related marketing strategies has become particularly important in the post-pandemic era, as global lockdowns and mobility restrictions accelerated the surge in online food ordering, virtual dining experiences, and social media food content, reinforcing the role of visual media in consumer decision-making (Mason et al., 2021; Seetharaman, 2020); businesses that invested in professional food photography or curated visually appealing user-generated content reported higher engagement and increased sales (Choe & Kim, 2018; Pham & Avnet, 2021), while the growing visual literacy and discernment of consumers fueled exponential demand for aesthetically pleasing food content (Fairchild, 2020), profoundly impacting culinary education as chefs, restaurateurs, and food entrepreneurs increasingly recognize the need to understand and apply principles of visual storytelling to meet evolving consumer expectations (Spence et al., 2016; Fairchild, 2020).

From an academic standpoint, the relationship between food photography and consumer behaviour warrants closer examination. The intersection of visual aesthetics and consumer psychology is a growing field of interest, particularly in disciplines such as marketing, media studies, and culinary arts. Despite the abundance of visual food content available online, there remains a need for structured analysis of how visual stimuli affect cognitive processing, emotional response, and behavioural outcomes in consumers. For instance, how does the visual portrayal of food influence taste expectations? Does the cultural background of the viewer impact their interpretation of food imagery? What role does image quality play in building trust and desirability for a brand? These questions are central to understanding the mechanisms through which visual appeal affects consumer engagement.

This study, titled “Food Photography in Culinary Arts: The Impact of Visual Appeal on Consumer Behaviour,” aims to address these questions through a comprehensive analysis of secondary data. By synthesizing information from published research articles, industry reports, academic journals, and digital analytics, this paper seeks to identify patterns and trends in consumer response to food photography. The scope of the study includes variables such as image quality, colour schemes, framing techniques, cultural context, and demographic influences. Particular attention is given to the psychological aspects of visual perception, including how consumers form expectations and make decisions based on visual cues.

Furthermore, this research considers how different segments of consumers, based on age, gender, cultural background, and lifestyle, respond to food imagery. For example, younger consumers who are active on social media platforms may exhibit different preferences and sensitivities compared to older consumers who rely more on traditional marketing materials. By examining these variables, the study aims to contribute a nuanced understanding of how visual presentation can be tailored to meet the preferences of diverse consumer groups.

Another important dimension of this research is its relevance to culinary professionals and educators. As the culinary field continues to evolve in response to technological and consumer trends, the incorporation of food photography skills into culinary training programs becomes increasingly important. Chefs and culinary students must not only master the art of cooking but also understand how to present their creations in a visually compelling manner. Food stylists, photographers, and marketers must collaborate closely to ensure that the final visual output resonates with the intended audience and effectively communicates the brand identity.

The findings of this research will have practical implications for those involved in food marketing, product development, culinary instruction, and hospitality management. By providing evidence-based insights into the role of visual appeal, the study will inform strategies for enhancing consumer satisfaction, strengthening brand loyalty, and increasing profitability. The broader aim is to highlight the importance of visual storytelling in the culinary industry and to encourage its thoughtful integration into both academic and commercial practices. To address the lack of real time behavioural data in previous studies, this research incorporates field observation to capture authentic consumer responses to food photography in dining settings.

In summary, this research is a timely and relevant contribution to the understanding of visual appeal in food photography and its impact on consumer behaviour. It underscores the strategic value of imagery in culinary arts and offers a framework for leveraging visual communication to meet evolving consumer expectations in the digital era.

2. Methodology

2.1 Research Design

This study adopts a mixed method approach that combines qualitative secondary data analysis with primary field observation to explore how visual appeal in food photography influences consumer behaviour in the context of culinary arts.

The secondary data synthesis interprets findings from existing sources including academic publications, digital marketing case studies, visual communication reports, and social media analytics to provide a broad understanding of themes and patterns surrounding consumer responses to food imagery.

Additionally, primary data were collected through structured field observation at selected cafés and restaurants to document real time consumer behaviour toward food photographs and presentations. The combination of secondary and primary methods enables a more comprehensive perspective on both theoretical and actual consumer reactions.

2.2 Data Sources

2.2.1 Secondary Data

a. Secondary data were collected from the following sources:
b. Peer reviewed journal articles on visual marketing, food presentation, consumer psychology, and culinary trends
c. Industry reports such as Nielsen, Statista, and HubSpot offering consumer engagement metrics and digital marketing insights
d. Case studies of food branding and campaigns showcasing practical applications of food photography

e. Social media analytics from platforms like Instagram, Facebook, and TikTok reporting consumer engagement with food images
f. Books and scholarly chapters on aesthetics, sensory marketing, and consumer behaviour

2.2.2 Primary Data

Primary data were collected through field observation at three cafés and restaurants in Langkawi between March and April 2025. Observations focused on specific behaviours:

a. Examining menu photographs before ordering
b. Comparing the actual dish with its photograph
c. Taking photographs of food before eating
d. Expressing verbal comments about the food's visual presentation
e. Time spent choosing based on photographs
f. Positive or negative reactions to food presentation

An observation checklist (see Appendix) was used to standardize data collection.

2.3 Data Analysis

Thematic analysis was employed for secondary data involving:

a. Familiarization with literature and reports
b. Initial coding of visual elements such as image quality, colour, and composition
c. Theme development such as visual appeal and emotional response, consumer engagement patterns, and cultural preferences
d. Theme interpretation by comparing patterns across sources and contexts

NVivo software and manual coding helped organize and extract meaningful relationships from the data.

2.4 Research Validity and Limitations

The integration of secondary and primary data strengthens the validity of findings through triangulation. However, limitations remain:

a. Secondary data: quality and methodologies of previous studies may vary and cultural biases may exist

b. Primary data: observations were limited to three locations and may not represent broader consumer behaviour
c. No direct interviews: real time reactions were observed but not further explored through interviews

Efforts were made to mitigate these by focusing on credible recent publications and selecting diverse field sites to capture a range of consumer responses.

3. Results and Discussion

This section presents the results derived from thematic analysis of secondary data sources, including academic journals, marketing reports, and digital media studies. The discussion is

organized under key themes that emerged from the data, which reflect how visual appeal in food photography influences consumer perceptions, emotional responses, and behavioural patterns.

3.1 Theme 1: Image Quality and Consumer Trust

Across multiple studies, image quality was consistently associated with increased consumer trust and willingness to purchase. High-resolution images with clear lighting, natural colours, and detailed textures were perceived as indicators of product freshness and professionalism (Pérez & Martínez, 2020). Consumers reported a higher likelihood of engaging with food brands or ordering food online when visuals were sharp and vibrant. Blurred or poorly lit images, by contrast, were linked to perceptions of carelessness, low hygiene, and reduced product quality (Raghunathan et al., 2021).

In the digital food landscape, visual clarity serves as a proxy for product reliability. Consumers subconsciously interpret well-photographed food as more hygienic and appetizing, highlighting the importance of investing in professional photography, especially for online menus, food delivery platforms, and social media campaigns.

Field observation confirmed that customers often scrutinized menu images and tended to avoid ordering dishes whose photos appeared unclear or unappealing.



Fig. 1. Image Quality and Consumer Trust

3.2 Theme 2: Colour and Emotional Response

Colour psychology plays a crucial role in food photography. Research shows that warm colours (e.g., red, orange, yellow) stimulate appetite and excitement, whereas cool tones (e.g., blue, green) are often associated with healthiness or freshness (Spence, 2015). For instance, fast-food brands tend to use red and yellow to evoke urgency and hunger, while organic food brands favour earthy tones to imply sustainability and wholesomeness.

Strategic use of colour can influence both the emotional appeal of a food image and its perceived flavour. This visual coding can help target specific consumer groups—for example, younger consumers may respond better to bold, high-contrast palettes, while health-conscious consumers may prefer muted, natural hues.

Observation revealed that dishes featuring warm vibrant tones attracted more attention and were ordered faster compared to muted colour dishes.

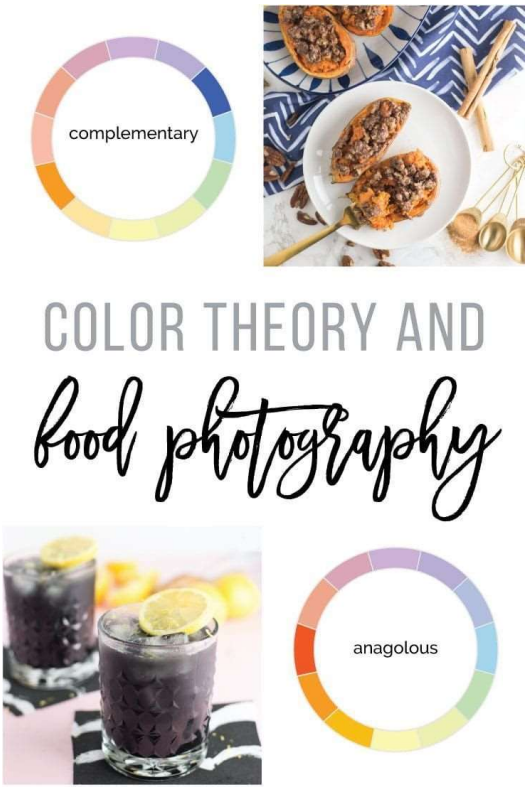


Fig. 2. Colour Theory and Food Photography

3.3 Theme 3: Composition and Plating Techniques

Data from food marketing case studies highlight that symmetry, negative space, and plating style greatly affect visual impact. The “flat lay” angle was the most engaging on Instagram, followed by close-up shots with shallow depth of field (Chen et al., 2019). Minimalist and elegant plating styles were preferred in fine-dining promotions, whereas abundant, overflowing presentations worked better for street food or buffet marketing.

The way food is composed in a photograph can imply cultural meaning, portion size, and dining experience. Culinary professionals must consider the storytelling aspect of composition to attract their target market—be it luxurious minimalism or hearty abundance.



Fig. 3. Composition and Plating Techniques using the rule of third

3.4 Theme 4: Social Media Engagement and Consumer Behaviour

According to recent digital analytics, food photographs that include lifestyle elements—such as a human hand, table setting, or branded plate—garner higher engagement (Statista, 2023). These contextual elements evoke familiarity and encourage viewers to imagine themselves in the dining scene. Additionally, the rise of user-generated content (UGC) has shifted trust dynamics, with many consumers finding peer-posted food photos more authentic and persuasive than official advertisements.

This shift toward authentic, “relatable” imagery has led to the popularity of influencer marketing in food-related content. Restaurants and brands must strategically balance curated visuals with real-life consumer content to build credibility and increase conversion rates.

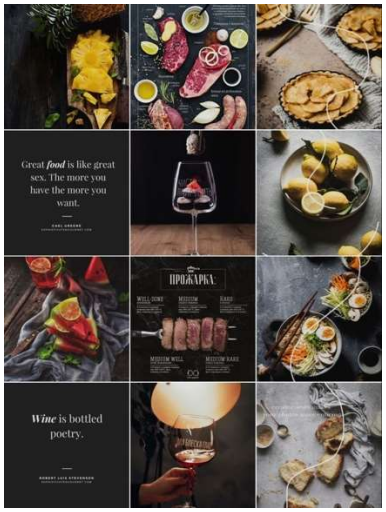


Fig. 4. Social Media Food Photography Example

3.5 Theme 5: Cultural and Demographic Preferences

Studies reviewed indicate that cultural background significantly influences the interpretation of food images. For example, Asian consumers often value communal dining visuals and ornate presentation, while Western audiences may lean toward individual plating and rustic authenticity (Lee & Choi, 2021). Age also plays a role—Millennials and Gen Z users are more responsive to trendy, dynamic photography, while older consumers prioritize clarity and nutritional indicators.

Discussion: Understanding cultural and demographic variations in visual preference is essential for global food brands and multicultural culinary establishments. Tailoring food photography styles to different markets enhances relevance and emotional connection with diverse consumers.



Fig. 5. Traditional Indian Foods

Table 1. Summary of Findings

Image Quality	Sharpness, lighting, texture	Increased trust and willingness to buy
Colour	Warm tones vs. cool tones	Appetite stimulation and health perception
Composition	Angle, symmetry, plating	Enhanced engagement and brand storytelling
Contextual Imagery	Human presence, UGC	Boosted authenticity and emotional connection
Cultural Factors	Presentation style, visual codes	Variable appeal across demographics

3.6 Theme 5: Field Observation Results

Field observation of 45 customers at three cafés and restaurants revealed notable behavioural patterns regarding the influence of food photography. Table 2 summarizes the frequency and percentage of observed behaviours.

Table 1. Observed consumer behaviours related to food photography

Observed Behaviour	Number of customers (n=45)	Percentage (%)
Looked at menu photographs before placing an order	39	86.7%
Compared the menu photograph with the actual dish	30	66.7%
Took a photograph of the food before eating	28	62.2%
Made verbal comments about the appearance or decoration of the food	24	53.3%

Showed positive reactions to the food presentation (e.g., smiling, expressing delight)	26	57.8%
Expressed disappointment because the dish did not match the photograph	7	15.6%
Spent more time deciding due to looking at the photographs	18	40%

The field observation findings largely aligned with the themes identified in secondary data, confirming that image quality, colour, composition, and cultural factors significantly shape consumer behaviour in practice.

4. Conclusion

The influence of visual appeal in food photography on consumer behaviour has evolved into a pivotal aspect of culinary arts and modern food marketing. This study, grounded in secondary data analysis and complemented by field observation, sought to examine how various visual components such as image quality, colour, composition, and cultural relevance affect consumer perception, engagement, and purchasing decisions. The findings underscore the strategic importance of food photography as not merely an artistic or aesthetic undertaking but as a powerful medium that significantly shapes consumer psychology and decision-making processes in a digital and image-saturated marketplace.

The analysis of diverse secondary sources, supported by field observation, reveals that consumers today often make food-related choices based on visual stimuli long before experiencing the actual product. This trend is most evident on social media platforms, where food imagery is abundant and influential. High-quality food photographs serve not only as visual enticements but also as trust-building mechanisms. Consumers associate sharp, vibrant, and professionally styled images with hygiene, freshness, and credibility. On the contrary, low-quality images can deter potential customers by projecting carelessness or lack of authenticity. Observations in real dining contexts confirmed that customers carefully examined menu photographs, often commenting on their clarity and attractiveness before making a choice.

Furthermore, the strategic use of colour in food photography emerged as a key determinant of emotional and psychological response. Warm tones such as reds and oranges have been shown to stimulate appetite and excitement, while cooler hues convey healthiness and freshness. This colour manipulation, when employed thoughtfully, enables food marketers and culinary professionals to subtly influence consumer moods and expectations. Field observation demonstrated that dishes with warm and vibrant tones were ordered more quickly and enthusiastically, supporting theoretical findings from the literature. Moreover, specific colours and plating styles may resonate differently depending on demographic and cultural contexts, emphasizing the need for culturally sensitive visual strategies in global food marketing.

Composition and styling also play a critical role in how food is perceived. Techniques such as the “flat lay” and close-up shots not only highlight the ingredients and textures but also serve to convey the story or lifestyle associated with the dish. Clean lines, negative space, and thoughtful symmetry communicate elegance and sophistication, while rustic or abundant presentations evoke homeliness or indulgence. Field observation noted that diners often photographed well-presented dishes and shared them online, indicating that visual narratives resonate not only digitally but also in real dining experiences.

One of the most compelling findings in this study pertains to social media engagement and authenticity. Consumer trust is increasingly shaped by relatable, lifestyle-oriented imagery,

particularly those incorporating user-generated content (UGC). These images, though sometimes less polished, are perceived as more authentic and therefore more persuasive. This indicates a shift in consumer values, where professional photography remains important but the inclusion of real-life moments and cultural context can enhance relatability and brand loyalty. This was evident during field observation, where several diners took photographs of their meals and shared them on social platforms, often tagging the restaurant and providing immediate feedback.

The study also draws attention to the diversity of consumer responses to food images. Age, cultural background, and digital literacy all influence how individuals interpret and respond to food visuals. For example, Gen Z and millennial users may prefer bold, dynamic, and visually saturated content, while older consumers may prioritize clarity and nutritional cues. Similarly, while Western markets may value minimalistic plating, Asian audiences might respond more positively to intricate, communal dining visuals. These variations were reflected in field observation, where younger customers engaged more with trendy and creative presentations, while older customers favoured simpler and clearer displays. Such insights highlight the necessity for segmentation in visual marketing strategies to ensure alignment with the preferences and expectations of different target audiences.

From a practical perspective, the implications of this study are profound for culinary educators, food entrepreneurs, digital marketers, and hospitality professionals. For culinary practitioners, this research highlights the need to integrate visual literacy and food styling into their core competencies. As food continues to be consumed both physically and visually, chefs must be equipped not only with culinary techniques but also with an understanding of how visual presentation affects the consumer experience. Culinary education institutions should consider embedding modules on food photography, social media branding, and visual storytelling within their curricula to produce more well-rounded professionals.

For food marketers and hospitality businesses, this study affirms the value of investing in high-quality, targeted, and culturally appropriate food imagery. Rather than relying on generic or stock images, brands should seek to create original visual content that aligns with their identity and resonates with their target market. The strategic use of food photography can differentiate a brand in a crowded marketplace, enhance online visibility, and ultimately influence purchasing behaviour.

Moreover, the findings contribute to the broader field of consumer behaviour and digital marketing by offering a structured understanding of how visual stimuli operate within food-related decision-making. While previous literature has addressed isolated elements of this topic, this study provides a more holistic view by integrating insights across visual arts, culinary presentation, consumer psychology, and digital media. It also reinforces the value of combining secondary data analysis with primary field observation to validate theoretical findings and capture real-time consumer reactions.

Nonetheless, this study is not without limitations. Relying predominantly on secondary sources and limited field observations means the findings are contingent upon the scope and cultural applicability of the existing literature and the observed settings. Future research could expand on this work by incorporating additional primary data such as interviews, focus groups, or experimental studies to validate and enrich the observed trends. There is also room to explore the neuropsychological mechanisms behind food image perception, as well as how augmented reality (AR), virtual reality (VR), and AI-generated imagery may reshape consumer engagement in the near future.

In conclusion, food photography is no longer a supplementary feature of culinary presentation but a core component of consumer engagement in the digital era. Its impact on consumer behaviour is both immediate and profound, influencing not only what people choose to eat but also how they feel about what they eat. As visual culture continues to evolve, the ability to communicate effectively through food imagery will remain a critical skill for culinary professionals and marketers alike. By recognising and harnessing the power of visual appeal — as demonstrated both through analysis of literature and observation of real consumer behaviour — stakeholders in the culinary arts can elevate their craft, enhance customer satisfaction, and thrive in an increasingly image-driven economy.

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IMPROVING RECRUITMENT EFFECTIVENESS USING A DECISION SUPPORT SYSTEM WITH THE SIMPLE ADDITIVE WEIGHTING METHOD (CASE STUDY: MAJESTYK BAKERY & CAKE SHOP)

Tengku Ovi Nurmartilis*, Surya Darma Nasution

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, Medan, Sumatera Utara, Indonesia

*Corresponding author e-mail address: tovinurmartilissumut@gmail.com

Abstract

An effective employee recruitment process is a crucial factor in ensuring the quality of human resources within a company. Majestyk Bakery & Cake Shop faces challenges in selecting the best candidates in an objective and efficient manner. This study aims to improve the recruitment process by developing a decision support system based on the Simple Additive Weighting (SAW) method. The SAW method is chosen for its ability to provide a more systematic assessment based on predefined weighted criteria such as education, work experience, skills, and personality. This system assists management in evaluating candidates based on a final score generated from the accumulation of each criterion's score. The results of the study indicate that the implementation of this decision support system can streamline the selection process and enhance the accuracy of decision-making. In conclusion, the system offers a more effective and objective solution to support the recruitment process at Majestyk Bakery & Cake Shop.
Keywords: Employee; Recruitment; SAW.

1. Introduction

Recruitment is a process carried out by an organization to attract, select, and place prospective employees who match the company's needs. According to (Farah and Zohriah 2024), recruitment involves various steps, starting from identifying workforce needs, disseminating job vacancy information, to selecting and placing candidates. This process is very important because the quality of recruited employees will affect the organization's performance and success.

Decision Support System (DSS) is an information system that assists decision-making in complex and unstructured situations. According to (Fu'adi and Diana 2022), DSS integrates data, models, and analysis to support the decision-making process. In the context of recruitment, DSS can be used to evaluate and compare candidates based on predetermined criteria, thereby facilitating managers in selecting the most suitable candidate.

Decision Support System (DSS) also enables organizations to process information more quickly and accurately, so that decisions made are more precise and data-driven. With the presence of DSS, the recruitment process can be carried out more efficiently, reducing the time and costs required, as well as increasing transparency in candidate selection. Therefore, the implementation of DSS in employee recruitment becomes very important to improve the effectiveness and efficiency of the process (Setiaji, 2020).

The Simple Additive Weighting (SAW) method is one of the techniques within DSS that can be applied in the recruitment process. This method is known for its simplicity in integrating various assessment criteria into a single final score that can be used to rank candidates. By using the

SAW method, Majestyk Bakery & Cake Shop can evaluate candidates based on various aspects such as work experience, skills, education, and cultural fit in a more structured manner (Zulkarnain, Patrie, and Triyono 2023)

The implementation of the SAW method in the recruitment process is expected to provide several benefits for Majestyk Bakery & Cake Shop. First, this method can enhance the efficiency of the selection process by reducing the time and costs required. Second, it can improve the accuracy in selecting the best candidates, thereby minimizing the risk of errors in recruitment. Third, with a structured system in place, the company can increase transparency and fairness in the selection process (Manik, Samosir, and Mesran 2022).

2. Methodology

This research was conducted at Majestyk Bakery & Cake Shop, located at Jl. Brigjend Katamso No.311 A-C, Medan Maimun, Medan City. The study was carried out over a period of three months, from March to May 2025. The research activities included title submission, permit application, field research implementation, thesis writing and supervision, as well as the publication of scientific work. The type of research employed was descriptive quantitative, utilizing a multi-criteria decision-making method, namely Simple Additive Weighting (SAW), to evaluate candidates based on predetermined criteria. This method was chosen for its ability to provide an objective, systematic, and measurable evaluation (Zumarniansyah et al. 2021).

The data sources comprised both internal and external elements. Internal data included primary information collected directly from the organization through structured interviews and standardized application forms, covering candidate attributes such as work experience, educational background, age, marital status, and residential address. External data sources incorporated industry standards for retail competencies, academic literature on SAW methodology, and governmental employment regulations to ensure alignment with best practices and legal requirements (Rohmah 2024).

Data collection was executed through dual approaches: Field research involved direct observation of recruitment processes and semi-structured interviews with HR personnel, while library research entailed systematic analysis of academic journals, methodological references, and technical documentation related to web-based decision support systems and multi-criteria evaluation frameworks (Sugiyono 2020). This comprehensive data strategy ensured both operational relevance and theoretical grounding for the development of the decision support system.

The alternatives in this research are the job applicants applying for positions at Majestyk Bakery & Cake Shop. Each alternative represents an individual who will be assessed and compared based on predetermined criteria. The data for the alternatives can be seen in Table 1 below.

Table 1. Data of Candidates for Majestyk Bakery & Cake Shop

Alternative	Code	Criteria				
		Work Experience	Education	Age	Marital Status	Address
Ita Purnama Sari	A1	3 years	D3	25 years	Married	Nearby
Ninda Okviandari	A2	6 years	D3	24 years	Married with 1 child	Fairly Nearby
Dormauli Manurung	A3	3 years	SMA	27 years	Married with 1 child	Moderate
Nurlailli	A4	5 years	D3	24 years	Single	Moderate
Enita Sibarani	A5	7 years	S1	28 years	Single	Nearby

Criteria are the factors or aspects used to assess and compare alternatives (job candidates) in the decision-making process. In this study, the criteria were tailored to meet the specific needs of Majestyk Bakery & Cake Shop in order to select qualified employees. The criteria points include the following:

Table 2. Data of Candidates Criteria

Code	Criteria	Criteria Weight	Type
C1	Work Experience	0.30	Benefit
C2	Education	0.20	Benefit
C3	Age	0.20	Benefit
C4	Marital Status	0.15	Cost
C5	Address	0.15	Cost
	Total	1	

Work experience is one of the primary criteria in the evaluation process. The longer the work experience, the higher the weight assigned.

Table 3. Work experience Scale (C1)

Work Experience Category	Criterion Weight
> 5 years	5
3 – 5 years	4
2 – 3 years	3
> 1 year	2
No Experience	1

Formal education level of the job candidates is also an important indicator. Higher education levels receive greater weight in the evaluation.

Table 4. Formal education level Scale (C2)

Education Category	Criterion Weight
Bachelor's Degree (S1)	5
Diploma (D3)	4
High School (SMA)	3

The age of job candidates is considered for suitability with the company's needs, with younger candidates regarded as more ideal.

Table 5. Age Scale (C3)

Age Category	Criterion Weight
18 – 20 years	5
21 – 24 years	4
25 – 29 years	3
30 – 35 years	2
> 35 years	1

Marital status affects the flexibility and work commitment of job candidates.

Table 6. Marital status Scale (C4)

Marital Status Category	Criterion Weight
Single	5
Married	4
Married with 1 child	3
Married with 2 children	2

Married with > 2 children	1

The distance of the candidate's residence from the workplace affects attendance and productivity.

Table 7. The distance of the candidate's Scale (C5)

Address Category	Criterion Weight
Nearby	5
Fairly Nearby	4
Moderate	3
Far	2
Very Far	1

3. Results and Discussion

The recruitment process at Majestyk Bakery & Cake Shop is designed to be more systematic and objective through the application of the Simple Additive Weighting (SAW) method. Five key criteria were used to evaluate candidates: work experience (C1), formal education (C2), age (C3), marital status (C4), and distance from residence (C5). Each criterion was assigned a specific weight based on its importance: C1 (0.30), C2 (0.20), C3 (0.20), C4 (0.15), and C5 (0.15). These weights were determined based on the operational needs and company culture.

The use of these criteria allows for a holistic assessment of candidates. For instance, work experience (C1) provides an indication of a candidate's familiarity with job responsibilities; formal education (C2) reflects their theoretical knowledge and adaptability; age (C3) is considered based on physical stamina and adaptability in a fast-paced retail environment; marital status (C4) relates to potential flexibility in scheduling; and distance to the workplace (C5) is a practical consideration for attendance and punctuality (Zulkarnain et al., 2023).

To support the objectivity of the selection process, normalization of candidate scores was conducted using the SAW method. Table 10 outlines the raw scores, which were then normalized in Table 11. Final scores were calculated using weighted sums, and the results are shown in Table 12. The highest scoring candidate was Ninda Okviandari (A2) with a final score of 0.9225, followed by Nurlailli (A4) with 0.83, and Enita Sibarani (A5) with 0.825.

This result illustrates that the SAW method enables a clear and transparent ranking of candidates, aligning with findings from previous studies. (Rachman & Daru, 2021).demonstrated that SAW effectively supported performance evaluations at PT GA Tiga Belas, offering consistency and transparency. Likewise, Manik, Samosir, & Mesran, (2022) applied SAW in student internship selection and concluded that the method simplified the decision-making process while increasing accuracy.

Additionally, Zumarniansyah et al. (2021) emphasized the SAW method's flexibility in evaluating multiple criteria simultaneously, which is beneficial in environments where decision-making must consider both qualitative and quantitative factors. This approach proved effective in this study, especially in balancing factors like technical skill (work experience, education) and personal factors (marital status, residence proximity).

In another related study, Devi (2020) developed a recruitment application using the SAW method. Her findings revealed that SAW enabled HR departments to assess candidates more objectively and efficiently based on structured criteria. The current study supports that claim by showing how

SAW improved the selection process at Majestyk Bakery, ensuring better alignment between candidate qualifications and company expectations.

Moreover, the SAW-based decision support system minimizes subjectivity. As noted by Setiaji, (2020), DSS implementation contributes to faster and more accurate decisions. This is particularly important in small-to-medium-sized enterprises like Majestyk Bakery, where resource constraints make efficient recruitment critical.

Finally, the use case diagram designed for this research, as described by Wijaya & Devitra, (2023). further illustrates the potential of developing a web-based system to automate the assessment process. This would allow HR staff to input applicant data, assign scores based on criteria, and receive ranked recommendations automatically.

In summary, the implementation of the SAW method in this study effectively supports the selection of the most suitable job candidates. It validates earlier research on the advantages of multi-criteria decision-making models in HR management and offers a practical framework that Majestyk Bakery can continue to apply and improve upon in future recruitment cycles.

Table 8. The assessment of job candidates Criteria Data

Criterion	Description
Work Experience (C1)	Length of work experience; longer experience is weighted higher.
Formal Education Level (C2)	Higher education levels receive greater weight in evaluation.
Age (C3)	Younger candidates are preferred based on company needs.
Marital Status (C4)	Affects flexibility and work commitment.
Distance from Residence to Work (C5)	Influences attendance and productivity.

A total of 5 job candidates were selected as alternatives in the assessment process. Each candidate was coded from A1 to A5. The selection was based on their activeness, qualifications, and suitability for the positions available at Majestyk Bakery & Cake Shop.

Table 9. Alternative Data

Code	Alternative
A1	Ita Purnama Sari
A2	Ninda Okviandari
A3	Dormauli manurung
A4	Nurlailli
A5	Enita Sibarani

The Simple Additive Weighting (SAW) method was applied through several stages: initial scoring, normalization, final score (preference) calculation, and ranking.

Table 10. Suitability Ratings

Code	Alternative	C1	C2	C3	C4	C5
A1	Ita Purnama Sari	4	4	3	4	5
A2	Ninda Okviandari	5	4	4	3	4
A3	Dormauli manurung	4	3	3	3	3
A4	Nurlailli	4	4	4	5	3
A5	Enita Sibarani	5	5	3	5	5

Table 11. Attribute Normalization Results

Alternative	C1 (B)	C2 (B)	C3 (B)	C4 (C)	C5 (C)
A1	4/5 = 0.80	4/5 = 0.80	3/4 = 0.75	3/4 = 0.75	3/5 = 0.60
A2	5/5 = 1.00	4/5 = 0.80	4/4 = 1.00	3/3 = 1.00	3/4 = 0.75
A3	4/5 = 0.80	3/5 = 0.60	3/4 = 0.75	3/3 = 1.00	3/3 = 1.00
A4	4/5 = 0.80	4/5 = 0.80	4/4 = 1.00	3/5 = 0.60	3/3 = 1.00
A5	5/5 = 1.00	5/5 = 1.00	3/4 = 0.75	3/5 = 0.60	3/5 = 0.60

Table 12. Score Calculation

Alternative	Vi
A1	(0.80×0.3) + (0.80×0.2) + (0.75×0.2) + (0.75×0.15) + (0.60×0.15) = 0.7575
A2	(1.00×0.3) + (0.80×0.2) + (1.00×0.2) + (1.00×0.15) + (0.75×0.15) = 0.9225
A3	(0.80×0.3) + (0.60×0.2) + (0.75×0.2) + (1.00×0.15) + (1.00×0.15) = 0.805
A4	(0.80×0.3) + (0.80×0.2) + (1.00×0.2) + (0.60×0.15) + (1.00×0.15) = 0.83
A5	(1.00×0.3) + (1.00×0.2) + (0.75×0.2) + (0.60×0.15) + (0.60×0.15) = 0.825

Table 13. Ranking

Rank	Code	Name	Vi Score
1	A2	Ninda Okviandari	0.9225
2	A4	Nurlailli	0.83
3	A5	Enita Sibarani	0.825
4	A3	Dormauli Manurung	0.805
5	A1	Ita Purnama Sari	0.7575

The use case diagram illustrates the interaction between users and the system during the assessment process, including inputting teacher data, assigning scores, calculating values using the SAW method, and viewing the ranking results. This diagram helps design an efficient workflow that can be further developed into a digital system in the future (Wijaya and Devitra 2023).

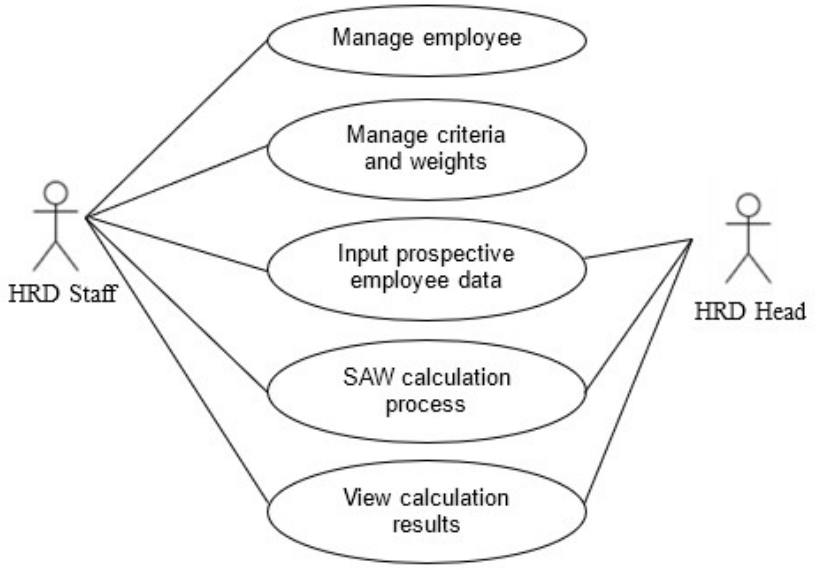


Fig.1. Use Case Diagram

Based on the analysis and calculations conducted, it can be concluded that the use of the Simple Additive Weighting (SAW) method in the decision support system for employee recruitment at Majestyk Bakery & Cake Shop effectively enhances the efficiency and objectivity of the selection

process. This method allows each job candidate to be evaluated fairly based on criteria relevant to the company's needs.

The calculation results demonstrate that the SAW method provides consistent and transparent outcomes, facilitating management in making final decisions. By implementing this system, the company not only obtains the most suitable candidates but also accelerates the selection process and minimizes subjectivity in decision-making.

Therefore, the use of the SAW method is highly recommended for continued application in future employee recruitment processes at Majestyk Bakery & Cake Shop.

4. Conclusion

Based on the research findings, the employee recruitment process at Majestyk Bakery & Cake Shop is conducted using the Simple Additive Weighting (SAW) method as part of a decision support system. The evaluation was carried out on five job candidates based on five main criteria: work experience, education, age, marital status, and address. Each criterion was assigned a specific weight reflecting its level of importance, namely: work experience (0.30), education (0.20), age (0.20), marital status (0.15), and address (0.15). The assessment data were obtained from registration forms and interview results, then processed using the SAW method to obtain preference scores for each candidate (Rachman and Daru 2021).

Through the SAW calculation, each candidate received a final score reflecting their suitability to the company's needs. The results showed that Ninda Okviandari (A2) achieved the highest score of 0.9225, due to high scores across almost all evaluated criteria. Therefore, Ninda Okviandari is recommended as the best candidate. The second rank was held by Nurlailli (A4) with a score of 0.83, followed by Enita Sibarani (A5) with 0.825, then Dormauli Manurung (A3) with 0.805, and lastly Ita Purnama Sari (A1) with a score of 0.7575.

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ANALYSIS OF THE SELECTION OF OUTSTANDING STUDENTS AT MTS AL-WASHLIYAH BULAN- BULAN USING SIMPLE ADDITIVE WEIGHTING (SAW) METHOD

Ilhan*, Surya Darma Nasution

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, Medan, Indonesia

*Corresponding author e-mail address: ajah60947@gmail.com

Abstract

The process of selecting excellent students at MTs Al-Washliyah Bulan-Bulan has been carried out in an ordinary and manual way, which makes it vulnerable to subjective and unclear assessments. This research aims to apply the Simple Additive Weighting (SAW) method to determine outstanding students with a more objective and measurable approach. This research uses a quantitative approach with secondary data derived from academic grades, attendance, discipline, participation in extracurricular activities, and student attitudes and behavior. The Simple Additive Weighting (SAW) method is used to normalize the data and give weights to each criterion, then calculate the final score to determine the best student. The results revealed that the student with the highest score of 0.98335 on behalf of Anggy Triana was recognized as the best performing student. Therefore, the Simple Additive Weighting (SAW) method proved effective as a tool for making decisions in the selection of outstanding students in a fair and transparent manner.
Keywords: Outstanding students; Simple Additive Weighting (SAW) method; Decision support system.

1. Introduction

Education is a major component in the development of improving the quality of the workforce. To improve the quality of education, rewarding outstanding students is one of the important strategies implemented by schools to increase students learning motivation and positive behavior. At various levels of education, including madrasah tsanawiyah, the selection of outstanding students has become a routine program with the aim of appreciating students' academic and non-academic achievements.

However, the selection of outstanding students in a number of schools, including MTs Al-Washliyah Bulan-Bulan, still faces a number of significant challenges. The selection process still runs in a conventional and manual way, and the assessment is unstructured and subjective. This has led to dissatisfaction from students and educators due to the absence of an objective, transparent and comprehensive evaluation system.

This issue is important to ensure fairness and quality in educational decision-making. Student assessment should include more than just academic grades, also considering attendance, discipline, participation in extracurricular activities, and attitude and behavior. Therefore, a decision support system (SPK) based approach is needed that can integrate these various criteria in a quantitative and measurable manner.

The Simple Additive Weighting (SAW) method is one of the methods used in Multi Attribute Decision Making (MADM) which has proven to be effective in solving decision-making problems with many criteria (Setiaji, 2013). The Simple Additive Weighting (SAW) method, often referred to

as the weighted sum method, is a method used in multicriteria decision making (MADM). This method works by calculating the total of the product of weights and performance ratings of each option based on existing attributes. Before performing the calculation, the first step is to normalize the decision matrix (X) so that it can be compared among various criteria (Mulyadi & Sachrul, 2021). This method normalizes the decision matrix, multiplies the normalized value by the weight of the criteria, and sums it up to find the best alternative. The Simple Additive Weighting (SAW) method has advantages in terms of its simple process and ability to produce objective and transparent decisions (Tugiyono, 2024). Explaining that the SAW method is a classic and basic way in MADM, but very effective. By multiplying the weights with the normalized performance values for each criterion, SAW regularly gives order to the existing choices (Taherdoost, 2023).

Various studies have shown the successful use of the Simple Additive Weighting (SAW) method covering various fields, including in the selection of outstanding students at SMK Dwi Warna Sukabumi being able to overcome the dominance of academic scores and include non-academic aspects in student evaluation (Sholihat & Gustian, 2021). The SAW method was used to determine the most outstanding teacher by considering various aspects such as educational background, non-academic achievements, tenure, discipline, and exam results. The evaluation showed that the teacher who obtained the highest score (A1 = 0.98) deserved to receive the award as the best teacher (Mulyadi & Sachrul, 2021). Other research by (Ismayadi et al., 2022) at SMA Negeri 1 South Siberut. (Infortech et al., 2024) at SDN Pulogadung 01 PG also shows that SAW can improve fairness and efficiency in the student selection process.

In addition to the realm of education, the Simple Additive Weighting (SAW) method was also successfully applied in the selection of the best fabrics at Modiss Textile Shop (Robo et al., 2023), BPS Jember partner performance assessment (Noya & Qoiriah, 2022). Baking Daily Store had difficulty in selecting suppliers efficiently because they only used instinct. They developed a Java-based desktop application that applies the SAW method to select suppliers in an objective way based on certain criteria (Fakhroji et al., 2025). SAW method is used to set priorities for recipients of the house renovation assistance program in Pandeglang Regency. This step includes weight assessment for each alternative candidate, then calculated to determine the recipient with the highest value (i.e. value = 1) as the top priority (Yunita et al., 2023). as well as in employee promotion (Putranto & Maulina, 2023). In fact, in the area of business and strategic management, decision support systems based on the K-Means method have also proven to be relevant in evaluating company performance (Ma & Tahyudin, 2024).

In general, the application of Decision Support Systems (DSS) has a crucial role in assisting the decision-making process based on diverse and complex data and criteria. This system integrates data analysis, mathematical models, and interfaces that support the decision-making process (Haffandi et al., 2024). (SPK is part of a computer-based information system that aims to support the decision-making process in an organization, not to replace the role of humans (Ukkas & Hogu, 2016). In the selection of outstanding students, a Decision Support System (SPK) based on the Simple Additive Weighting (SAW) method not only simplifies the selection process, but also ensures transparency and accountability of each decision.

With this background, this article aims to analyze and apply the Simple Additive Weighting (SAW) method to the selection process of outstanding students at MTs Al-Washliyah Bulan-Bulan. It is hoped that this research will be able to present an objective solution to improve accuracy in the selection process, be fair and measurable, and become a reference for other educational institutions in adopting similar methods.

2. Methodology

With this background, this article aims to analyze and apply the Simple Additive Weighting (SAW) method to the selection process of outstanding students at MTs Al-Washliyah Bulan-Bulan. It is hoped that this research will be able to present an objective solution to improve accuracy in the selection process, be fair and measurable, and become a reference for other educational institutions in adopting similar methods.

The research procedure was carried out in several planned steps, which included:

i. Identifying problems that arise due to the unstructured selection process of outstanding students.
ii. Data collection through documentation of student grades as well as interviews with teachers and principals.
iii. Determination of alternatives and criteria that include five main assessment aspects.
iv. Giving weight to each criterion based on the results of interviews with the school.
v. Normalization and calculation of preference scores using the Simple Additive Weighting (SAW) method.
vi. Establish the final position in the ranking to select the best students based on the highest score

For Data Instruments and Sources, the data used is secondary data obtained by documentation methods and structured interviews. Data collection tools include:

i. Academic report card scores
ii. Student attendance data
iii. Notes on discipline
iv. Involvement in extracurricular activities
v. Attitude or behavioral assessments from teachers

Based on the available data and the results of the interviews conducted, the criteria and weights were determined as follows:

i. C1: Academic score (40%)
ii. C2: Attendance (20%)
iii. C3: Discipline (15%)
iv. C4: Extracurricular participation (15%)
v. C5: Attitude or behavior (10%)

Based on the data that has been collected, it can be concluded that the data used in the analysis process includes:

Table 1. Raw Data from Data Collection

Alternative	Criteria				
	Academic Grades	Attendance	Discipline	Extracurricular Participation	Attitude/Behavior
Anggy Triana	Very good	6-10	Discipline Enough	Scouts and Paskibra	Good
Fira Sabila	Good	11-15	Discipline Enough	Scouts and Paskibra	Good
Harum Kirana	Very good	11-15	Disciplined	Scouts	Very good
Kanaya	Good enough	6-10	Disciplined	Not Participating	Good
Nur Aikin	Good	11-15	Disciplined	Paskibra	Very good

Bayu Iswandi	Very good	6-10	Disciplined	Scouts and Paskibra	Good enough
Fauzi Maulana	Good	6-10	Discipline Enough	Paskibra	Good enough
Muhammad Agung Arya	Good	11-15	Discipline Enough	Paskibra	Good enough
Rafa Aditya	Very good	6-10	Discipline Enough	Not Participating	Good enough
Rudi	Good	11-15	Disciplined	Scouts and Paskibra	Good

This data is then converted into a quantitative scale according to a predetermined rubric, then normalized to be analyzed using the Simple Additive Weighting (SAW) method.
The Simple Additive Weighting (SAW) method is included in the Multi Attribute Decision Making (MADM) technique. The process consists of two main steps:

i. Normalize the decision matrix, so that all data is in the same scale range as the formula:

$$r_{ij}=\frac{x_{ij}}{\max(x_{ij})}$$

That is, the original value of x_{ij} is divided by the highest (maximum) value of all alternatives on that criterion. Used to ensure that the normalized value increases as the original value increases.
If the criteria are cost, then the formula:

$$r_{ij}=\frac{\min(x_{ij})}{x_{ij}}$$

This means that the minimum value of all alternatives is divided by the original value x_{ij}, so that smaller values are considered better.

Description:
x_{ij} = Initial value of the i-th alternative against the j-th criterion
r_{ij} = Value after going through the normalization process

ii. Calculation of preference scores for each alternative with the formula:

$$V_i = \sum_{j=1}^{n} w_j \, . r_{ij}$$

That is, the normalized value for each criterion is multiplied by its weight, then summed.
Description:
V_i = Overall score of the i-th alternative
w_j = Weight value on the j-th criterion
r_{ij} = Normalization result of the i-th alternative against the j-th criterion
n = Total of all criteria applied
The alternative that has the highest value V_i is selected as the best option because it has fulfilled all the criteria specified with the highest overall score.

3. Results and Discussion

This research uses the Simple Additive Weighting (SAW) method approach to evaluate ten ninth grade students at MTs Al-Washliyah Bulan-Bulan by considering five criteria: academic achievement (C1), attendance rate (C2), discipline (C3), involvement in extracurricular activities

(C4), and behavior/attitude (C5). Each criterion is given a priority weight: 40%, 20%, 15%, 15%, and 10% respectively. The data obtained is then converted into value weights based on a predetermined rating scale, after which it is normalized so that all alternatives have the same range of values.
The following is the first step to select outstanding students through the application of the Simple Additive Weighting (SAW) method:

i. Assigning weights to each criterion
Below are the weights given to each criterion:
a. The weight value on the Academic score criterion.

Table 2. Academic grade weight value

Scale	Criteria Weight
Very good	100
Good	90
Good enough	80
Bad	70
Very Bad	60

b. The weight value on the Attendance criteria.

Table 3. Weight value of attendance criteria

Total Attendance	Criteria Weight
1-5	100
6-10	90
11-15	80
16-20	70
>20	60

c. Weight value on Discipline criteria.

Table 4. Weight value of discipline criteria

Scale	Criteria Weight
Very Disciplined	100
Discipline	90
Discipline Enough	80
No Discipline	70
Extremely Indiscipline	60

d. Weight value on Extracurricular Participation criteria.

Table 5. Weight value of extracurricular participation criteria

Extracurricular	Criteria Weight
Scouts and Paskibra	100
Scout	50
Paskibra	50
Not Participating	0

e. Weight value on Attitude/Behavior criteria

Table 6. Weight value of Attitude/Behavior criteria

Scale	Criteria Weight
Very Good	100

Good	90
Good enough	80
Bad	70
Very Bad	60

ii. Alternative Values and Data

After giving a weight value to each criterion, alternative data coding is carried out and criteria assessment is given to each student:

a. Alternative value

Alternative values are obtained by converting each student's data into numerical weights according to five criteria, which are the basis for calculating the Simple Additive Weighting (SAW) method.

Table 7. Alternative

Code	Alternative
A1	Anggy Triana
A2	Fira Sabila
A3	Harum Kirana
A4	Kanaya
A5	Nur Aikin
A6	Bayu Iswandi
A7	Fauzi Maulana
A8	Muhammad Agung Arya
A9	Rafa Aditya
A10	Rudi

b. Assigning criteria values to each alternative

After determining the alternative value, then we find the maximum and minimum value of each criterion.

Table 8. Criteria Assessment for Each Alternative

Alternative	Criteria				
	C1	C2	C3	C4	C5
A1	100	90	80	100	90
A2	90	80	80	100	90
A3	100	80	90	50	100
A4	80	80	90	50	90
A5	90	80	90	50	100
A6	100	80	80	100	80
A7	90	80	80	50	80
A8	90	80	90	80	80
A9	100	90	80	0	80
A10	90	80	90	100	90

iii. Calculating Normalization and Calculating Final Score

The next stage is to carry out data normalization and calculate the final score to rank students by applying the Simple Additive Weighting (SAW) method.

a. Normalization

To ensure that the values of each criterion can be compared fairly, the next step is to perform normalization. Normalization aims to convert values that have different scales or units into equivalent values, making it easier to calculate and evaluate alternatives objectively.

Table 9. Normalization

Alternative	Criteria				
	C1	C2	C3	C4	C5
A1	1.0	1.0	0.889	1.0	1.0
A2	0.9	0.889	0.889	1.0	0.9
A3	1.0	0.889	1.0	0.5	1.0
A4	0.8	0.889	1.0	0.5	0.9
A5	0.9	0.889	1.0	0.5	1.0
A6	1.0	0.889	0.889	1.0	0.8
A7	0.9	0.889	0.889	0.5	0.8
A8	0.9	0.889	0.889	0.5	0.8
A9	1.0	1.0	0.889	0	0.8
A10	0.9	0.889	1.0	1.0	0.9

b. Calculating the final score

After normalization is complete, the next step is to calculate the final score for each option. The final score is calculated by summing up the product of the normalized value of each criterion and the predetermined weight. The goal of this process is to find the option with the highest value, which is considered the best option.

i. Skor akhir Anggy Triana = (1.0 x 0.40) + (1.0 x 0.20) + (0.889 x 0.15) + (1.0 x 0.15) + (1.0 x 0.10) = 0.40 + 0.20 + 0.13335 + 0.15 + 0.10 = 0.98335
ii. Skor akhir Fira Sabila = (0.9 x 0.40) + (0.889 x 0.20) + (0.889 x 0.15) + (1.0 x 0.15) + (0.9 x 0.10) = 0.36 + 0.1778 + 0.13335 + 0.15 + 0.09 = 0.91115
iii. Skor akhir Harum Kirana = (1.0 x 0.40) + (0.889 x 0.20) + (1.0 x 0.15) + (0.5 x 0.15) + (1.0 x 0,10) = 0.40 + 0.1778 + 0.15 + 0.075 + 0.10 = 0.9028
iv. Skor akhir Kanaya = (0.8 x 0.40) + (0.889 x 0.20) + (1.0 x 0.15) + (0.5 x 0.15) + (0.9 x 0.10) = 0.32 + 0.1778 + 0.15 + 0.075 + 0.09 = 0.8728
v. Skor akhir Nur Aikin = (0.9 x 0.40) + (0.889 x 0.20) + (1.0 x 0.15) + (0.5 x 0.15) + (1.0 x 0.10) = 0.36 + 0.1778 + 0.15 + 0.075 + 0.10 = 0.8628
vi. Skor akhir Bayu Iswandi = (1.0 x 0.40) + (0.889 x 0.20) + (0.889 x 0.15) + (1.0 x 0.15) + (0.8 x 0.10) = 0.40 + 0.1778 + 0.13335 + 0.15 + 0.08 = 0.94115
vii. Skor akhir Fauzi Maulana = (0.9 x 0.40) + (0.889 x 0.20) + (0.889 x 0.15) + (0.5 x 0.15) + (0.8 x 0.10) = 0.36 + 0.1778 + 0.13335 + 0.075 + 0.08 = 0.82615
viii. Skor akhir Muhammad Agung Arya = (0.9 x 0.40) + (0.889 x 0.20) + (0.889 x 0.15) + (0.5 x 0.15) + (0.8 x 0.10) = 0.36 + 0.1778 + 0.13335 + 0.075 + 0.08 = 0.82615
ix. Skor akhir Rafa Aditya = (1.0 x 0.40) + (1.0 x 0.20) + (0.889 x 0.15) + (0 x 0.15) + (0.8 x 0.10) = 0.40 + 0.20 + 0.13335 + 0 + 0.08 = 0.81335
x. Skor akhir Rudi = (0.9 x 0.40) + (0.889 x 0.20) + (1.0 x 0.15) + (1.0 x 0.15) + (0.9 x 0.10) = 0.36 + 0.1778 + 0.15 + 0.15 + 0.09 = 0.7778

iv. Final Result

After the entire calculation process is complete, the final stage is carried out by selecting the best alternative based on the final score obtained. The choice with the highest score is considered the best choice because it has the most optimal performance according to all the criteria set.

Table 10. Final score

Students	Final Score
Anggy Triana	0.98335
Fira Sabila	0.91115
Harum Kirana	0.9028

Kanaya	0.8728
Nur Aikin	0.8628
Bayu Suwandi	0.94115
Fauzi Maulana	0.82615
Muhammad Agung Arya	0.82615
Rafa Aditya	0.81335
Rudi	0.7778

Student Anggy Triana was determined to be the best performing student from classes 9A and 9B as she had the highest final score, 0.98335, as shown in the table above. This result shows that Anggy Triana was selected as the best performing student. This shows that Simple Additive Weighting (SAW) can help schools make transparent, fast, and fair decisions.

4. Conclusion

This study shows that the Simple Additive Weighting (SAW) method can support the implementation of the selection of outstanding students at MTs Al-Washliyah Bulan-Bulan. By considering five main criteria: academic grades, attendance, discipline, extracurricular participation, and attitude or behavior, the Simple Additive Weighting (SAW) method can combine all elements of assessment into a fair, measurable, and transparent system. Based on the calculation results, it can be concluded that the Simple Additive Weighting (SAW) method prioritizes many aspects of assessment rather than just one. The student with the name Anggy Triana obtained the highest score (0.98335) and was designated as the best student. This shows that the method allows for a thorough and balanced assessment of student performance.

Overall, the application of the Simple Additive Weighting (SAW) method in this decision support system is effective in reducing the subjectivity of judgment that often arises in the manual selection process. In addition, this method provides a more rational and accountable basis for decision-making in an educational environment.

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COMPARATIVE ANALYSIS OF EMPLOYER-REQUIRED EMPLOYABILITY SKILLS: A MULTI-DATASET ASSESSMENT OF GRADUATE COMPETENCIES

Normala binti Rahmat[1]*, Norhayati binti Jamil[2], Azwa binti Hasnan[1]

[1] Department of Electrical Engineering, Politeknik Sultan Azlan Shah, Behrang Stesen, 35950 Behrang, Perak, Malaysia

[2] Department of Mathematic Science and Computer, Politeknik Sultan Azlan Shah, Behrang Stesen, 35950 Behrang, Perak, Malaysia

*Corresponding author's email: drnormala1974@gmail.com

Abstract

In the twenty-first century, producing quality graduates with strong employability skills is essential for maintaining competitiveness in the global workforce. While extensive research has identified core employability skill constructs valued by employers, there remains a need to examine how the importance of these skills evolves over time, particularly in enhancing graduate work performance. This study addresses that gap by analyzing longitudinal trends in employer perceptions of seven key employability skill constructs: communication, teamwork, critical thinking and problem-solving, personal qualities, technology, organizational, and continuous learning skills. Employing a quantitative comparative design, the study draws on five datasets from Ekspo Kerjaya Industri Politeknik (ExKIP) events held from 2020 to 2024, involving 123 employers from sectors including engineering, services, retail, and human resources. Descriptive statistics, rank trend analysis, and one-way ANOVA were employed to assess both the consistency and variation in skill importance across cohorts. Results show that all constructs received high ratings (above 4.3), but rankings shifted: personal qualities consistently ranked highest, while teamwork and technology skills rose in importance. Communication, organizational, and continuous learning skills declined in rank. Though differences were not statistically significant, findings underscore shifting employer expectations and the need for responsive curriculum reform. The study provides valuable insights for improving graduate employability and work performance in dynamic professional environments.

Keywords: Employability skills; Work performance; ANOVA.

1. Introduction

In today's rapidly evolving global economy, employers are placing increasing emphasis on the employability skills of graduates to ensure organizational agility and competitiveness. Employability skills defined as a blend of cognitive, interpersonal, and technical competencies are critical in enabling individuals to obtain, maintain, and thrive in employment across diverse sectors. Beyond domain-specific knowledge, attributes such as communication, teamwork, adaptability, and critical thinking have emerged as essential, particularly considering technological advancement and changing workforce dynamics. The emphasis on employability is especially significant within Technical and Vocational Education and Training (TVET) institutions, including Malaysia's polytechnic system, which is mandated to produce industry-ready graduates. In alignment with national development strategies such as the 11th Malaysia Plan and the Malaysian Education Blueprint for Higher Education, polytechnics have increasingly incorporated soft skill development into their curriculum to close the graduate skills gap. However, persistent

mismatches between graduate attributes and industry expectations continue to be reported, raising concerns about curriculum responsiveness and the effectiveness of training interventions.

Previous research has extensively mapped the theoretical frameworks of employability, such as the SCANS Report (1991), the Partnership for 21st Century Skills (P21), and the Malaysian Soft Skills Scale (My3S), all of which highlight communication, problem-solving, and digital literacy as core competencies. However, there remains a critical gap in the literature concerning the temporal evolution of these skill requirements how employer expectations shift over time and how such changes are reflected in the perceptions of graduates attending structured recruitment engagements. To address this gap, the present study conducts a multi-dataset comparative analysis of employer perceptions gathered during the Ekspo Kerjaya Industri Politeknik (ExKIP), an annual job and internship placement initiative hosted by Malaysia's polytechnics. Specifically, this research investigates the trends in employer-rated importance of seven core employability skill constructs, communication skills, teamwork, critical thinking and problem-solving, personal qualities, technology skills, organizational skills, and continuous learning skills across five cohorts (ExKIP 8.0 to ExKIP 12.0). The study employs a quantitative time-series design, using descriptive statistics, trend analysis, and one-way ANOVA to examine both stability and change in employer priorities over a five-year period. By exploring longitudinal employer feedback, this study aims to contribute evidence-based insights into how graduate readiness is perceived in the labour market and to inform curriculum development in polytechnic education. The findings offer valuable implications for educators, curriculum developers, and policymakers seeking to align educational outcomes with contemporary workforce demands, ultimately enhancing graduate employability and sustainable career outcomes.

2. Literature Review

In the rapidly evolving 21st-century labour market, the importance of graduate employability skills has intensified, prompting a surge of scholarly attention toward understanding the alignment or lack thereof between employer expectations and graduate competencies. A consistent theme across global and regional studies is the widening gap between the skills graduates possess and those demanded by employers (García-Álvarez et al., 2022; McGunagle & Zizka, 2020; Nadarajah, 2021; Tushar & Sooraksa, 2023). Although employability frameworks such as the SCANS Report (1991), the 21st Century Skills Framework, and Malaysia's My3S have long guided curriculum development, significant implementation gaps persist particularly in embedding soft and digital skills that directly affect job performance. Employers consistently emphasize core competencies such as communication, teamwork, problem-solving, adaptability, and critical thinking as essential for productivity, innovation, and effective workplace integration (Coetzee & Goede, 2024; Daud et al., 2021; Tushar & Sooraksa, 2023). These soft skills are not only central to hiring decisions but are also linked to employee collaboration, job effectiveness, and long-term career success (Succi & Canovi, 2020). A bibliometric analysis by Wahab et al. (2024) identified four research priorities in employability studies: broad skills acquisition, generic skill development, work-related training, and curriculum enhancement all integral to graduate work readiness.

Despite institutional efforts, recent employer surveys continue to report skill deficiencies among graduates. In Malaysia's Technical and Vocational Education and Training (TVET) sector, for example, employers remain concerned about graduates' underdeveloped communication abilities, particularly in expressing technical knowledge, engaging in team-based tasks, and demonstrating workplace etiquette (Jamil et al., 2023). These gaps in interpersonal and communication competencies are further exacerbated by increasing employer expectations for emotional intelligence, adaptability, and English language proficiency (Iqbal et al., 2023; Uddin, 2021). The rise of Industry 4.0 and widespread digital transformation accelerated by the COVID-

19 pandemic has redefined the skill sets considered essential for employability. According to the World Economic Forum (2023), the most in-demand competencies include analytical thinking, active learning, digital literacy, and self-management. UNESCO-UNEVOC (2022) similarly underscores the importance of digital adaptability, entrepreneurial mindsets, and interdisciplinary communication in modern vocational systems. The Asian Development Bank (2021) advocates for the integration of digital technologies into education to transform traditional learning ecosystems into more adaptive, skills-focused platforms for future employment.

While generic competencies such as ICT, teamwork, and leadership are frequently taught, graduates often struggle with higher-order skills such as critical thinking, problem-solving, and complex communication competencies crucial to real-world job performance (Nadarajah, 2021; Yong & Ling, 2023). Moreover, graduates' self-perceived strengths often diverge from employer priorities. Employers value interpersonal communication, flexibility, and workplace readiness, while graduates tend to emphasize creativity, analytical thinking, and personal achievement (Iqbal et al., 2023; Uddin, 2021). This disconnect suggests that many graduates are insufficiently prepared for the interpersonal and organizational demands of employment.
A semi-systematic review by Tushar and Sooraksa (2023) reinforces the enduring importance of skills like teamwork, problem-solving, and lifelong learning, which remain highly valued across decades. García-Álvarez et al. (2022) identified 41 transversal competencies grouped into five dimensions, with job-related basic skills, socio-relational abilities, and self-management being most highly valued by employers. Tang (2021) adds that value-based education which incorporates ethics, emotional intelligence, and civic responsibility can further enhance employability outcomes.

Despite widespread recognition of these skill demands, most employability research remains cross-sectional, providing only static snapshots. Few studies have examined temporal shifts in employer expectations, particularly through longitudinal or multi-year analysis. In addition, existing research often generalizes findings across higher education, overlooking the vocational mission of Malaysian polytechnics to produce industry-ready graduates. This study addresses these research gaps by analyzing five consecutive datasets from the ExKIP graduate employability initiative, focusing on real-time employer feedback during graduate interviews. Through longitudinal analysis of key skill trends, the study offers context-specific insights that contribute both to academic discourse and practical strategies for curriculum alignment and performance-based training. Ultimately, the integration of "pedagogies for employability" remains vital. These strategies, which aim to embed transferable and work-relevant competencies within academic programs, are critical for preparing graduates to succeed in dynamic workplace environments (García-Álvarez et al., 2022; Wahab et al., 2024). Institutions that proactively align their curricula with evolving employer expectations especially by leveraging longitudinal data are better equipped to close the skill gap, improve job performance outcomes, and enhance graduate employability in the global economy.

3. Methodology

3.1 Research Design

This study adopts a quantitative comparative design, utilizing secondary datasets from five consecutive ExKIP events (ExKIP 8.0 to 12.0). A cross-sectional time-series approach enabled both between-group and within-group analyses to identify evolving trends in employer perceptions of graduate employability skills. The study specifically measured changes in the perceived importance of seven key skill constructs.

3.2 Data Sources and Collection

Data were collected from employers who participated in Ekspo Kerjaya Industri Politeknik (ExKIP) events an annual career fair involving polytechnic students and industry partners. Employers provided feedback during or after graduate interview sessions for job and internship placements. The datasets include:

i. ExKIP 8.0 (Year 2020)
ii. ExKIP 9.0 (Year 2021)
iii. ExKIP 10.0 (Year 2022)
iv. ExKIP 11.0 (Year 2023)
v. ExKIP 12.0 (Year 2024)

Each dataset includes employer ratings of seven employability skill constructs using a standardized instrument.

3.3 Sampling and Respondents

A total of 123 employers across the five ExKIP events were included in the analysis. These employers represent diverse industry sectors:

i. Engineering and manufacturing
ii. Services and hospitality
iii. Human resources and administration
iv. Retail and sales
v. Others (e.g., logistics, ICT)

Purposive sampling was used, focusing on employers who actively participated in the interview or selection processes and completed the skill assessment forms.

3.4 Instrumentation

The instrument was adopted and adapt from (Rahmat, N, 2017) used across all five datasets evaluates employer perceptions of graduate competencies based on seven employability skill constructs:

i. Communication Skills
ii. Personal Qualities
iii. Teamwork Skills
iv. Critical Thinking and Problem-Solving
v. Technology Skills
vi. Organizational Skills
vii. Continuously Skills

Each construct was rated using a Likert-type scale, typically ranging from 1 (Not Important) to 5 (Very Important), capturing the perceived importance of each skill in enhancing graduate work performance.

3.5 Data Analysis

To evaluate trends and differences in skill perception over time, both descriptive and inferential analyses were applied:

i. Descriptive Statistics (means, standard deviations)

ii. Trend Ranking Analysis (ranking by cohort)
iii. One-Way ANOVA to test for significant differences in ratings across cohorts

Assumptions of normality and homogeneity of variance were tested using Levene's Test, respectively.

3.6 Ethical Considerations

Since the study uses anonymized secondary data from institutional records, no personal identifiers were used. Ethical clearance was obtained from the relevant polytechnic research ethics committee to ensure compliance with data handling and confidentiality protocols.

4. Results and Analysis

4.1 Descriptive Statistics and Trend Analysis of Employability Skills

This analysis presents the descriptive statistics and trend analysis of employer-rated graduate employability skills across five ExKIP cohorts (ExKIP 8.0 to ExKIP 12.0). The study focused on seven key employability skill constructs: Communication Skills, Personal Qualities, Teamwork Skills, Critical Thinking and Problem Solving, Technology Skills, Organizational Skills, and Continuous Learning Skills.

4.1.1 Descriptive Analysis

Table 1 and Fig. 1 display the mean scores for each skill construct based on employer assessments for the five consecutive cohorts. All skill constructs received high average scores (above 4.30 on a 5-point Likert scale), indicating that graduates were generally perceived as competent. However, notable variations in score patterns over time suggest changing priorities or perceived strengths and weaknesses among graduates.

Table 1. Mean Scores of Employability Skill Constructs by ExKIP Cohort

Skill Construct	ExKIP 8	ExKIP 9	ExKIP 10	ExKIP 11	ExKIP 12
Communication Skills	4.38	4.74	4.55	4.45	4.32
Personal Qualities	4.78	4.83	4.80	4.74	4.63
Teamwork Skills	4.70	4.67	4.62	4.62	4.47
Critical Thinking & Problem Solving	4.56	4.75	4.60	4.53	4.37
Technology Skills	4.37	4.59	4.43	4.40	4.44
Organizational Skills	4.55	4.58	4.53	4.51	4.32
Continuous Learning Skills	4.76	4.70	4.59	4.48	4.37

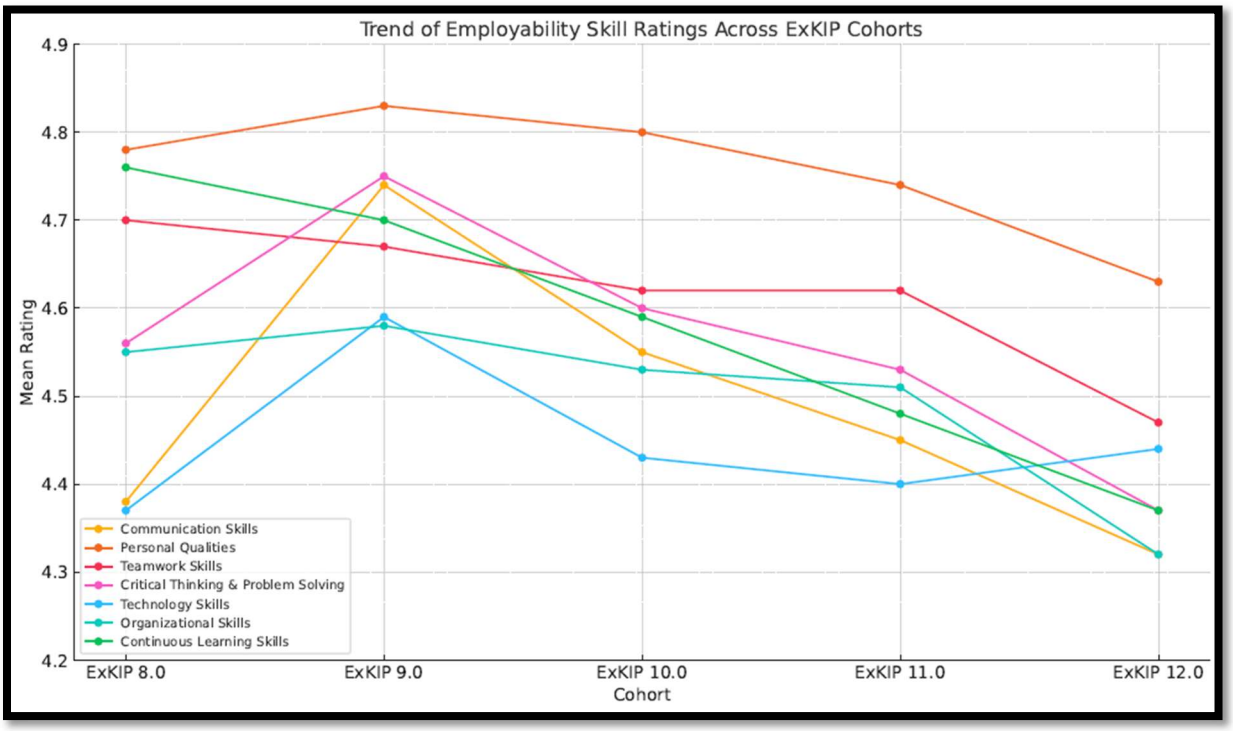


Fig.1. Trend of employability skill ratings across ExKIP cohorts

The analysis of the ExKIP datasets across five cohorts (ExKIP 8.0 to ExKIP 12.0) reveals consistent trends in employer evaluations of graduate employability skills. Among the seven skill constructs assessed, personal qualities consistently achieved the highest mean scores each above 4.60 underscoring the persistent importance of attributes such as integrity, responsibility, and professionalism in workplace contexts. These findings align with previous literature emphasizing character and ethical behaviour as core components of employability. Teamwork skills also demonstrated a positive trajectory, rising to the second rank from ExKIP 10.0 onward. This suggests that collaboration and interpersonal effectiveness have become increasingly valued in contemporary, team-based work environments. Conversely, communication skills, which initially recorded strong evaluations peaking in ExKIP 9.0 (M = 4.74) experienced a subsequent decline in both rank and mean score. This trend may reflect shifting employer expectations or growing concerns regarding graduates' ability to effectively express and articulate ideas.

An especially noteworthy development is the significant improvement in technology skills, which progressed from lower rankings in earlier cohorts to third place in ExKIP 12.0. This upward shift reflects the rising importance of digital competencies and technical adaptability in response to technological transformation across industries. In contrast, organizational skills and continuous learning skills exhibited a gradual decline in both ranking and mean ratings. Although still valued—with scores remaining above 4.3 these skills appear to be receiving comparatively less emphasis amid a labour market increasingly focused on digital fluency and problem-solving capabilities. Overall, all seven employability constructs maintained high mean values, indicating a consensus among employers regarding their relevance. However, the evolving rank trends point to a realignment in priorities, with increasing emphasis placed on personal integrity, teamwork, and technological literacy. These insights highlight the imperative for educational institutions to adapt their curricula and instructional approaches in alignment with the dynamic needs of the labour market and industry expectations.

4.1.2 Trend Ranking Analysis

Table 2 and Fig. 2 present the rank order of each skill construct based on the mean scores per cohort. This ranking reveals dynamic shifts in employer priorities.

Table 2. Rank Trend of Employability Skills Across ExKIP Cohorts

Skill Construct	ExKIP 8 (Rank)	ExKIP 9	ExKIP 10	ExKIP 11	ExKIP 12
Communication Skills	7	3	5	6	6
Personal Qualities	1	1	1	1	1
Teamwork Skills	3	5	2	2	2
Critical Thinking & Problem Solving	4	2	3	3	4
Technology Skills	6	6	7	7	3
Organizational Skills	5	7	6	4	7
Continuous Learning Skills	2	4	4	5	5

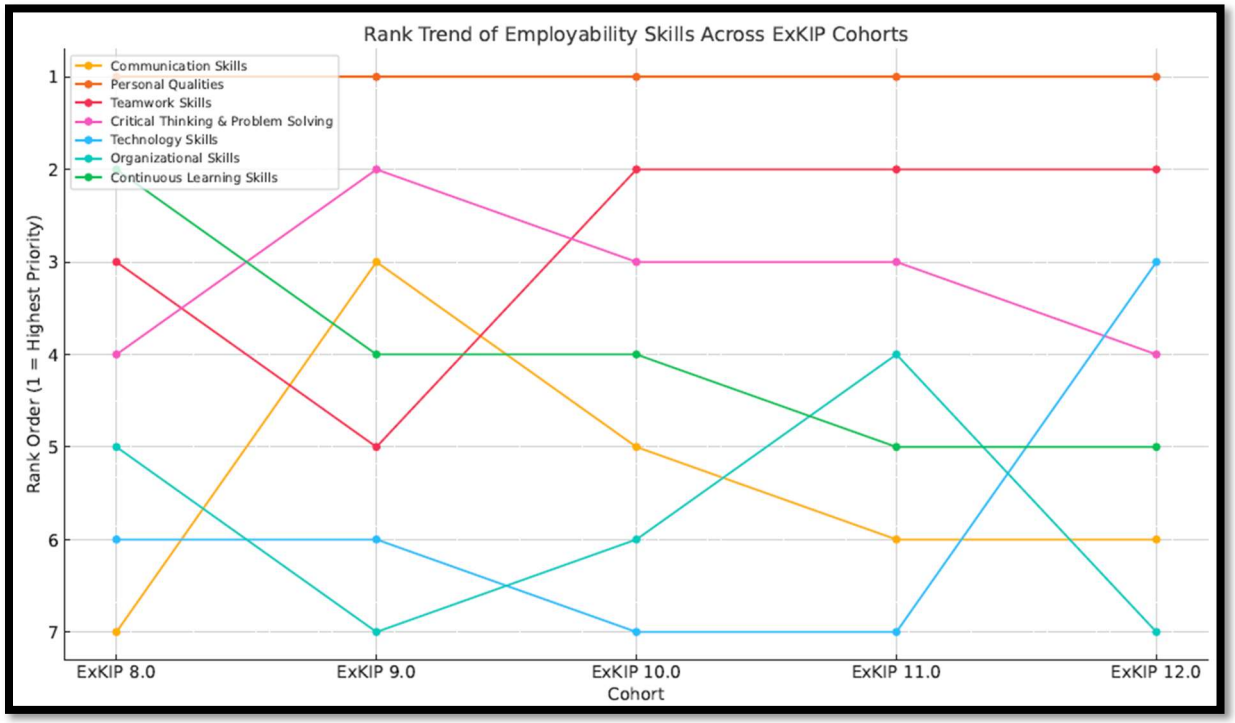


Fig.2. Rank trend of employability skill ratings across ExKIP cohorts

An in-depth examination of the rank order trends across the five ExKIP cohorts provides valuable insights into the evolving priorities of employers regarding graduate employability skills. The consistency of Personal Qualities occupying the top rank (Rank 1) from ExKIP 8.0 through ExKIP 12.0 clearly signals that attributes such as integrity, responsibility, and professionalism are foundational expectations that remain non-negotiable in the eyes of employers. Teamwork Skills demonstrated an upward trend, stabilizing at Rank 2 from ExKIP 10.0 onward. This rise in rank reinforces the importance of interpersonal collaboration, especially as workplaces become increasingly cross-functional and team-oriented. Similarly, Critical Thinking and Problem Solving maintained a strong presence in the top three rankings across all cohorts, underlining employers' demand for analytical and decision-making capabilities in dynamic work environments.

A significant trend shift was observed in Technology Skills, which improved its rank from the bottom positions (Ranks 6–7) in earlier cohorts to Rank 3 in ExKIP 12.0. This upward movement reflects a broader digital transformation in industry practices, making technical fluency a more central criterion in hiring decisions. In contrast, Communication Skills experienced a notable drop in rank from 3rd place in ExKIP 9.0 to 6th in ExKIP 12.0 suggesting a potential saturation or changing interpretation of communication competency, possibly replaced in urgency by more digitally driven skills. Organizational Skills and Continuous Learning Skills both trended downward over time, settling at lower ranks in the most recent cohort. This may indicate a shift in focus from traditional administrative strengths and general adaptability to more immediate and specialized competencies. These ranking trends suggest that while foundational soft skills remain important, employers are increasingly prioritizing traits and abilities aligned with collaboration, critical thinking, and technology use. The results call for education providers to re-examine curricular priorities to better align graduate skillsets with these evolving market expectations.

4.2 ANOVA Results on Graduate Employability Skills Across Cohorts

4.2.1 Homogeneity of Variances

Levene's test was used to assess the assumption of homogeneity of variances for each employability skill variable as shown in Table 3. The results showed that six out of seven variables met the assumption, with p-values > 0.05, indicating that the variances across the five cohorts were not significantly different. However, Problem Solving and Quality (MeanPQ) showed a significant Levene statistic, $F(4, 118) = 2.624$, $p = .038$, indicating a violation of the equal variances' assumption for this skill.

Table 3. Homogeneity of variances results using Levene's test

Skill Variable	Levene's Statistic	df1	df2	Sig. (p-value)	Interpretation
MeanCS	1.270	4	118	.286	☑ Equal variances assumed
MeanPQ	2.624	4	118	.038	✕ Equal variances not assumed
MeanTW	0.580	4	118	.677	☑ Equal variances assumed
MeanCTPS	0.607	4	118	.659	☑ Equal variances assumed
MeanTS	2.099	4	118	.085	☑ Equal variances assumed
MeanOS	0.461	4	118	.764	☑ Equal variances assumed
MeanCLS	1.362	4	118	.251	☑ Equal variances assumed

4.2.2 One-Way ANOVA Results

The purpose of this study was to examine whether there were statistically significant differences in employer-rated graduate employability skills across five cohorts (ExKIP 8.0 to 12.0). Using one-way ANOVA, seven key skill domains were analyzed: Communication Skills (MeanCS), Problem Solving and Quality (MeanPQ), Teamwork Skills (MeanTW), Critical Thinking and Problem Solving (MeanCTPS), Technical Skills (MeanTS), Organizational Skills (MeanOS), and Continuous Learning Skills (MeanCLS) as shown in Table 4.

The results revealed that none of the skill domains showed statistically significant differences across the five cohorts. This suggests that graduates from ExKIP 8.0 to 12.0 were perceived by employers to possess relatively consistent levels of employability skills. Among all the variables, MeanCLS (Lifelong Learning Skills) and MeanCS (Communication Skills) recorded higher F-

values (1.672 and 1.633, respectively), indicating slight variation across cohorts, but these differences were not statistically significant at the $p < .05$ level. It is important to note that Levene's test indicated a violation of the assumption of homogeneity of variances for one variable MeanPQ (Problem Solving and Quality). This suggests that the ANOVA result for MeanPQ should be interpreted with caution, and that future analysis might benefit from using a Welch ANOVA or non-parametric alternatives (such as the Kruskal-Wallis's test) to validate these findings for that specific skill domain.

Table 4. One-way ANOVA results

Skill Variable	F	Sig. (p-value)	Interpretation
MeanCS	1.633	.170	✗ Not significant
MeanPQ	1.189	.319	✗ Not significant
MeanTW	0.760	.553	✗ Not significant
MeanCTPS	1.574	.186	✗ Not significant
MeanTS	0.453	.770	✗ Not significant
MeanOS	0.692	.599	✗ Not significant
MeanCLS	1.672	.161	✗ Not significant

As an interpretation, this study contributes to the understanding of graduate employability by highlighting the consistency of skill ratings across multiple graduating cohorts. The absence of statistically significant differences suggests that the educational program and training frameworks provided by the ExKIP initiative have maintained a steady quality in preparing graduates with core employability skills. From a practical standpoint, these findings imply that employers have perceived similar levels of graduate preparedness over time, with no major improvements or declines in key competencies. Educational institutions may use this insight to reinforce successful elements in their curriculum while also identifying areas where innovation or enhancement might be introduced to produce future-ready graduates.

5. Discussion

The analysis of employability skill constructs across five ExKIP cohorts (8.0 to 12.0) reveals a stable yet evolving landscape of employer expectations, with clear implications for graduate work performance. All seven employability skill constructs communication skills, personal qualities, teamwork skills, critical thinking and problem solving, technology skills, organizational skills, and continuous learning skills maintained high mean scores (above 4.3), reflecting a consistently positive perception of graduate readiness. However, changes in rank order over time provide deeper insights into shifting priorities within the labour market and their relationship to graduate job performance.

i. Personal Qualities and Workplace Reliability
   Among the assessed competencies, personal qualities consistently ranked highest, with scores ranging from 4.63 to 4.83. These attributes including integrity, adaptability, work ethic, and responsibility are strongly associated with on-the-job dependability, motivation, and self-management. Their continued prioritization across cohorts underscores their foundational role in workplace success, regardless of industry (Tang, 2021). Graduates who exhibit strong personal qualities are more likely to contribute positively to organizational culture and sustain high levels of performance over time.

ii. Technological Fluency and Digital Performance
The marked rise in the ranking of technology skills, from the lowest positions in early cohorts to third in ExKIP 12.0, aligns with global trends emphasizing digital transformation and the increasing integration of technology in work processes (World Economic Forum, 2023). Graduates with strong digital competencies are better prepared to adapt to new tools and systems, work effectively in remote or hybrid environments, and drive process efficiency. These abilities are directly linked to higher levels of productivity, adaptability, and innovation in the workplace.

iii. Communication and Critical Thinking: Declining Yet Essential
Despite their historically strong evaluations, communication skills and critical thinking exhibited a decline in both ranking and perceived importance—communication falling from third to sixth, and critical thinking from second to fourth across the cohorts. This trend may reflect a disconnect between graduate proficiency and employer expectations, or a shift in how these skills are evaluated in increasingly digital work contexts (Jamil et al., 2023). Nonetheless, both remain critical for effective decision-making, interpersonal interaction, problem resolution, and client engagement. Deficiencies in these areas may impair team dynamics, hinder productivity, and reduce the overall effectiveness of graduate employees.

iv. Organizational and Continuous Learning Skills: Foundational but Undervalued?
The downward trends observed in organizational skills and continuous learning skills may suggest that employers now consider them basic expectations rather than differentiators. However, their importance to time management, task prioritization, and adaptability in fast-evolving job roles remains vital (Asian Development Bank, 2021). Graduates lacking in these areas may struggle to keep pace with change, manage workloads, or embrace lifelong learning—traits increasingly essential in dynamic and automated work environments.

v. Teamwork Skills: Sustaining Collaborative Efficiency
Teamwork skills held a consistent and prominent position (ranked second from ExKIP 10.0 onward), affirming their relevance in today's cross-functional and cooperative work settings. Employers continue to prioritize graduates who can collaborate effectively, build interpersonal relationships, and contribute to collective goals. Strong team players enhance organizational cohesion and project success, making this skill a key performance indicator in diverse workplace environments (UNESCO-UNEVOC, 2022).

vi. Implications for Curriculum Design and Institutional Strategy
Although ANOVA results indicated no statistically significant changes across cohorts, the observable shifts in skill prioritization point to emerging performance expectations. These findings call for adaptive and forward-thinking curriculum strategies that align educational outcomes with labour market demands. As noted in recent literature, institutions must go beyond technical training and adopt holistic, learner-centered approaches that integrate digital literacy, interpersonal development, and real-world application (Tang, 2021; World Economic Forum, 2023). Embedding soft skills into technical instruction through project-based learning, simulations, and industry engagement can better prepare graduates for the complexity of contemporary work.

In summary, the evolving employer perspectives captured in this study underscore the integral relationship between graduate skill development and sustained workplace performance. By aligning curriculum design with shifting industry expectations, higher education institutions particularly polytechnics can equip students not only to enter the workforce but to excel within it.

6. Conclusion and Recommendations

6.1 Conclusion

This study conducted a comparative analysis of employer-required employability skills using data collected from five ExKIP events (8.0 to 12.0), drawing on feedback from 123 employers across various industry sectors. The findings revealed consistent employer emphasis on seven core employability constructs: communication, teamwork, problem-solving, adaptability, critical thinking, interpersonal skills, and self-management. Among these, personal qualities remained the most highly rated attribute throughout all cohorts, reinforcing the enduring value of integrity, responsibility, and professionalism in the workplace. However, the data also highlight a dynamic shift in employer expectations, with rising emphasis on technical and digital competencies particularly technology skills, which showed a notable increase in perceived importance by the final cohort. In contrast, communication and organizational skills showed a gradual decline in both rank and mean ratings, suggesting that these areas may require renewed instructional focus. This evolving prioritization aligns with broader labour market transformations, including digitalization, automation, and the growing demand for agile and adaptable talent.

The descriptive statistics and trend analyses emphasize the urgent need for adaptive curriculum design that not only sustains the development of interpersonal and cognitive skills but also incorporates emerging digital literacies and self-management competencies. Polytechnic institutions, given their mandate to prepare students for industry-focused careers, must respond proactively to these changes. This includes embedding structured soft skill training, reinforcing critical thinking and communication, promoting lifelong learning, and integrating technology use across disciplines. By aligning educational strategies with employer expectations, institutions can better prepare graduates to thrive in a fluid and increasingly complex employment landscape. These targeted efforts will not only close existing skills gaps but also enhance graduates' ability to contribute meaningfully to organizational performance and innovation in the digital age.

6.2 Recommendations

Considering the findings from this study, a multi-pronged strategy is recommended to ensure that educational institutions remain responsive to evolving employer expectations and successfully equip graduates with relevant and adaptable skillsets.

i. Curriculum Enhancement and Innovation
   To address shifting priorities in the labour market, institutions should integrate employability skills as core learning outcomes across all academic programs. This includes the systematic embedding of interpersonal, communication, and critical thinking training within technical and disciplinary subjects to reinforce soft skills in context-specific applications. Project-based learning, industry simulations, and problem-solving modules should be expanded to support real-world skill development and encourage applied learning across disciplines. Maintaining the existing strengths in graduate preparation is essential, but educational designers must also enhance problem-solving and quality-related competencies, especially given the observed variance in this domain.

ii. Strengthening Industry-Academia Collaboration
   To keep curricula aligned with evolving workplace demands, institutions should formalize industry advisory panels that participate in periodic curriculum reviews and provide actionable feedback. Internship and apprenticeship programs must be broadened to offer students

authentic exposure to contemporary workplace dynamics. Institutions are also encouraged to engage employers more actively, through activities such as mock interviews, skill workshops, and curriculum review sessions, ensuring that learning objectives are informed by real-time industry insights.

iii. Systematic Assessment of Employability Skills
Institutions should implement standardized tools such as the Malaysian Soft Skills Scale (My3S) or customized rubrics to assess and track students' soft skill development over time. Establishing feedback mechanisms for both students and lecturers will facilitate continuous improvement by identifying strengths and addressing gaps in employability competencies.

iv. Capacity Building for Educators
To support the integration of soft skills into curricula, it is recommended that institutions provide professional development programs for educators. These should include certification and training in pedagogies relevant to 21st-century skills, updates on emerging industry trends, and best practices for soft skill instruction.

v. Future Research and Longitudinal Evaluation
Further inquiry is needed to deepen the understanding of employer expectations and validate the long-term effectiveness of employability training. Future studies should incorporate qualitative approaches, such as employer interviews and focus groups, to gain richer insights into skill expectations. Moreover, longitudinal tracking of graduate outcomes post-employment would help determine the lasting impact of educational interventions. Comparative research across different institutions or regional contexts is also recommended to distinguish between local and national employer requirements.

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ANALYSIS OF CURRENT RATIO (CR) AND DEBT TO ASSET RATIO (DAR) ON PROFITABILITY RATIO IN MSME WALL DECORATIONS OF MS. HASTUTI

Tamara Ramadana*, Juli Meliza

Financial Management, College of Financial Management, Medan, Indonesia

*Corresponding author e-mail address: newjuili07@gmail.com

Abstract

This study aims to assess the financial performance of the Wall Decoration MSME owned by Mrs. Hastuti throughout 2024 by utilizing key financial ratios: Current Ratio (CR), Debt to Asset Ratio (DAR), and Return on Assets (ROA). The analysis is based on monthly financial reports from January to December 2024, collected through field observation and direct interviews. A descriptive quantitative approach was employed, supported by multiple linear regression analysis. The findings reveal that the business exhibits a very high level of liquidity (CR between 6.25 and 10.35), low solvency (DAR between 0.09 and 0.15), and relatively strong though fluctuating profitability (ROA ranging from 1% to 38%). The results of the regression analysis indicate that CR and DAR jointly have a significant impact on ROA (p-value = 0.000); however, only CR demonstrates a statistically significant partial effect (p-value = 0.010). The Adjusted R^2 value of 95.9% indicates that the model explains a substantial proportion of the variation in ROA. Based on these results, it is recommended that the MSME improve the strategic use of its current assets and consider appropriate external financing options to support sustainable business growth.
Keywords: MSME; Financial Performance; Financial Ratios.

1. Introduction

In the business world, financial health is a crucial aspect that must be managed optimally and systematically. One of the key indicators of a company's operational success is its ability to generate profits. To assess whether a business is in sound financial condition, financial statement analysis particularly through financial ratios, serves as an effective evaluation tool. The outcomes of such analysis can assist business owners in assessing financial performance over a specific period and serve as a basis for strategic decision-making aimed at improving profitability.

Commonly used financial ratios include liquidity, solvency, profitability, and activity ratios. This study specifically focuses on three key ratios: the Current Ratio (CR) as a measure of liquidity, the Debt to Asset Ratio (DAR) as a measure of solvency, and the Return on Assets (ROA) as an indicator of profitability. ROA is a critical metric for assessing how effectively a company manages its assets to generate profit (Almira & Wiagustini, 2020). A high ROA indicates efficient resource utilization; however, in practice, ROA values often fluctuate due to various internal factors.

Interestingly, some companies with high CR values report low ROA figures, suggesting that current assets are not being used productively. Conversely, businesses with lower CR levels may achieve higher profitability due to more efficient managerial practices. This raises the question of whether higher liquidity consistently correlates with greater profitability. Similarly, the use of debt, as reflected in DAR, may reduce ROA if not supported by adequate productivity, but it can also boost earnings if managed strategically and efficiently.

Therefore, considering the uncertainties surrounding the relationship between liquidity and solvency on profitability, this study seeks to investigate whether CR and DAR significantly influence profitability ratios and to what extent each ratio contributes to business profitability. This research focuses on a financial ratio analysis particularly the relationship between CR and DAR on ROA based on the financial reports of a small enterprise located in Tanjung Morawa District, specifically in the village of Medan Senembah. The enterprise is engaged in handicrafts, specifically a wall decoration business owned by Mrs. Hastuti.

This study aims to determine whether the MSME owned by Mrs. Hastuti has implemented sound financial management and whether it is capable of utilizing its available resources efficiently to generate profits, pay business debts, and meet obligations related to its assets. The following section presents the financial report analysis data regarding the financial health of Mrs. Hastuti's business using financial ratio metrics for the year 2024, analyzed quarterly.

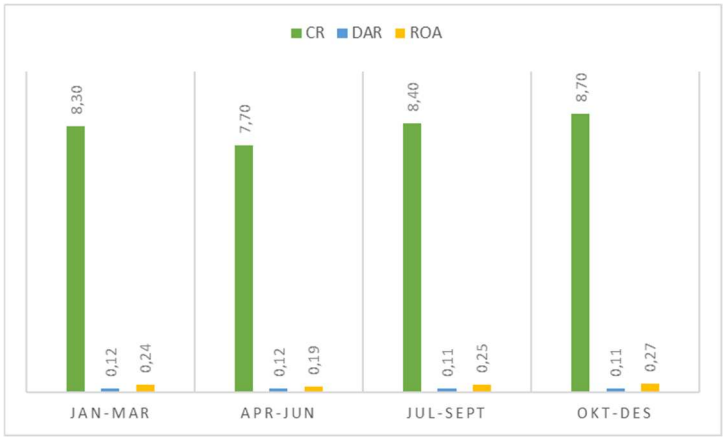


Fig. 1. Financial Ratio Analysis Chart of Mrs. Hastuti's MSME for the Year 2024

Based on the financial report data of the Wall Decoration MSME throughout 2024, an analysis was conducted on three key financial ratios: the Current Ratio (CR), Debt to Asset Ratio (DAR), and Return on Assets (ROA). The results reveal that the CR in each quarter exhibited very high values, ranging from 7.70 to 8.70. Meanwhile, the DAR remained consistently low, stabilizing within the range of 0.11 to 0.12 throughout the year.

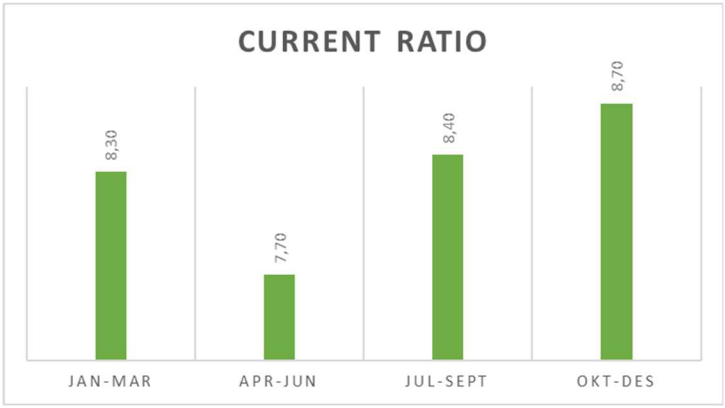


Fig. 2. Results of the Current Ratio Analysis

Based on the quarterly Current Ratio (CR) data, fluctuations are evident, with the company maintaining a very high level of liquidity throughout the year. In the first quarter (January–March),

the CR stood at 8.30, slightly declined to 7.70 in the second quarter (April–June), then rose again to 8.40 in the third quarter (July–September), and peaked at 8.70 in the fourth quarter (October–December). The annual average CR was approximately 8.28, significantly exceeding the ideal standard range of 1.5 to 2.5. This indicates that the company possesses a very strong ability to meet its short-term obligations. However, such a high ratio may also reflect suboptimal utilization of current assets, such as cash or receivables not being redirected into productive investments. Therefore, the company should reassess the efficiency of its current asset management and consider more strategic use of funds to support business growth and operational effectiveness.

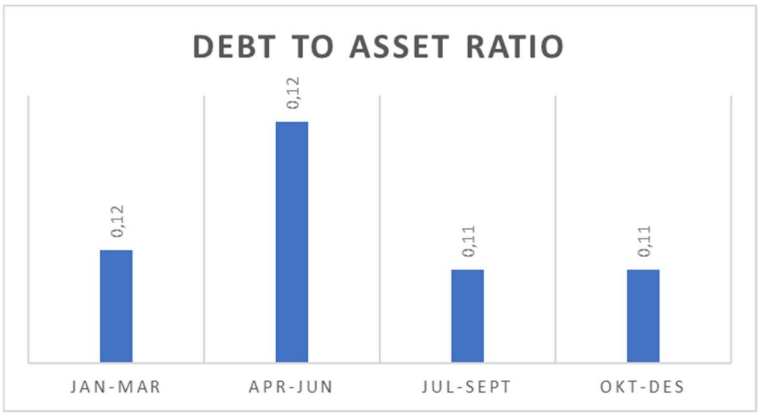


Fig. 3. Results of the Debt to Asset Ratio Analysis

Subsequently, the quarterly Debt to Asset Ratio (DAR) data indicate that the company is in a very strong financial position and tends to use debt very prudently. In the first two quarters (January–June), the DAR was recorded at 0.12, slightly decreasing to 0.11 in the third quarter, and remaining stable through the end of the year. This means that only about 11% to 12% of the company's total assets were financed through debt, while the remainder came from internal funds. This ratio reflects the company's low dependence on borrowing, resulting in relatively low financial risk. Nevertheless, the limited use of debt could also imply that the company has not yet maximized its potential for external funding to accelerate business growth. Therefore, the company may consider adopting a more balanced financing strategy to ensure that available capital is utilized more optimally.

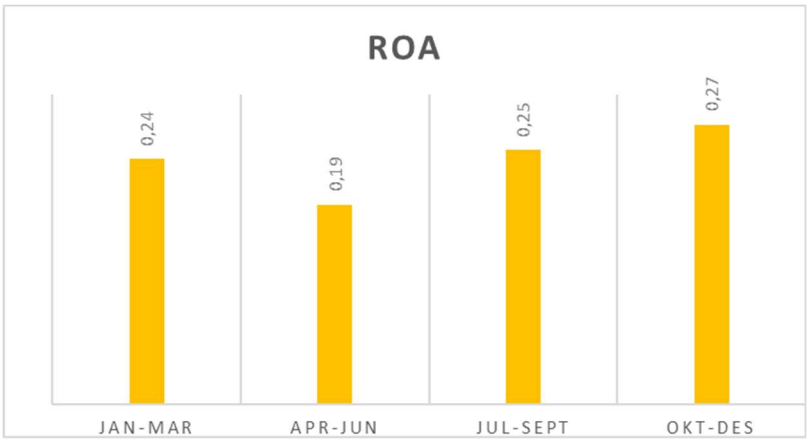


Fig. 4. Results of the Return on Assets (ROA) Analysis

Based on the quarterly Return on Assets (ROA) data for the year 2024, the Wall Decoration MSME owned by Mrs. Hastuti demonstrated a fairly strong profitability performance with an

upward trend throughout the year. ROA was recorded at 0.24 (24%) in the first quarter, and declined to 0.19 (19%) in the second quarter due to a decrease in net income and assets, particularly cash. However, ROA increased again to 0.25 (25%) in the third quarter and reached its highest point of the year at 0.27 (27%) in the fourth quarter, indicating improved efficiency in asset utilization. An ROA above 20% reflects a very high level of profitability for an MSME.

This analysis aims to provide an overview of the extent to which Mrs. Hastuti's MSME efficiently utilizes its business assets relative to its obligations, as well as to measure the enterprise's efficiency in managing costs against revenue or sales, and to observe the level of net business profit.

2. Methodology

2.1 Types and Sources of Data

This study employs both primary and secondary data sources. Primary data refer to information gathered firsthand by the researcher directly from original sources, either from individuals or groups. In this study, primary data were collected through direct interviews with respondents to obtain relevant information.

Secondary data, in contrast, are those that have been previously collected, processed, and published by other entities rather than the researcher. The secondary data used in this research comprises the financial statements of the Wall Decoration MSME owned by Mrs. Hastuti for the 2024 period.

The data in this study are classified as internal, obtained directly from Mrs. Hastuti, the business owner and operator of the Wall Decoration MSME.

2.2 Population and Sample

Population refers to the complete group of elements or subjects from which data are gathered in a study (Sugiyono, 2021). In this research, the population includes the financial records of the Wall Decoration MSME owned by Mrs. Hastuti for the 2024 fiscal year.

A sample represents a portion of the population that possesses similar characteristics and is chosen to be analyzed in the study. The sample in this research consists of the monthly financial statements of Mrs. Hastuti's Wall Decoration MSME from January to December 2024. Given the limited scope of the population and the use of all available data, this study employs a total sampling technique, in which the entire population is treated as the research sample.

2.3 Data Collection Technique

The data in this study were collected using a field research approach, primarily through direct observation. To obtain relevant information, the researcher conducted unstructured interviews. Field research entails collecting empirical data by visiting the organization or business under study in person (Sugiyono, 2021).

2.4 Operational Definitions

This research was conducted at a micro, small, and medium enterprise (MSME) operating in the handicraft industry specifically, Mrs. Hastuti's Wall Decoration business. The aim of the study is

to analyze the financial statements for the 2024 fiscal year by examining two independent variables: the Liquidity Ratio (X_1), measured using the Current Ratio (CR), and the Solvency Ratio (X_2), measured using the Debt to Asset Ratio (DAR). The dependent variable (Y) in this study is the Profitability Ratio, which is assessed using Return on Assets (ROA).

2.4.1 Current Ratio (CR)

The Current Ratio is a financial indicator used to evaluate a company's capacity to fulfill its short-term liabilities by utilizing its current assets [3]. This ratio reflects the company's liquidity position namely, how swiftly and sufficiently its current assets can be mobilized to cover immediate obligations. While a higher CR indicates stronger liquidity, an excessively high value may suggest underutilized current assets or inefficiencies in asset management.

The primary objective of this ratio is to assess short-term financial resilience, specifically a company's ability to meet its obligations without having to liquidate long-term assets. In this research, the CR is computed by dividing total current assets by total current liabilities, then multiplying the result by 100% to express it as a percentage. The formula used is (Shofwatun et al., 2021) :

$$\text{Current Ratio} = \text{Current Liabilities} / \text{Current Assets} \times 100\%$$

The CR is interpreted as follows:

i. A CR below 100% indicates poor liquidity, meaning current assets are insufficient to meet short-term liabilities.
ii. A CR between 100% and 200% suggests that the company is financially sound and capable of managing its short-term obligations.
iii. A CR above 200% reflects high liquidity, which may also imply inefficiency in the utilization of current assets.

Accordingly, in this study, the Current Ratio is used as a benchmark for evaluating the short-term liquidity of the enterprise, which is a key component of overall financial health.

2.4.2 Debt to Asset Ratio (DAR)

The Debt to Asset Ratio (DAR) is a financial indicator that assesses the proportion of a company's total assets that are financed through debt. This ratio reflects the company's reliance on external borrowing to support its operational activities. A higher DAR suggests a greater portion of asset financing comes from liabilities, which could increase financial risk if not matched by strong repayment capabilities. In contrast, a lower DAR indicates that the company primarily uses its own capital to fund its assets, suggesting stronger financial independence.

The main purpose of this ratio is to evaluate a company's solvency its ability to fulfill both short-term and long-term obligations using the total assets it owns. In this study, the DAR is calculated by dividing total liabilities by total assets, and multiplying the result by 100% to express it as a percentage. The formula is as follows (Yeyen & Ahmad, 2022):

$$\text{Debt to Asset Ratio} = \text{Total Liabilities} / \text{Total Assets} \times 100\%$$

The interpretation of the DAR is as follows:

i. A DAR below 50% indicates low reliance on debt and reflects a stable financial position.
ii. A DAR of 50% suggests a balanced funding structure between debt and equity.

iii. A DAR above 50% indicates high dependency on debt, which may expose the company to increased financial risk.

Accordingly, in this research, the DAR serves as a key measure of the firm's capital structure and its vulnerability to risk arising from the use of debt in financing its assets.

2.4.3 Return on Asset (ROA)

Return on Assets (ROA) is a financial ratio used to assess a company's capability to generate net income from the total assets it owns (Winarno, 2019). It serves as a measure of how efficiently a company leverages its asset base to produce profits. A higher ROA reflects stronger financial performance, indicating that each unit of asset contributes significantly to earnings. Conversely, a lower ROA may signal poor asset utilization or elevated operational expenses.
The primary aim of calculating ROA is to evaluate the firm's effectiveness in turning its assets into profit. In this study, ROA is determined by dividing net profit by total assets, and the result is then multiplied by 100% to convert it into a percentage. The formula used is as follows (Charisma et al., 2021):

$$\text{Return on Assets} = \text{Net Profit} / \text{Total Assets} \times 100\%$$

The interpretation of ROA values is as follows:

i. An ROA below 1% suggests low profitability and inefficient use of assets.
ii. An ROA between 1% and 5% indicates moderate efficiency in converting assets into profit.
iii. An ROA above 5% demonstrates high efficiency in utilizing assets for earnings generation.

In this research, Return on Assets functions as a key indicator of managerial effectiveness in optimizing available resources to achieve financial profitability.

2.5 Data Analysis

2.5.1 Data Analysis Method

The data analysis in this study adopts a quantitative approach, which relies on statistical and mathematical methods to quantify and interpret the data under investigation [2]. The analysis is conducted using a multiple linear regression model, a statistical technique designed to examine the relationship between multiple independent variables and a single dependent variable. This method allows the researcher to assess the extent to which the independent variables influence the dependent variable, both collectively (simultaneously) and separately (partially) (Matondang & Nasution, 2022).

2.5.2 Classical Assumption Tests

Before proceeding with hypothesis testing, it is essential to conduct classical assumption tests to ensure the validity and reliability of the regression model parameters. These tests are crucial for verifying that the model meets the fundamental assumptions of linear regression. The classical assumption tests applied in this study include the normality test, heteroscedasticity test, multicollinearity test, and autocorrelation test.

a) Normality Test

The purpose of the normality test is to assess whether the data used in the regression model

follow a normal distribution (Ghozali, 2021). Given that the sample size is fewer than 50 observations, the Shapiro-Wilk test is utilized. This test evaluates the normality of a data set by comparing the observed data sequence to what would be expected under a normal distribution using the W statistic.

The decision criteria are as follows:

i. If the significance value (sig.) is less than 0.05, H_0 is rejected, indicating that the data are not normally distributed.
ii. If the significance value (sig.) is greater than 0.05, H_0 is accepted, indicating that the data are normally distributed.

b) Heteroscedasticity Test

This test examines whether the variance of the residuals is consistent across all observations in the regression model. Constant variance indicates homoscedasticity, while varying residual variance reflects heteroscedasticity. In this study, heteroscedasticity is tested using both the White test and scatterplot method.

The interpretation guidelines are as follows:

i. If the calculated chi-square value is less than the critical value from the chi-square distribution table, there is no evidence of heteroscedasticity.
ii. If the calculated chi-square value exceeds the critical value, heteroscedasticity is indicated.

c) Multicollinearity Test

This test is conducted to identify whether there is a high correlation among the independent variables in the regression model. A well-specified model should not exhibit multicollinearity, meaning that each predictor variable is relatively independent.

In this study, the Variance Inflation Factor (VIF) is employed to detect multicollinearity by measuring how much the variance of a regression coefficient increases due to multicollinearity. The decision criteria are as follows (Ghozali, 2021):

i. If VIF < 10, multicollinearity is not present.
ii. If VIF > 10, multicollinearity is present.

Additionally, the Tolerance value, which is the reciprocal of VIF, serves as an alternative indicator:

i. If Tolerance > 0.10, the model is free from multicollinearity.
ii. If Tolerance < 0.10, multicollinearity is present.
The smaller the Tolerance value, the higher the potential risk of multicollinearity among the predictors.

d) Autocorrelation Test

The autocorrelation test evaluates whether the residuals from the regression are correlated over time. In a reliable regression model, residuals should be independent of one another. This study applies the Durbin-Watson (DW) test to assess the presence of autocorrelation. Interpretation of the DW statistic follows established guidelines to determine whether positive or negative autocorrelation exists among residuals (Ghozali, 2021).

Null Hypothesis	Decision	Condition
No evidence of positive autocorrelation	Reject H_0	$0 < d < dl$
	No Desicon	$dl \leq d \leq du$
Absence of positive autocorrelation	Reject H_0	$4 - dl < d < 4$
	No Desicon	$4 - du \leq d \leq 4 - d$
No indication of negative autocorrelation	Do Not Reject H_0	$du < d < 4 < - du$
Absence of negative autocorrelation		
No presence of either positive or negative autocorrelation		

Fig. 5. Interpretation of the Durbin-Watson (DW) statistic for detecting autocorrelation in regression residuals

i. Multiple Linear Regression

Multiple linear regression is a statistical technique used to evaluate the relationship between two or more independent variables and a single dependent variable. The goal is to measure the extent to which the independent variables influence the dependent variable, both jointly (simultaneously) and individually (partially) [9]. The regression model used in this study is expressed as follows:

$$Y = a + b_1X_1 + b_2X_2 + e$$

Where:

Y = Dependent variable (e.g., Net Profit Margin or profitability)
a = Constant (intercept)
b_1, b_2 = Regression coefficients for each independent variable
X_1, X_2 = Independent variables (e.g., Current Ratio and Debt to Asset Ratio)
e = Error term (residual)

ii. Hypothesis Testing

a) Coefficient of Determination (R^2)

The coefficient of determination (R^2) measures how well the independent variables explain the variation in the dependent variable. An R^2 value approaching 1 indicates that the independent variables (X_1 and X_2) possess a strong explanatory power over the dependent variable (Y).

b) Simultaneous Test (F-test)

The F-test is employed to determine whether the independent variables collectively have a statistically significant effect on the dependent variable. In the context of this study, the F-test assesses whether the Current Ratio and Debt to Asset Ratio together influence Return on Assets. The decision criteria are as follows:

If the calculated F value is less than or equal to the critical F table value, the null hypothesis (H_0) is accepted and the alternative hypothesis (H_1) is rejected, indicating no significant simultaneous effect.

If the calculated F value exceeds the F table value, H_0 is rejected and H_1 is accepted, suggesting that the independent variables jointly exert a significant influence.

iii. Partial Test (t-test)

The t-test is used to evaluate the individual effect of each independent variable on the dependent variable. Specifically, it measures whether the Current Ratio and Debt to Asset Ratio independently affect Return on Assets. The decision rules are:

a) If the calculated t value is less than or equal to the critical t table value, H_0 is accepted and H_1 is rejected, indicating that the variable does not significantly affect the outcome.

b) If the calculated t value is greater than the t table value, H_0 is rejected and H_1 is accepted, indicating a significant individual effect from the variable.

3. Results and Discussion

3.1 Current Ratio (CR)

Based on the calculation of financial report data from the Wall Decoration MSME owned by Mrs. Hastuti for the 2024 period using the Current Ratio (CR) formula, the following results were obtained:

Month	Current Assets		Current Liabilitie		CR
JANUARY	Rp	830.000	Rp	100.000	8,30
FEBRUARY	Rp	1.035.000	Rp	100.000	10,35
MARCH	Rp	625.000	Rp	100.000	6,25
APRIL	Rp	770.000	Rp	100.000	7,70
MAY	Rp	750.000	Rp	100.000	7,50
JUNE	Rp	790.000	Rp	100.000	7,90
JULY	Rp	830.000	Rp	100.000	8,30
AUGUST	Rp	850.000	Rp	100.000	8,50
SEPTEMBER	Rp	840.000	Rp	100.000	8,40
OCTOBER	Rp	825.000	Rp	100.000	8,25
NOVEMBER	Rp	880.000	Rp	100.000	8,80
DECEMBER	Rp	845.000	Rp	100.000	8,45

Fig. 6. Presentation of Current Ratio (CR) Analysis Results

Based on monthly financial data from January to December, the current assets of Mrs. Hastuti's Wall Decoration MSME ranged from IDR 625,000 to IDR 1,035,000, with current liabilities consistently recorded at IDR 100,000 each month. The calculation results indicate that the Current Ratio (CR) ranged from 6.25 to 10.35. The highest CR was recorded in February (10.35), while the lowest occurred in March (6.25); nevertheless, all values remained well above the healthy benchmark of CR > 2. This suggests that the business maintains an excellent level of liquidity and is more than capable of meeting its short-term obligations.

3.2 Debt to Asset Ratio (DAR)

Based on the financial data calculations for the 2024 period of Mrs. Hastuti's Wall Decoration MSME using the Debt to Asset Ratio (DAR) formula, the following results were obtained:

Month	Total Debt		Total Assets		DAR
JANUARY	Rp	100.000	Rp	865.000	0,12
FEBRUARY	Rp	100.000	Rp	1.070.000	0,09
MARCH	Rp	100.000	Rp	660.000	0,15
APRIL	Rp	100.000	Rp	805.000	0,12
MAY	Rp	100.000	Rp	785.000	0,13
JUNE	Rp	100.000	Rp	825.000	0,12
JULY	Rp	100.000	Rp	865.000	0,12
AUGUST	Rp	100.000	Rp	885.000	0,11
SEPTEMBER	Rp	100.000	Rp	875.000	0,11
OCTOBER	Rp	100.000	Rp	860.000	0,12
NOVEMBER	Rp	100.000	Rp	915.000	0,11
DECEMBER	Rp	100.000	Rp	880.000	0,11

Fig. 7. Presentation of Debt to Asset Ratio (DAR) Analysis Results

Based on data from January to December, the monthly total liabilities of Mrs. Hastuti's Wall Decoration MSME remained constant at IDR 100,000, while total assets varied between IDR 660,000 and IDR 1,070,000. The analysis results show that the Debt to Asset Ratio (DAR) ranged from 0.09 to 0.15. The highest value occurred in March (0.15), indicating that 15% of the assets were financed by debt, while the lowest occurred in February (0.09). This low solvency ratio indicates that the business has minimal reliance on external financing and is primarily supported by owner's equity, reflecting a stable financial condition with low risk of default. However, it also implies that the potential use of debt for business expansion has not yet been optimized. In the context of MSMEs, well-managed and measured debt usage can serve as a strategic growth lever. Therefore, overall, the MSME's solvency condition is considered very strong, though there remains room to wisely leverage external financing to support future business development.

3.3 Return To Assets (ROA)

Based on the calculation of financial report data from Mrs. Hastuti's Wall Decoration MSME for the 2024 period using the Return on Assets (ROA) formula, the following results were obtained:

Month	Net Profit		Total Assets		ROA
JANUARY	Rp	205.000	Rp	865.000	0,24
FEBRUARY	Rp	405.000	Rp	1.070.000	0,38
MARCH	Rp	5.000	Rp	660.000	0,01
APRIL	Rp	145.000	Rp	805.000	0,18
MAY	Rp	125.000	Rp	785.000	0,16
JUNE	Rp	165.000	Rp	825.000	0,20
JULY	Rp	205.000	Rp	865.000	0,24
AUGUST	Rp	225.000	Rp	885.000	0,25
SEPTEMBER	Rp	215.000	Rp	875.000	0,25
OCTOBER	Rp	205.000	Rp	860.000	0,24
NOVEMBER	Rp	255.000	Rp	915.000	0,28
DECEMBER	Rp	215.000	Rp	880.000	0,24

Fig. 8. Presentation of Return on Assets (ROA) Analysis Results

Based on financial data from January to December, the net income of Mrs. Hastuti's Wall Decoration MSME ranged from IDR 5,000 to IDR 405,000, with total assets ranging between IDR 660,000 and IDR 1,070,000. The calculation results indicate that ROA fluctuated between 1% and 38%. The highest value occurred in February (38%), reflecting a high level of efficiency in asset utilization, while the lowest was recorded in March (1%) due to minimal profit likely caused by a decline in sales. In general, ROA remained at a favorable level in most months, ranging between 16% and 28%, with an average above 20%, indicating that the assets were used quite effectively to generate profit. However, the significant fluctuations in earnings reveal instability in income. Therefore, the business needs to improve efficiency during certain months, particularly in cost management and marketing strategies, in order to stabilize profitability and maintain ROA at an optimal level.

3.4 Normality Test

Table 1. Results of the Normality Test

	Shapiro-Wilk		
	Statistic	Statistic	Sig.
ROA	.866	.866	.058

a. Lilliefors Significance Correction

Based on the results of the normality test, the Shapiro-Wilk test produced a significance value (sig.) of 0.058 (rounded to 0.06), which is greater than 0.05. This indicates that the data are normally distributed.

3.4.1 Heteroscedasticity Test

The purpose of the heterosceSdasticity test is to assess whether the variance of residuals differs across observations within the regression model. In this study, the analysis was conducted using both the White test and a scatterplot approach, with the results presented as follows:

Table 2. Results of the White Test

Modeli Summaryi

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.776[a]	.603	.304	.00001

Note. a. Predictors: (Constant), x1x2, x1_kuadrat, x2_kuadrat

N * R Square = 12 * 0.603= 7,236

Chi Squre Tabel 7.81473 (Df = 3)

Therefore, based on the results above, it can be concluded that the Chi-Square value is less than the Chi-Square table value (7.236 < 7.81473), indicating that there is no indication of heteroscedasticity in the data.

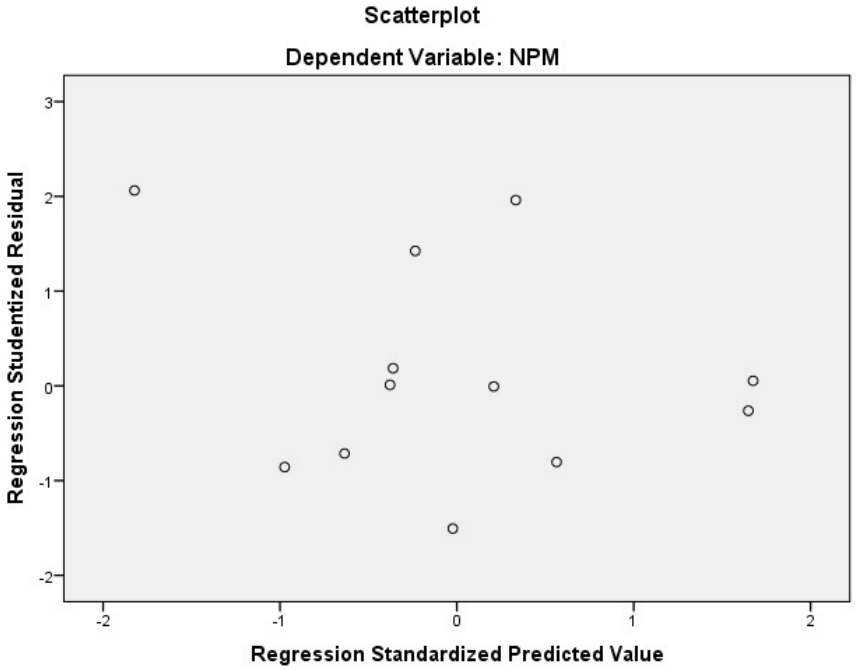


Fig. 9. Results of the Scatterplot Test

The scatterplot results show that the data points are randomly distributed, both above and below the zero value on the vertical (Y) axis. Therefore, it can be concluded that there is no indication of heteroscedasticity in this regression model.

3.4.2 Multicollinearity Test

Table 3. Results of the Multicollinearity Test

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	CR	.362	2.764
	DAR	.362	2.764

Note. a. Dependent Variable: ROA

Based on the coefficients table, the Variance Inflation Factor (VIF) is 2.764, which is below the threshold of 10. This suggests that multicollinearity is not present among the independent variables in the regression model.

3.4.3 Autocorrelation Test

Table 4. Results of the Autocorrelation Test

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.995[a]	.990	.986	.00420	1.985

Note. a. Predictors: (Constant), DAR, CR

b. Dependent Variable: ROA

According to the Model Summary table, the Durbin-Watson (DW) statistic is 1.985. Since the value falls between dU and 4 – dU (1.5794 < 1.985 < 2.4206), it can be concluded that the regression model does not exhibit signs of autocorrelation.

3.4.4 Multiple Linear Regression Test

Table 5. Results of the Multiple Linear Regression Test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-.670	.103		-6.525	.001		
	CR	.103	.007	1.061	14.086	.000	.362	2.764
	DAR	.462	.412	.085	1.122	.313	.362	2.764

Note. a. Dependent Variable: ROA

$$Y = -0{,}670 + 0{,}103\ X1 + 0{,}462\ X2$$

a. The constant value is –0.670, suggesting that when both X_1 and X_2 are zero, the predicted value of Y would be –0.670. However, this value holds little practical relevance.
b. The regression coefficient for X_1 is +0.103, which implies that for each unit increase in X_1, the dependent variable Y is expected to increase by 0.103.
c. Similarly, the regression coefficient for X_2 is +0.462, meaning that a one-unit increase in X_2 corresponds to a 0.462 increase in Y.

3.4.5 Coefficient of Determination Test (R^2)

Table 6. Results of the Coefficient of Determination Test

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.995[a]	.990	.986	.00420	1.985

*Note.*a. Predictors: (Constant), DAR, CR
b. Dependent Variable: ROA

The Adjusted R Square value of 0.986 indicates that 98.6% of the variation in the dependent variable (Y) is explained by the combined effect of the independent variables X_1 and X_2. This reflects the model's strong explanatory power in capturing the relationship between the independent and dependent variables. The remaining 1.4% is likely due to factors outside the model, such as unmeasured variables or data-related errors.

3.4.6 Simultaneous Test (F-Test)

Table 7. Results of the Simultaneous Test

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.009	2	.004	241.060	.000[b]
	Residual	.000	5	.000		

Total	.009	7	

*Note.*a. Dependent Variable: ROA
b. Predictors: (Constant), DAR, CR

The significance value (Sig.) obtained is 0.000 (< 0.05), indicating that the independent variables have a statistically significant simultaneous effect on the dependent variable.

3.4.7 Partial Test (t-Test)

Table 8. Results of the Partial Test

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-.670	.103		-6.525	.001		
	CR	.103	.007	1.061	14.086	.000	.362	2.764
	DAR	.462	.412	.085	1.122	.313	.362	2.764

Note. a. Dependent Variable: ROA

- **i.** The significance value (Sig.) for variable X_1 is 0.000 (< 0.05), suggesting that X_1 has a statistically significant effect on the dependent variable Y.
- **ii.** The significance value (Sig.) for variable X_2 is 0.313 (> 0.05), indicating that X_2 does not exert a statistically significant influence on Y.

4. Conclusion

Based on the results of financial ratio analysis and statistical testing of Mrs. Hastuti's Wall Decoration MSME in 2024, it can be concluded that the liquidity level (CR) is very high (6.25–10.35), indicating the business's strong ability to meet its short-term obligations, although it also suggests that excess current assets have not been optimally utilized. The solvency ratio (DAR) is low (0.09–0.15), reflecting minimal dependence on debt, but also implying that external financing potential has not been fully leveraged. The profitability ratio (ROA) is fairly good (16%–38%) despite its fluctuations, indicating that asset management is effective but not yet stable. Moreover, the results of the multiple linear regression test show that CR and DAR have a significant simultaneous effect on ROA (Sig. = 0.000). Partially, only CR has a significant effect (Sig. = 0.010), while DAR is not significant (Sig. = 0.354). The Adjusted R^2 value of 0.959 indicates that the model explains 95.9% of the variation in profitability.

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IMPACT OF TIKTOK ON GEN Z'S ENTREPRENEURIAL DRIVE AND THRIFT BUSINESS IN MEDAN

Rahel Simanullang*, Surya Darma Nasution

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, Medan, Indonesia

*Corresponding author e-mail address: rahelsimanullang21@gmail.com

Abstract

The rapid development of digital technology has significantly influenced daily life, especially among Gen Z. TikTok, beyond being a source of entertainment, has become a platform for business development and promotion. This study aims to analyze the impact of TikTok as a digital platform on increasing entrepreneurial interest and thrift business opportunities among Generation Z in Medan. Using a quantitative approach, data were collected through questionnaires distributed to 100 active TikTok users involved in or interested in the thrift business. The results show a positive and significant relationship between TikTok usage and increased interest in entrepreneurship and thrift business opportunities. TikTok serves as an effective medium for marketing, business education, and personal branding-factors that influence entrepreneurial decisions. The study concludes that TikTok has strong potential as a strategic tool to foster entrepreneurial spirit among Gen Z, particularly in creative and trend-driven fields like the thrift business. Their results give us a deeper understanding of how digital platforms can support the economic potential of the younger generation.
Keywords: TikTok; Entrepreneurial Interest; Thrift Business.

1. Introduction

The development of digital technology has changed the way humans interact, access information, and carry out economic activities. One significant impact of this transformation is the emergence of various social media platforms, particularly TikTok, which is no longer used solely for entertainment but also serves as a productive medium—especially in the context of entrepreneurship (Julia, Zunaedi, & Putra 2024) and is used to help people become more creative (Fitri et al., 2021). Social media has become essential in modern life as a means of interaction and business expansion, with TikTok emerging as Generation Z's preferred platform in recent years (Sundari & Nasoha, 2024). Gen Z is a generation that was born and grew up in the internet era, which shows a high tendency towards the use of digital media as a tool for self-exploration, communication (Wulandari & Furnamasari, 2021) (Abrar, 2020), and the creation of business opportunities (Gawer, 2022) individuals with such interests actively seek business opportunities and design strategies to develop their businesses (Sihaloho et al., 2020). Entrepreneurial interest is the ability to create and implement new ideas creatively to capitalize on business opportunities in order to achieve goals (Pradesy et al., 2024) (Nurhayati, 2020), along with a commitment to business objectives (Purwaningsih & Burhanudin, 2021).

TikTok was first launched in 2016 in China, and in 2020 it experienced quite rapid development to become global (Azhari & Ardiansah, 2022). TikTok is a social media platform that is not only a medium for entertainment but also a strategic promotional media platform. With features such as short videos, the For You Page (FYP), and live streaming (Sangadji et al., 2024) (Abidin, 2020). TikTok has become one of the most popular digital platforms and has a major influence on content consumption patterns and user interactions, especially among young people (Andini et al., 2024). TikTok is known as a content platform that is famous as the fastest growing virtual entertainment

industry (Rika Widianita & M Nawari, 2023). Previous research has revealed that TikTok contributes to increasing interest in entrepreneurship (Dhitara & Ardiansyah, 2022) (Yasin, 2022) among students and the younger generation (Karimah et al., 2025). In addition, the features available on the TikTok application make it easier for business actors to reach the market (Priyono & Dian Permata Sari, 2023) and build relationships with consumers (Kharisma & Nawawi, 2023). However, most of the existing research still focuses on the general aspect of digital promotion, not specifically exploring how TikTok influences entrepreneurial interest and creates specific business opportunities such as thrift businesses (buying and selling quality used goods), especially in the city of Medan.

Therefore, a more in depth study is needed on how TikTok, as a digital platform tool based on algorithms and creative content, can be optimally utilized by Generation Z in creating and developing thrift businesses. In Medan City, with its rapid digital dynamics and high Gen Z population, it is a relevant location to explore this phenomenon. This research is important because it not only answers the understanding of information technology but also provides practical contributions to the strategy for developing young technology-based entrepreneurship in today's digital era.

2. Methodology

This study uses a quantitative approach to analyze the influence of TikTok application usage on entrepreneurial interest and thrift business opportunities among Generation Z in Medan City. Data were collected through the distribution of online questionnaires to respondents selected using purposive sampling techniques based on the following criteria:

i. Aged between16–27 years
ii. Actively using TikTok, and
iii. Having involvement or interest in the thrift business through the platform.

The population of the study consisted of Generation Z individuals residing in Medan City, based on the classification of the Central Statistics Agency (BPS). The number of samples was determined by the Slovin formula using a margin of error of 10%, namely 100 respondents. The purposive sampling technique was used to ensure that respondents matched the characteristics needed in the study.

The instrument used was a closed questionnaire based on a 5-point Likert scale, covering three main variables: TikTok usage (independent variable), entrepreneurial interest, and thrift business opportunities (dependent variable). Each variable was measured using 5 indicators that had been tested for validity with Pearson Product Moment and reliability with Cronbach's Alpha. The test results showed that all items were valid ($r > 0.197$) and reliable ($\alpha > 0.7$).

The questionnaire was distributed online via Google Form. The collected data were then analyzed using SPSS version 22. In addition to primary data, this study also utilized secondary data from journals, scientific articles, and relevant statistical reports.

2.1 Data Analysis Techniques

The data analysis was carried out using descriptive statistics and multiple linear regression**.** The following statistical tests were employed:

i. t-test: to measure the partial effect of TikTok usage on each dependent variable,
ii. F test: to determine the simultaneous influence,

iii. Coefficient of determination (R^2): to determine the extent to which TikTok usage explains variance in entrepreneurial interest and thrift business opportunities.

3. Results and Discussion

This study was conducted to examine the extent to which the use of TikTok as a digital platform influences entrepreneurial interest and thrift business opportunities among Generation Z in Medan City. Based on the results of the questionnaire distributed to 100 respondents, several key findings were identified that were relevant to the research objectives.

i. Average of Research Variables

Analysis of the three variables shows that TikTok is used quite intensively by Gen Z and has a positive relationship with entrepreneurial activities.

Table 1Summary of Average Research Variables

Variables	Highest Score	Average
TikTok Usage (P1-P5)	"Often/Very Often"	3.51
Interest in Entrepreneurship (P6-P10)	"Interested/Very Interested"	3.69
Thrift Business Opportunities (P11-P15)	"Effective/Very Effective"	3.93

Results indicate that the majority of respondents not only actively use TikTok, but also show an interest in entrepreneurship and a positive perception of the thrift business opportunities provided by the platform.

ii. Validity Test

Validity testing was carried out to determine the extent to which the research instrument used Pearson correlation between the scores of each question item and the total score.

Table 2. Validity Test Results

No	Variables	Code	r Count	r Table	Information
1	Using the TikTok Application as a Digital Platform (X1)	P1	0.357	0.197	Valid
2		P2	0.486	0.197	Valid
3		P3	0.491	0.197	Valid
4		P4	0.492	0.197	Valid
5		P5	0.375	0.197	Valid
6	Interest in Entrepreneurship (Y1)	P6	0.463	0.197	Valid
7		P7	0.356	0.197	Valid
8		P8	0.500	0.197	Valid
9		P9	0.478	0.197	Valid
10		P10	0.439	0.197	Valid
11	Thrift Business Opportunities (Y2)	P11	0.607	0.197	Valid
12		P12	0.547	0.197	Valid
13		P13	0.399	0.197	Valid
14		P14	0.291	0.197	Valid
15		P15	0.660	0.197	Valid

The results of all questions used in the questionnaire are valid. It is known that the R calculation value is greater than the R table.

iii. Reliability Test

Reliability testing was conducted to determine the reliability of the research instrument from the use of the TikTok application as a digital platform, interest in entrepreneurship, and thrift business opportunities.

Table 3. Reliability Test Results

No	Variables	Cronbach's Alpha	Provisions	Information
1	Using the TikTok Application as a Digital Platform (X1)	0.774	0.7	Reliable
2	Interest in Entrepreneurship (Y1)	0.787	0.7	Reliable
3	Thrift Business Opportunities (Y2)	0.765	0.7	Reliable
4	All Items	0.759	0.7	Reliable

Note. Cronbach Alpha value is > 0.7 which states that each variable is reliable.

1. Multiple Linear Regression Test Results
   Regression tests were conducted to determine the effect of TikTok usage on two dependent variables, namely entrepreneurial interest and thrift business opportunities.

Table 4. Partial Test Results (t-Test)

Variables	Coefficient (B)	t-count	Sig. (p)
Interest in Entrepreneurship	0.522	3,945	0,000
Thrift Business Opportunities	0.344	2,463	0.016

p-values <0.05 indicate that both variables have a significant influence on the use of TikTok as a platform for entrepreneurship.

Table 5. Simultaneous Test Results (F Test)

Source	F-count	Sig. (p)
Regression model	61,209	0,000

The results of the F test show that the use of TikTok is simultaneously significantly influenced by the variables of entrepreneurial interest and thrift business opportunities.

Table 6. Results of the Determination Coefficient (R^2)

Model	R^2
Regression	0.558

The R^2 value of 55.8% indicates that variations in TikTok usage in the context of entrepreneurship can be explained by entrepreneurial interest and thrift business opportunities.

The results of this study indicate that TikTok is not only used as an entertainment medium by Generation Z but has also become a strategic platform that encourages entrepreneurial activities, especially in thrift businesses. The finding that the TikTok usage variable is significantly related to entrepreneurial interest and thrift business opportunities is consistent with previous studies, which highlight the role of social media in shaping entrepreneurial spirit and behavior among young people.

TikTok's influence on entrepreneurial interest can be explained through easy access to educational content, engaging visual experiences, and community-based marketing models. Content such as business tips videos, testimonials from successful sellers, and tutorials on building a business has strengthened the perception that entrepreneurship is something that is possible and can be started on a small scale.

Meanwhile, thrift business opportunities are also increasing along with the high engagement of TikTok users towards creatively packaged used products. The live streaming, storytelling, and promotion features supported by the TikTok algorithm allow business actors to reach a wide audience without high costs. This is a strategic opportunity, especially for young people who are just starting a business and have limited capital.

Overall, these results confirm that TikTok has strategic value as a digital economic empowerment tool for the younger generation. With a relevant, creative, and consistent content approach, TikTok can be a powerful tool in shaping a new generation of entrepreneurs in the era of digital transformation.

4. Conclusion

This study clearly answers the main question regarding how the use of the TikTok application as a digital platform affects entrepreneurial interest and thrift business opportunities among Generation Z in Medan City. Based on the results of quantitative analysis of data from 100 respondents, it was found that TikTok has a positive and significant influence on both variables. Interactive features such as short-form videos, live streaming, and personalized, interest-based algorithms have been shown to facilitate branding, market reach, and effective product promotion among young users.

Overall, this study concludes that TikTok is not merely an entertainment platform, but also a strategic tool for fostering digital entrepreneurship, particularly within the context of the growing thrift business trend among Gen Z. This study contributes new insights by providing empirical evidence of the direct relationship between digital platform usage and youth-driven entrepreneurial development. The findings underscore the potential of leveraging social media platforms like TikTok to nurture economic participation and innovation among the younger generation.

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DETERMINATION OF OUTSTANDING TEACHERS BASED ON PERFORMANCE CRITERIA AND DEDICATION WITH THE *SIMPLE ADDITIVE WEIGHTING* (SAW) METHOD CASE STUDY OF SMK SWASTA NURUL AMALIYAH

Cintya*, Surya Darma Nasution

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, Medan, North Sumatra, Indonesia

*Corresponding author e-mail address: cintyacrytya5@gmail.com

Abstract

The selection of outstanding teachers is a form of appreciation for their dedication and performance in supporting the quality of education. However, the assessment process is often conducted subjectively and not based on an objective and measurable system. This study aims to systematically identify outstanding teachers by utilizing the *Simple Additive Weighting* (SAW) method. The research was conducted at SMK Swasta Nurul Amaliyah, involving ten teachers as alternatives and three main evaluation criteria: discipline, attendance rate, and contribution as a homeroom teacher. Each criterion was assigned a weight, followed by assessment, normalization, and calculation of preference values using the SAW method. The results showed that the teacher with the highest score was Meriyanti Nasution, S. Pd, with a score of 1.00 and was declared the outstanding teacher. The implementation of the SAW method demonstrated its ability to deliver an objective, fair, and accountable evaluation. This study is expected to serve as a reference in information-based decision-making processes in the field of education.
Keywords: Teacher; Performance; SAW.

1. Introduction

Teachers are professionals with specific qualifications who carry out their duties to educate, teach, guide, motivate, and facilitate students in learning to achieve predetermined educational goals (Nurzannah, 2022). Teachers play a crucial role as professional educators who not only teach but also shape the character and personality of their students. In performing their duties, teachers serve as motivators, facilitators, and role models (Tari & Hutapea, 2020). An outstanding teacher is one who demonstrates the highest level of performance and deserves recognition based on a set of criteria established by the school (Rambe et al., 2023).

Therefore, awarding outstanding teachers is important as a form of appreciation for their dedication. Unfortunately, the assessment of outstanding teachers is often subjective and not based on systematic standards (Ramadani & Heltiani, 2020), even though teachers' performance and dedication significantly impact the quality of education. Teacher performance refers to the outcomes achieved by teachers in fulfilling their responsibilities, which include aspects such as teaching, discipline, responsibility, attendance, and professional development (Nugraha & Mursyidin, 2024). Performance encompasses teaching ability, innovation, and school involvement (Rohayati et al., 2023), while dedication reflects commitment in the educational process (Serli et al., 2022). A teacher's dedication can be seen in how consistently they fulfill their duties with discipline, responsibility, activeness, productivity, and by providing the best service to students (Rahayu & Sindar, 2022).

At SMKS Nurul Amaliyah, there is currently no official system for evaluating outstanding teachers. To address this, the present study proposes the *Simple Additive Weighting* (SAW) method, which

is known to be effective for multi-criteria decision making due to its simplicity and accuracy (Al Jufri, 2022). Previous studies have shown that SAW can produce objective and transparent decision support systems (Prima & Efendi, 2022). This study aims to identify and weight the assessment criteria, apply the SAW method, and generate teacher rankings based on their performance and dedication. The benefits include both theoretical and practical contributions for researchers, schools, higher education institutions, and future research.

The Simple Additive Weighting (SAW) method is an effective multi-criteria decision-making technique widely applicable in vocational education settings. It enables objective, structured, and measurable evaluation of alternatives, such as assessing outstanding teachers or evaluating training programs. SAW improves transparency and consistency in decision-making by minimizing subjectivity and supporting data-driven judgments (OECD, 2021).

In addition to performance, teacher dedication is often overlooked in previous decision support studies. Unlike existing studies that only focused on measurable achievements, this study incorporates dedication criteria through homeroom teacher responsibilities. This makes the assessment model more holistic and fairer. Recent studies by Hasanah & Sari (2023) and Yuliana & Firmansyah (2024) confirm the effectiveness of integrating multiple role dimensions using SAW in the education sector.

2. Methodology

This research was conducted at SMK Swasta Nurul Amaliyah, located on Jl. Sei Merah, Dagang Kerawang Village, Tanjung Morawa Subdistrict, Deli Serdang Regency, North Sumatra. The study was carried out over a period of four months, from March to June 2025. The research activities included title submission, permit application, field research implementation, thesis writing and supervision, as well as the publication of scientific work. This study employs a descriptive quantitative approach by applying a multi-criteria decision-making method, namely Simple Additive Weighting (SAW), to select outstanding teachers based on predetermined criteria. The selection of this method is justified by its capability to deliver objective, systematic, and quantifiable evaluations.

To ensure data validity, any inconsistencies or missing values were resolved by triangulating teacher attendance logs, interview transcripts, and formal performance documentation. A data dictionary was created to define key variables used in the study. For example, 'Discipline' was measured using school logbooks, while 'Attendance' reflected the total days present divided by total working days.

To ensure data validity and reliability, this study employed data triangulation methods, cross-checking interview transcripts, observation notes, and formal school records. The consistency of the assessment was validated by matching the data with performance logs and daily attendance records. The criteria weights were also confirmed through internal school discussions and approved by the school principal.

The data used in this study include both primary and secondary sources. Primary data were obtained through direct field observations and interviews with the principal, vice principal, and teaching staff at SMK Swasta Nurul Amaliyah. Meanwhile, secondary data were gathered from school documents such as teacher attendance records, performance evaluations, attendance reports, as well as literature and references from journals and books related to the SAW method and teacher assessment. Data collection was conducted through two approaches: field research and literature review. Field research included physical observation of teacher activities, structured

interviews with school officials, and documentation of the interviews. The literature review was carried out by collecting relevant references related to the SAW method and the evaluation system for outstanding teachers.

In this study, ten teachers were considered as alternatives in the assessment process. The teacher data are presented in Table 1 below:

Table 1. Teacher Data of SMKS Nurul Amaliyah

Code	Teacher Name	L/P	Class Teacher	Attendance	Discipline
A1	Encep Nursalam, ST	L	Waka. Sarpras	17 days	Disciplined
A2	Sri Yunita, S.Pd	P	Homeroom Teacher	16 days	Moderately Disciplined
A3	Maulidia Indapuri, S.Kom	P	Homeroom Teacher	15 days	Moderately Disciplined
A4	May Wahyu Susanthy, SE, S.Pd	P	Homeroom Teacher	18 days	Disciplined
A5	Prapti Wahyuni, SE	P	Homeroom Teacher	15 days	Moderately Disciplined
A6	Poniasih, S.Pd	P	Homeroom Teacher	17 days	Disciplined
A7	Drs. Samsul Bahri Lubis	L	Homeroom Teacher	17 days	Disciplined
A8	Lisa Armaini, S.PdI	P	Homeroom Teacher	12 days	Undisciplined
A9	Meriyanti Nasution, S.Pd	P	Homeroom Teacher	19 days	Highly Disciplined
A10	Asniah, S.Pd, M.Pd	P	Homeroom Teacher	15 days	Moderately Disciplined

The assessment criteria in this study were determined based on the results of observations and internal discussions, which included discipline (C1), attendance (C2), and the role as a homeroom teacher (C3). Each criterion was assigned a weight corresponding to its level of importance. A detailed overview is presented in Table 2 below.

Table 2. Teacher Evaluation Criteria

Code	Criteria	Weight	Type	Priority
K1	Disciplined	0,50	*Benefit*	1
K2	Attendance	0,25	*Benefit*	2
K3	Homeroom Teacher	0,25	*Benefit*	3

Discipline was assessed based on the number of instances of tardiness, using a scale from 1 to 5, as shown in Table 3:

Table 3. Discipline Scale (C1)

Scale	Discipline Weight
5	Highly Disciplined
4	Disciplined
3	Moderately Disciplined
2	Less Disciplined
1	Undisciplined

For attendance, the assessment was based on the percentage of days present compared to the total number of working days, as detailed in Table 4:

Table 4. Attendance Scale (C2)

Percentage of Attendance	Scale (1-5)	Description
≤ 60%	1	Highly Low
61% - 70%	2	Low
71% - 80%	3	Fair
81% - 90%	4	Good
91% - 100%	5	Excellent

Meanwhile, the role of a homeroom teacher was evaluated based on the teacher's involvement in guiding and mentoring students, as shown in Table 5:

Table 5: Homeroom Teacher Assessment Scale (C3)

Scale	Criteria Weight
Highly Low	1
Low	2
Fair	3
Good	4
Excellent	5

The initial assessment results for the 10 teachers based on each criterion are presented in Table 6, which contains descriptive data prior to being converted into numerical values:

Table 6. Alternative Data and Criteria Scores

Code	Alternative (A)	Criteria (K)		
		K1	K2	K3
A1	Encep Nursalam, ST	Disciplined	Good	Low
A2	Sri Yunita, S.Pd	Moderately Disciplined	Fair	Good
A3	Maulidia Indapuri, S.Kom	Moderately Disciplined	Fair	Fair
A4	May Wahyu Susanthy, SE, S.Pd	Disciplined	Good	Excellent
A5	Prapti Wahyuni, SE	Moderately Disciplined	Fair	Fair
A6	Poniasih, S.Pd	Disciplined	Good	Good
A7	Drs. Samsul Bahri Lubis	Disciplined	Good	Good
A8	Lisa Armaini, S.PdI	Undisciplined	Highly Low	Low
A9	Meriyanti Nasution, S.Pd	Highly Disciplined	Excellent	Excellent
A10	Asniah, S.Pd, M.Pd	Moderately Disciplined	Fair	Fair

To support a systematic assessment process, a research framework was employed. The stages in this framework began with problem identification, followed by data collection (observation, interviews, and documentation), determination of alternatives and criteria, and continued with the application of the SAW method. This included the construction of a decision matrix, score normalization, weighting, and the calculation of final scores. The teacher with the highest score was then designated as the outstanding teacher.

3. Results and Discussion

3.1 Results

The three main criteria used in the assessment of outstanding teachers are discipline (C1), attendance (C2), and the role as a homeroom teacher (C3). Discipline is measured by the punctuality of teachers in performing their duties, attendance reflects the teacher's level of commitment to the teaching and learning process, while the role as a homeroom teacher represents additional responsibilities in mentoring students. These three criteria are used to comprehensively evaluate the quality and dedication of teachers.

Table 7. Teacher Criteria Data

Code	Criteria	Brief Description
K1	Disciplined	Attendance and punctuality in performing duties.
K2	Attendance	The presence of teachers is very important as mentors, educators, and role models who help shape students' character and increase their motivation to learn.
K3	Homeroom Teacher	A homeroom teacher is a teacher who guides, directs, and monitors the development of students in a class.

A total of 10 teachers were selected as alternatives in the assessment process. Each teacher was coded from A1 to A10. The selection was based on their activeness, contribution, and employment status at the school.

Table 8. Alternative Data

Code	Teacher Name
A1	Encep Nursalam, ST
A2	Sri Yunita, S.Pd
A3	Maulidia Indapuri, S.Kom
A4	May Wahyu Susanthy, SE, S.Pd
A5	Prapti Wahyuni, SE
A6	Poniasih, S.Pd
A7	Drs. Samsul Bahri Lubis
A8	Lisa Armaini, S.PdI
A9	Meriyanti Nasution, S.Pd
A10	Asniah, S.Pd, M.Pd

The *Simple Additive Weighting* (SAW) method was applied through several stages: initial scoring, normalization, final score (preference) calculation, and ranking.

Table 9. Suitability Ratings

Code	Alternative (A)	Criteria (K)		
		K1	K2	K3
A1	Encep Nursalam, ST	4	4	2
A2	Sri Yunita, S.Pd	3	3	4
A3	Maulidia Indapuri, S.Kom	3	3	3
A4	May Wahyu Susanthy, SE, S.Pd	4	4	5
A5	Prapti Wahyuni, SE	3	3	3
A6	Poniasih, S.Pd	4	4	4
A7	Drs. Samsul Bahri Lubis	4	4	4
A8	Lisa Armaini, S.PdI	1	1	2
A9	Meriyanti Nasution, S.Pd	5	5	5
A10	Asniah, S.Pd, M.Pd	3	3	3

Table 10. Attribute Normalization Results

Code	K1	K2	K3
A1	0.80	0.80	0.40
A2	0.60	0.60	0.80
A3	0.60	0.60	0.60
A4	0.80	0.80	1.00
A5	0.60	0.60	0.60
A6	0.80	0.80	0.80
A7	0.80	0.80	0.80
A8	0.20	0.20	0.40
A9	1.00	1.00	1.00
A10	0.60	0.60	0.60

Table 11. Score Calculation

Code	Preference Value (SAW)
A1	(0.50×0.80) + (0.25×0.80) + (0.25×0.40) = 0.70
A2	(0.50×0.60) + (0.25×0.60) + (0.25×0.80) = 0.65
A3	(0.50×0.60) + (0.25×0.60) + (0.25×0.60) = 0.60
A4	(0.50×0.80) + (0.25×0.80) + (0.25×1.00) = 0.85
A5	(0.50×0.60) + (0.25×0.60) + (0.25×0.60) = 0.60
A6	(0.50×0.80) + (0.25×0.80) + (0.25×0.80) = 0.80
A7	(0.50×0.80) + (0.25×0.80) + (0.25×0.80) = 0.80
A8	(0.50×0.20) + (0.25×0.20) + (0.25×0.40) = 0.25
A9	(0.50×1.00) + (0.25×1.00) + (0.25×1.00) = 1.00
A10	(0.50×0.60) + (0.25×0.60) + (0.25×0.60) = 0.60

Table 12. Ranking

Rangking	Code	Alternative	Value SAW
1	A9	Meriyanti Nasution, S.Pd	1.00
2	A4	May Wahyu Susanthy, SE, S.Pd	0.85
3	A6	Poniasih, S.Pd	0.80
3	A7	Drs. Samsul Bahri Lubis	0.80
5	A1	Encep Nursalam, ST	0.70
6	A2	Sri Yunita, S.Pd	0.65
7	A3	Maulidia Indapuri, S.Kom	0.60
7	A5	Prapti Wahyuni, SE	0.60
7	A10	Asniah, S.Pd, M.Pd	0.60
10	A8	Lisa Armaini, S.PdI	0.25

The use case diagram illustrates the interaction between users and the system during the assessment process, including inputting teacher data, assigning scores, calculating values using the SAW method, and viewing the ranking results. This diagram helps design an efficient workflow that can be further developed into a digital system in the future.

The implications of this study suggest that integrating objective evaluations like SAW may foster greater motivation among teachers. Transparency in the evaluation process can boost fairness perceptions and professional accountability. Additionally, comparisons with previous works, such as Rohayati et al. (2023), affirm the SAW method's adaptability in school-based contexts. However, unlike prior studies that focused only on performance, this research includes dedication aspects such as homeroom responsibilities, making it more comprehensive

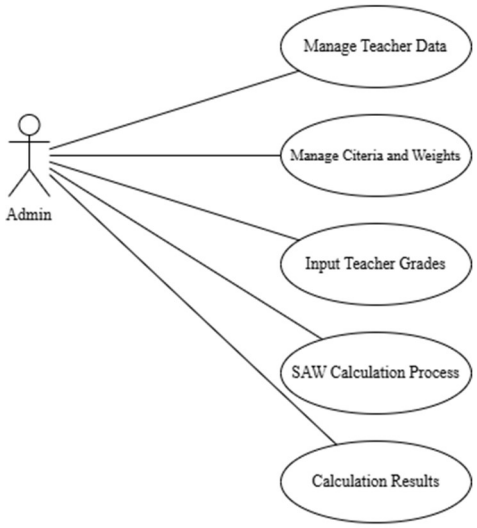


Fig. 1. Use Case Diagram

To further enhance reliability, a sensitivity analysis was conducted by adjusting the weights of each criterion by ±10%. Results showed stable teacher rankings, indicating that the SAW model is robust against moderate fluctuations in weights.

3.2 Discussion

Based on the research findings, the assessment of outstanding teachers at SMK Swasta Nurul Amaliyah was conducted using three main criteria: discipline, attendance, and the role as a homeroom teacher. These criteria were selected as they are considered to best represent teachers' performance and dedication to the school. Each criterion was assigned a specific weight, with discipline given the highest weight of 0.50, while attendance and homeroom teacher responsibilities were each weighted at 0.25. The evaluation involved ten active teachers currently teaching at the school. Assessment scores were derived from the results of observations and institutional data, and subsequently analyzed using the Simple Additive Weighting (SAW) method (Al Jufri, 2022).

Compared to the findings of Rohayati et al. (2023) and Serli et al. (2022), who applied SAW in different school contexts with limited performance criteria, this study offers a broader approach by including dedication indicators through homeroom teacher duties. This addition provides a more comprehensive model and may serve as a recommendation for the implementation of multi-criteria evaluations in other educational institutions.

Based on the computation results derived through the SAW method, each teacher received a final score indicating their level of achievement. The results showed that Meriyanti Nasution, S. Pd obtained the highest score of 1.00, having achieved maximum scores in all criteria, and was thus designated as the outstanding teacher. In second place was May Wahyu Susanthy, S. Pd with a score of 0.85, followed by Poniasih, S. Pd and Drs. Samsul Bahri Lubis, who both received a score of 0.80. The SAW method has proven effective in providing an objective, fair, and measurable evaluation, as each decision is based on clear data and established formulas. This

method enables the school to identify outstanding teachers in a transparent manner and serves as a motivation for other teachers to continuously enhance their performance.

4. Conclusion

This study established three main criteria for evaluating teacher performance: discipline, attendance, and the role as a homeroom teacher. These criteria were selected as they reflect the teacher's commitment and responsibility in carrying out daily tasks, as well as their direct contribution to student development. The weights for each criterion were determined by the school principal based on their level of importance in supporting educational quality. Discipline was assigned the highest weight of 0.50, as it is considered a key indicator of professionalism and responsibility. Attendance and the role as a homeroom teacher were each assigned a weight of 0.25, since, although important, their contributions are viewed as complementary to discipline. This weighting system aims to ensure that the assessment results objectively and proportionally reflect the real needs of the school.

The SAW (*Simple Additive Weighting*) method was applied through the following steps: constructing a decision matrix based on teacher scores for each criterion, normalizing the scores, multiplying the normalized values by the corresponding weights, and summing the results to obtain the final scores. This process was conducted for all teacher candidates considered as alternatives. Overall, the steps were implemented effectively and successfully produced a decision regarding the selection of the outstanding teacher. The results showed that Meriyanti Nasution, S. Pd (A9) obtained the highest score of 1.00 and was designated as the outstanding teacher. Other high-scoring teachers included May Wahyu Susanthy (A4) with a score of 0.85, as well as Poniasih (A6) and Drs. Samsul Bahri Lubis (A7), who each received a score of 0.80. These results indicate that the SAW method successfully produced an objective and transparent outcome.

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APLIKASI KULIM SMART PAY (KSPay): PERSEPSI DALAM KALANGAN PENGGUNA DI BANDAR KULIM

Liza Suhana binti Ramli*, Nor Hayati binti Mohamad Alli, Asna Khairunisa binti Nazari

Civil Engineering Department, Politeknik Tuanku Sultanah Bahiyah, Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: liza@ptsb.edu.my

Abstrak

Peningkatan jumlah kenderaan saban tahun telah memberi kesan kepada sistem meletak kenderaan di bandar-bandar di Malaysia. Bagi menyokong kecekapan pengurusan tempat letak kenderaan, aplikasi mudah alih di dalam telefon pintar telah digunapakai secara meluas seiring dengan kepesatan teknologi masa kini. Majlis Perbandaran Kulim (MPKK) telah mengambil inisiatif mewujudkan Aplikasi Kulim Smart Pay (KSPay) sebagai satu ciri parkir pintar dan telah digunakan oleh komuniti di bandar Kulim sejak tahun 2022. Kajian ini dilaksanakan untuk mengenal pasti persepsi pengguna terhadap aplikasi KSPay selepas tiga tahun dikuatkuasakan. Instrumen kajian yang digunakan adalah borang maklum balas yang diedarkan kepada 377 responden yang terdiri daripada pengguna kenderaan dan penduduk di sekitar bandar Kulim. Dapatan kajian menunjukkan persepsi yang positif terhadap aplikasi KSPay dengan majoriti 80.48% pengguna berpuas hati dalam aspek teknikal, mesra pengguna dan keselamatan data. Kajian ini turut mencadangkan keperluan penambahbaikan bagi aplikasi KSPay agar lebih inklusif untuk memantapkan pengurusan parkir kenderaan di sekitar bandar Kulim dan memperkukuh penerimaan masyarakat terhadap sistem digital ini.
Kata Kunci: Kulim Smart Pay; Aplikasi Mudah Alih; Parkir Pintar.

1. Pengenalan

Pertambahan rakyat Malaysia saban tahun telah memberi kesan kepada peningkatan penggunaan kenderaan terutama di bandar-bandar. Peningkatan jumlah kenderaan di bandar telah menyebabkan kesesakan lalu lintas dan kesukaran mencari tempat letak kereta, terutama pada waktu puncak. Adriana, N., Ashraf, M., & Erwan, M. (2025) menyatakan, di Malaysia sekitar 700, 000 pendaftaran kenderaan baharu direkodkan setiap tahun, dengan 88% pengguna lebih memilih kenderaan persendirian. Permintaan terhadap tempat letak kereta turut meningkat sejajar dengan keperluan untuk memperbaiki persekitaran bandar dan menyediakan kemudahan parkir yang mencukupi. Menurut kajian ini, pengguna-pengguna kereta di Malaysia akan terus bergantung kepada kereta sebagai pengangkutan yang utama dan adalah sukar untuk berubah kepada pengangkutan awam.

Rentetan itu, timbulnya beberapa masalah yang berkaitan dengan tempat letak kereta di bandar-bandar iaitu kesulitan semasa mencari tempat letak kereta terutamanya pada waktu puncak. Kesan daripada masalah ini telah mengakibatkan kesesakan lalu lintas kerana pemandu kenderaan akan berlegar-legar di sekitar kawasan parkir untuk tempoh yang lama untuk mencari petak kosong. Menurut Nandyal, S., Sultana, S., & Anjum, S. (2017), menyatakan bahawa untuk menemukan petak parkir yang kosong boleh mengambil masa lebih daripada 10 minit bagi sekitar 66% pengunjung, terutamanya pada hujung minggu atau hari cuti umum.

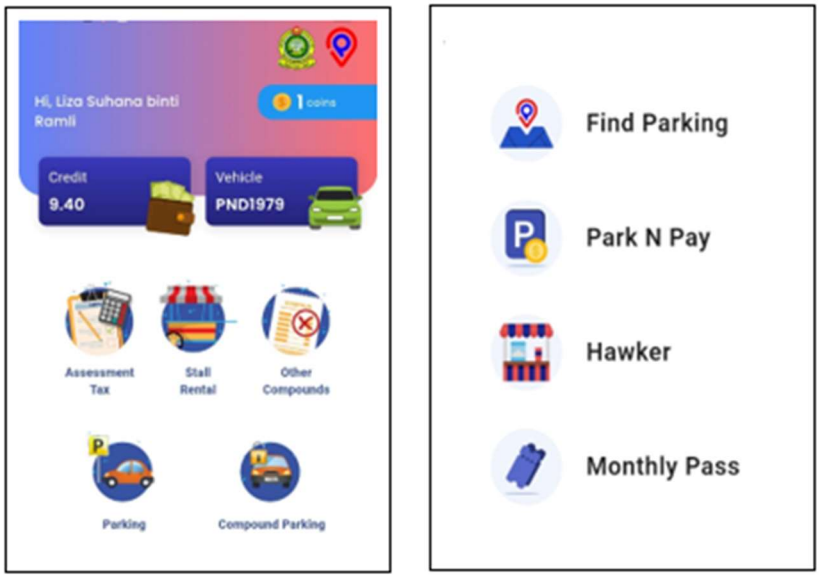
Penyediaan parkir telah menjadi masalah utama di bandar-bandar moden dan pelbagai sistem parkir pintar telah dibangunkan. Antara muka aplikasi akan berasaskan kepada jenis telefon

pintar di mana perkhidmatan seperti pengawasan parkir, pembayaran dalam talian, tempahan parkir dan panduan kenderaan akan menjadi ciri umum sistem parking pintar (Fahim, A., Hasan, M., & Chowdhury, M. A., 2021). Sistem parkir berbayar dapat mengawal kenderaan di kawasan tertentu manakala teknologi pintar meningkatkan kecekapan pencarian parkir (Adriana, N., Ashraf, M., & Erwan, M., 2025).

Seiring dengan perkembangan teknologi dan kepesatan penggunaan aplikasi mudah alih di dalam telefon pintar, Majlis Perbandaran Kulim telah mengambil inisiatif mewujudkan satu aplikasi iaitu Kulim Smart Parking (KSP) yang telah diperkenalkan pada tahun 2022 untuk memudahkan pengguna mencari petak parkir dan membayar parkir secara digital. Aplikasi Kulim Smart Parking kemudiannya telah ditambah baik dan dijenamakan semula menjadi Kulim Smart Pay (KSPay) pada Januari 2025 yang bertujuan untuk meningkatkan kecekapan transaksi sekaligus mengurangkan pembayaran secara tunai. Penambahbaikan ini bukan sahaja meningkatkan pengalaman pengguna, malah memperluaskan fungsi aplikasi untuk merangkumi lebih banyak perkhidmatan selain pembayaran parkir. Menurut YBhg. Dato' Haji Elmi bin Yusoff, Yang Dipertua MPKK, "Kulim Smart Pay atau dahulunya dikenali sebagai Kulim Smart Parking yang telah dilancarkan pada tahun 2021 kini telah dijenamakan semula dan dikembangkan menjadi ‘super apps’ yang menggabungkan pelbagai perkhidmatan penting dalam satu platform." (Portal Rasmi Pihak Berkuasa Tempatan Negeri Kedah, 2025).

Kulim Smart Pay (KSPay) memudahkan transaksi tanpa tunai untuk perkhidmatan seperti pembayaran cukai taksiran, sewaan premis dan pelbagai kompaun, sekaligus mempromosikan kemudahan, kecekapan, dan keselamatan. Dengan mengurangkan keperluan untuk menguruskan wang tunai secara fizikal, KSPay dapat meminimumkan risiko kecurian dan kehilangan, sambil menyelaraskan pengurusan kewangan untuk individu dan perniagaan. Kulim Smart Pay adalah transformasi besar yang menyokong aspirasi Kedah Cashless 2025, yang membolehkan setiap transaksi di Kulim kini dapat dilakukan secara digital dengan lebih cepat dan efisien (Portal Rasmi Pihak Berkuasa Tempatan Negeri Kedah Darul Aman, 2025). Menurut Amin, S. I. M., Ab Hamid, S. N., & Norhisam, N. H. (2022), di Malaysia, jumlah transaksi pembayaran digital mencecah 5.5 bilion pada tahun 2020, iaitu 14% peningkatan berbanding 2019 (BNM 2020). Jumlah pengeluaran wang tunai daripada mesin pengeluaran tunai (RM377.3 bilion) pula mencatatkan 19% kemerosoton dalam tempoh yang sama. Situasi ini jelas membuktikan pengguna di Malaysia telah mula beralih ke era masyarakat tanpa tunai dan pembayaran secara digital. Saffu, K., Walker, J. H., & Hinson, R. (2008) dalam kajian mereka mendapati peningkatan aplikasi perbankan atas talian telah membantu mewujudkan pengurangan kos, peningkatan peluang perniagaan, mendorong penjimatan masa dan menyediakan perkhidmatan persendirian dengan pelanggan. Walaubagaimanapun, Jurnal Teknologi Maklumat Malaysia (2023) menyatakan, sebahagian pengguna menghadapi kesukaran dalam menggunakan aplikasi kerana faktor seperti kurangnya kesedaran, masalah teknikal serta cabaran bagi golongan tertentu dan individu yang kurang celik teknologi.

Walaupun aplikasi KSPay telah dibangunkan sejak tahun 2022 dan telah digunakan secara meluas oleh komuniti sebagai medium digital bagi memudahkan urusan parkir, tiada kajian empirikal telah dijalankan untuk menilai persepsi pengguna terhadap aplikasi tersebut. Sehubungan itu, kajian ini bertujuan untuk meneliti persepsi pengguna terhadap penggunaan aplikasi KSPay di bandar Kulim, sekali gus memberikan gambaran menyeluruh mengenai tahap penerimaannya dalam kalangan pengguna. Aspek fungsi teknikal, tahap mesra pengguna dan keyakinan kepada keselamatan data dinilai untuk melihat sejauhmana penerimaan komuniti terhadap aplikasi ini.



Rajah 1. Antaramuka Aplikasi Kulim Smart Pay

2. Metodologi

Kajian ini menggunakan instrumen soal-selidik berdasarkan Technology Acceptance Model (TAM), yang dibangunkan oleh Davis, F. D. (1989) dan kemudiannya diperhalusi oleh Venkatesh et al. (2003). Model ini telah digunakan secara meluas dalam menilai penerimaan pengguna terhadap platform digital. Konstruk teras dalam TAM iaitu Persepsi Penggunaan (Perceived Usefulness) dan Kemudahan Penggunaan (Perceived Ease of Use) menjadi asas kukuh untuk menilai bagaimana pengguna berinteraksi dan menerima aplikasi KSPay selain item yang dibangunkan sendiri mengikut kesesuaian kajian.

Populasi kajian melibatkan komuniti penduduk di Daerah Kulim yang telah memuat turun dan menggunakan Aplikasi Kulim Smart Pay. Berdasarkan Portal Rasmi Pihak Berkuasa Tempatan Negeri Kedah Darul Aman (2025), sebanyak 109 635 pemuat turun aplikasi ini sehingga November 2024. Dengan memilih pemuat turun aplikasi ini sebagai responden, gambaran yang lebih jelas dapat diperolehi tentang pandangan dan penerimaan terhadap Aplikasi Kulim Smart Pay. Menurut Krejcie, R. V., & Morgan, D. W. (1970), bilangan sampel yang sesuai dengan 100 000 populasi adalah 384. Bilangan respon yang digunapakai adalah hampir sama iaitu sebanyak 377 respon. Ini memenuhi pernyataan (S. Ajay S and M. Micah B. (2014) bahawa bilangan sampel yang sesuai dengan ketepatan 10% adalah lebih kurang 100 orang untuk populasi melebihi 100 000. Teknik persampelan secara *simple random sampling* digunakan dalam kajian ini (T. S. Nanjundeswaraswamy and S. Divakar, 2021).

Soal selidik dijalankan secara dalam talian dengan menggunakan *Google Form* dan pautan soal selidik ini diedarkan melalui medium Facebook Majlis Perbandaran Kulim dan menggunakan beberapa aplikasi seperti WhatsApp dan Telegram. Soal selidik mengandungi tiga bahagian; Bahagian A: Demografi Responden, Bahagian B: terbahagi kepada tiga item iaitu Teknikal, Mesra Pengguna dan Keselamatan Data dan Bahagian C: Cadangan Untuk Penambahbaikan Aplikasi KSPay. Untuk Bahagian B, sebanyak 4 soalan aspek Teknikal (Persepsi Penggunaan), 4 soalan aspek Mesra Pengguna (Kemudahan Penggunaan) dan 3 soalan aspek Keselamatan Data telah dibangunkan. Tempoh pengumpulan data bermula 12 Februari 2025 sehingga 15 April 2025.

Ujian rintis dijalankan untuk mendapatkan nilai kebolehpercayaan bagi instrumen yang dibangunkan. Nilai Cronbach Alpha yang diperolehi bagi aspek Teknikal ialah 0.85, 0.90 bagi aspek Mesra Pengguna dan 0.89 bagi aspek Keselamatan Data. Nilai Cronbach Alpha yang diperolehi melebihi 0.60 untuk kedua-dua bahagian menunjukkan tahap kebolehpercayaan soal-selidik sesuai digunakan untuk kajian (Robertson, O. & Evans, M. S., 2020). Kajian ini menggunakan Excel untuk ujian-ujian deskriptif dan SPSS untuk ujian kebolehpercayaan.

3. Dapatan dan Perbincangan

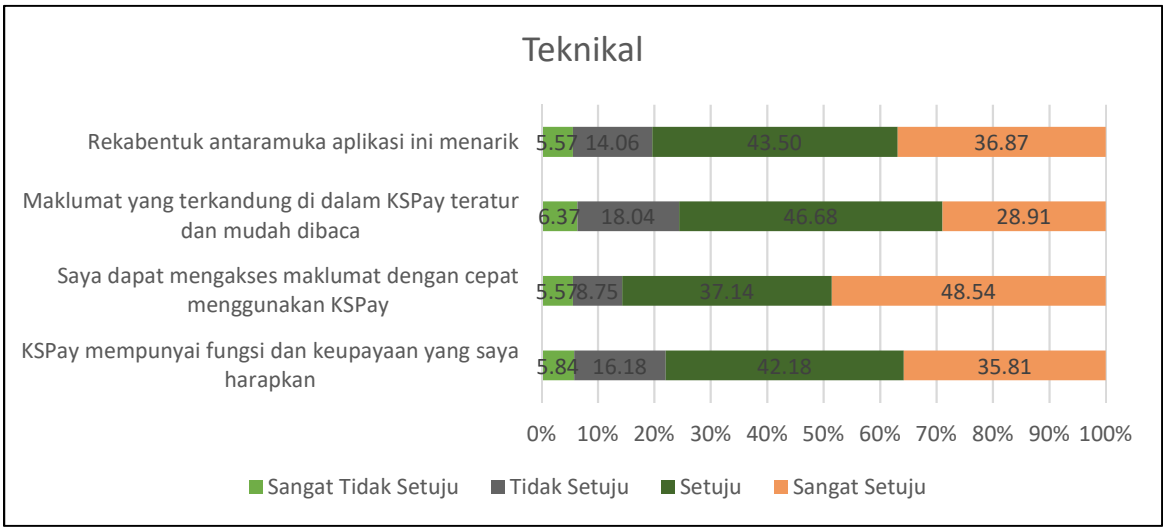
Bilangan responden yang terlibat dalam kajian ini adalah dalam kalangan pemuat turun Aplikasi KSPay di dalam Daerah Kulim dengan jumlah respon yang digunapakai adalah sebanyak 377 respon. Jadual 1 menunjukkan demografi responden dalam kajian ini. Daripada 377 responden, sebanyak 58.9% (N = 222) adalah perempuan dan selebihnya adalah responden lelaki iaitu sebanyak 41.1% (N = 155). Sementara itu, majoriti responden berumur antara 17 - 25 tahun iaitu 32.4% (N = 122) diikuti umur 26 – 35 tahun iaitu 26.5% (N = 100) dan umur 36 – 45 iaitu 22.3% (N = 84). Peratus respon yang paling tinggi adalah daripada kalangan pelajar iaitu 44.3% (N = 167) diikuti pekerja sektor kerajaan iaitu 22.8% (N = 86) dan 20% (N = 75) yang terdiri daripada pekerja sektor swasta. Daripada segi kekerapan penggunaan aplikasi KSPay dalam seminggu, majoriti responden menggunakannya sebanyak 1 – 3 kali seminggu iaitu 70.3% (N = 265).

Jadual 2. Demografi Responden

No.	Demografi	Frekuensi (N)	Peratusan (%)
1	Jantina		
	Lelaki	155	41.1
	Perempuan	222	58.9
2	Umur		
	17 – 25	122	32.4
	26 – 35	100	26.5
	36 – 45	84	22.3
	46 – 55	42	11.1
	56 ke atas	29	7.7
3	Pekerjaan		
	Sektor kerajaan	86	22.8
	Sektor swasta	75	20.0
	Bekerja sendiri	22	5.8
	Pelajar	167	44.3
	Tidak bekerja	27	7.1
4	Kekerapan Penggunaan Seminggu		
	1 – 3 kali	265	70.3
	4 – 6 kali	86	22.8
	7 kali atau lebih	26	6.9

3.1 Aspek Teknikal (Persepsi Penggunaan)

Rajah 2 menunjukkan respon pengguna bagi aspek teknikal penggunaan Kulim Smart Pay (KSPay).



Rajah 2. Aspek Teknikal Penggunaan Aplikasi Kulim Smart Pay (KSPay)

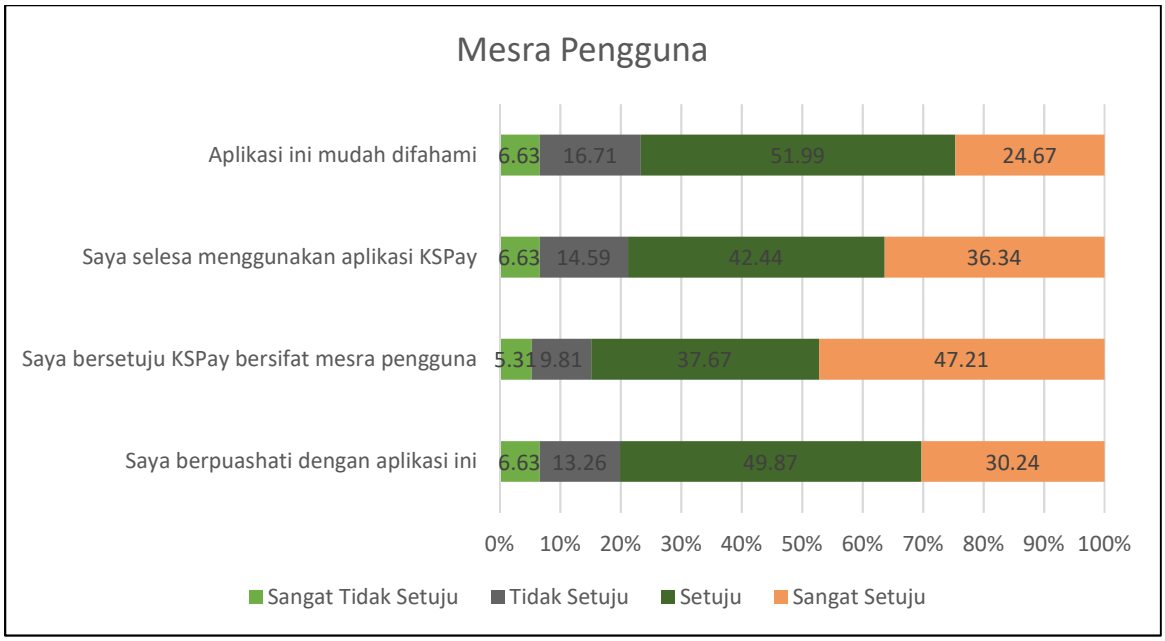
Majoriti responden sangat bersetuju (36.87%) dan bersetuju (43.5%) bahawa aplikasi KSPay mempunyai rekabentuk antaramuka yang menarik. Responden sangat bersetuju (28.91%) dan bersetuju (46.68%) bahawa maklumat yang terdapat di dalam aplikasi KSPay teratur dan memudahkan pengguna untuk membacanya. Sebanyak 48.54% sangat bersetuju dan 37.14% bersetuju menyatakan mereka dapat mengakses maklumat dengan cepat menggunakan aplikasi ini. Selain itu, 35.81% sangat bersetuju dan 42.18% bersetuju bahawa KSPay mempunyai fungsi dan keupayaan yang mereka harapkan.

Hasil kajian Shaari, J., Yamin, S. I. A., & Ahmad, M. I. (2021) menyatakan penggunaan aplikasi dapat menambah pengetahuan dan kemahiran pengguna dalam tempoh yang lebih pendek. Pernyataan ini menyokong dapatan kajian ini dengan majoriti pengguna sangat bersetuju bahawa aplikasi KSPay memberikan akses maklumat yang cepat.

3.2 Aspek Mesra Pengguna (Kemudahan Penggunaan)

Rajah 3 menunjukkan respon bagi aspek mesra pengguna bagi aplikasi Kulim Smart Pay (KSPay). Berdasarkan tersebut didapati aspek mesra pengguna, sebanyak 24.67% sangat bersetuju dan majoriti 51.99% bersetuju bahawa aplikasi KSPay mudah difahami cara penggunaannya. 36.34% sangat bersetuju dan 42.44% bersetuju dengan kenyataan 'Saya selesa menggunakan aplikasi KSPay'. Majoriti pengguna sangat bersetuju (47.21%) dan bersetuju (37.67%) bahawa KSPay bersifat mesra pengguna. Pengguna berpuashati dengan aplikasi KSPay dengan dapatan sangat setuju 30.24% dan setuju 49.87%.

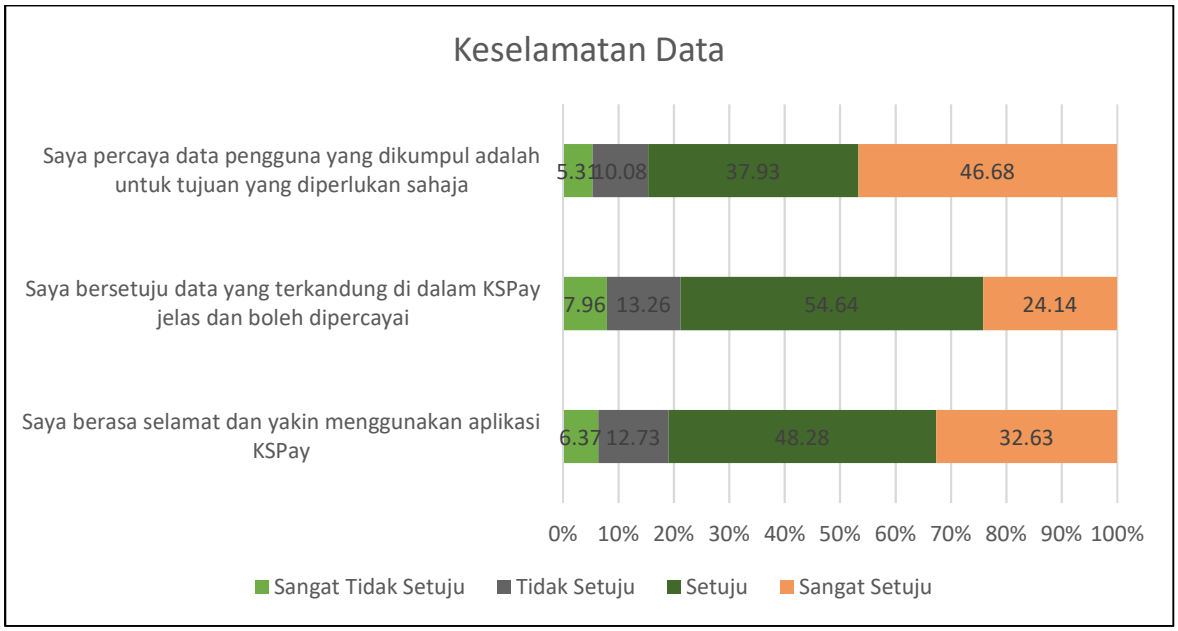
Sifat mesra pengguna merupakan ciri penting yang perlu ada pada sesebuah aplikasi. Menurut kajian Sabahaudin, M. F. N., & Ab Aziz, M. F. (2024), penyepaduan pemantauan data masa nyata, antara muka mesra pengguna dan penderia termaju dengan ketara meningkatkan kecekapan tempat letak kereta dan kepuasan pengguna.



Rajah 3. Aspek Mesra Pengguna Bagi Aplikasi Kulim Smart Pay (KSPay)

3.3 Aspek Keselamatan Data

Rajah 4 menunjukkan dapatan bagi aspek keselamatan data pengguna di dalam aplikasi KSPay.



Rajah 4. Aspek Keselamatan Data Pengguna Di Dalam Aplikasi Kulim Smart Pay (KSPay)

Majoriti responden sangat bersetuju (46.68%) dan bersetuju (37.93%) bahawa mereka percaya data yang dikumpul dan disimpan di dalam aplikasi KSPay adalah untuk tujuan yang diperlukan sahaja tanpa meragui kemungkinan data disalahguna oleh PBT atau pembangun aplikasi. 24.14% sangat bersetuju dan majoriti 54.64% bersetuju data yang terkandung di dalam KSPay adalah jelas dan boleh dipercayai. Data yang dimaksudkan adalah data rekod parkir, rekod saman dan pemakluman daripada Majlis Perbandaran Kulim. Selain itu, pengguna sangat

bersetuju (32.63%) dan bersetuju (48.28%) bahawa mereka berasa selamat dan yakin menggunakan aplikasi KSPay.

Keselamatan data menjadi keutamaan dan disokong oleh kajian Abrar F., Mehedi H & Muhtasim A. C. (2021) yang menyatakan keselamatan dalam protokol komunikasi data akan terus menjadi sumber kebimbangan utama dalam sistem parkir pintar pada masa hadapan. Oleh itu, lebih penekanan akan diberikan kepada protokol komunikasi tanpa wayar bagi memastikan keselamatan data lebih terjamin.

Secara keseluruhannya, sebanyak 11 item berbentuk pernyataan telah dikemukakan kepada responden berkenaan pandangan terhadap penggunaan aplikasi *KSPay*. Ketiga-tiga aspek iaitu teknikal, mesra pengguna dan keselamatan data menunjukkan purata sangat setuju dan setuju sebanyak 80.48%. Hasil analisis dapat dirumuskan seperti dalam Jadual 2.

Jadual 2. Skor Min Bagi Item Bahagian B

Bil	Item	Skala 1	2	3	4	Min
Persepsi Penggunaan (Teknikal)						
B1	Rekabentuk antaramuka aplikasi ini menarik	5.57% (21)	14.06% (53)	43.5% (164)	36.87% (139)	3.12
B2	Maklumat yang terkandung di dalam KSPay teratur dan mudah dibaca	6.37% (24)	18.04% (68)	46.68% (176)	28.91% (109)	3.00
B3	Saya dapat mengakses maklumat dengan cepat menggunakan KSPay	5.57% (21)	8.75% (33)	37.14% (140)	48.54% (183)	3.29
B4	KSPay mempunyai fungsi dan Keupayaan yang saya harapkan	5.84% (22)	16.18% (61)	42.18% (159)	35.81% (135)	3.10
Kemudahan Penggunaan (Mesra Pengguna)						
B5	Aplikasi ini mudah difahami	6.63% (25)	16.71% (63)	51.99% (196)	24.67% (93)	2.95
B6	Saya selesa menggunakan Aplikasi KSPay	6.63% (25)	14.59% (55)	42.44% (160)	36.34% (137)	3.10
B7	Saya bersetuju KSPay bersifat mesra pengguna	5.31% (20)	9.81% (37)	37.67% (142)	47.21% (178)	3.27
B8	Saya berpuashati dengan aplikasi ini	6.63% (25)	13.26% (50)	49.87% (188)	30.24% (114)	3.02
Keselamatan Data						
B9	Saya percaya data yang dikumpul adalah untuk tujuan yang diperlukan sahaja	5.31% (20)	10.08% (38)	37.93% (143)	46.68% (176)	3.26
B10	Saya bersetuju data yang terkandung di dalam KSPay jelas dan boleh dipercayai	7.96% (30)	13.26% (50)	54.64% (206)	24.14% (91)	2.95
B11	Saya berasa selamat dan yakin Menggunakan Aplikasi KSPay	6.37% (24)	12.73% (48)	48.28% (182)	32.63% (123)	3.10

Jadual 2 menunjukkan hasil analisis penilaian pengguna terhadap aplikasi KSPay. Sebanyak 11 item penyataan telah digariskan berkaitan dengan aplikasi ini. Berdasarkan data-data yang diperolehi daripada jadual 3 di atas, responden memberikan jawapan berdasarkan skala 1 (sangat tidak setuju), 2 (tidak setuju), 3 (setuju) dan 4 (sangat setuju). Manakala jumlah min bagi majoriti item menunjukkan nilai melebihi 3.10. Berdasarkan Jadual 3 di bawah, dapat dirumuskan persepsi pengguna terhadap aplikasi Kulim Smart Pay berada pada tahap yang tinggi.

Jadual 3. Tahap Persepsi Pengguna Mengikut Skala

Skala	Tahap
1.0 - 2.0	Rendah
2.1 - 3.0	Sederhana
3.1 - 4.0	Tinggi

Namun begitu, skor min bagi item B2, B5, B8 dan B10 berada pada tahap sederhana. Ini menunjukkan persepsi pengguna terhadap susunan menu di dalam antara muka KSPay masih perlu diperbaiki dan ini memberi kaitan kepada tahap kefahaman dan kurangnya kepuasan semasa menggunakan KSPay. Kepercayaan pengguna terhadap data yang terkandung di dalam KSPay pula masih belum mencapai tahap yang tinggi dan memerlukan usaha daripada pihak PBT untuk meningkatkan keyakinan pengguna dalam aspek keselamatan data setiap pemuat turun aplikasi KSPay.

4. Kesimpulan

Penggunaan aplikasi mudah alih di dalam telefon pintar kini semakin meluas digunakan di dalam sistem pengurusan parkir kenderaan di Malaysia disebabkan oleh keupayaannya untuk menyediakan akses maklumat secara pantas dan mudah kepada pengguna tanpa mengira masa dan lokasi. Kewujudan aplikasi Kulim Smart Pay telah menawarkan kelebihan pelbagai fungsi dan memberi kesan yang baik kepada pengguna. Ini dibuktikan oleh respon majoriti pengguna dalam kajian ini yang yakin dan berpuashati terhadap aspek teknikal, mesra pengguna dan keselamatan data aplikasi KSPay. Ini menunjukkan penerimaan masyarakat terhadap aplikasi ini adalah positif berdasarkan persepsi majoriti pengguna berada pada tahap yang tinggi. Penambahbaikan seperti penambahan ciri keselamatan aplikasi dan pelaksanaan kempen kesedaran digital yang lebih meluas turut dicadangkan ke arah penggunaan KSPay yang lebih efisyen.

Kajian ini diharap dapat memberi gambaran yang lebih jelas kepada pihak yang bertanggungjawab dalam merancang sistem dan menggubal polisi berkaitan pengurusan kenderaan dan parkir pintar di bandar Kulim. Walaupun skop kajian ini melibatkan komuniti di bandar Kulim, namun respon yang konsisten diutarakan seperti dalam kajian-kajian yang lepas. Pengurusan sistem meletak kenderaan diharap akan menjadi lebih efektif dengan mengambilkira sudut pandang pengguna dalam kajian ini bagi membantu PBT dalam menangani isu pertambahan kenderaan dan pengurusan parkir di bandar Kulim.

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AN ANALYSIS OF THE IMPACT OF MANAGERIAL CAPABILITIES AND FINANCIAL STRATEGIES ON THE BUSINESS SUSTAINABILITY OF MSMES IN HAMPARAN PERAK DISTRICT

Pricila Oktarani*, Muliyani

Management Department, School of Management Studies, 20219 Medan, North Sumatra, Indonesia

*Corresponding author e-mail address: oktaranipricila@gmail.com

Abstract

This study aims to examine the extent to which Managerial Capability and Financial Strategy influence Business Sustainability among Micro, Small, and Medium Enterprises (MSMEs) in the Hamparan Perak District. The research employed a quantitative approach using a survey method, involving 66 respondents consisting of MSME owners or managers who have been operating their businesses for at least one year. Data analysis was conducted with the assistance of SPSS version 22, covering validity tests, reliability tests, multiple linear regression analysis, hypothesis testing through t-tests and F-tests, as well as the measurement of the coefficient of determination. The research findings indicate that Managerial Capability and Financial Strategy simultaneously have a significant effect on Business Sustainability, with a Significant level of 0.000 (< 0.05). Partially, the Managerial Capability variable (X1) contributes significantly to the dependent variable, with a Significant value of 0.000 and a regression coefficient of 0.327. Similarly, the Financial Strategy variable (X2) shows a significant effect with a Significant value of 0.001 and a regression coefficient of 0.265. The coefficient of determination (R^2) is 0.914, indicating that 91.4% of the variation in Business Sustainability can be explained by these two independent variables. Based on these results, it is suggested that MSME actors enhance their managerial capabilities through capacity-building programs such as training, mentoring, and business networking development. On the other hand, financial management strategies should be strengthened through the adoption of digital technologies, including accounting applications and digital cashier systems, to accelerate financial recording and analysis processes. Digitalization efforts are also expected to strengthen operational efficiency and business competitiveness amid dynamic market changes.

Keywords: Managerial Capability; Financial Strategy; Business Sustainability.

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) play a highly strategic role in Indonesia's economy. In 2024, the Ministry of Finance reported that this sector contributed more than 60% to the Gross Domestic Product (GDP) and absorbed nearly 97% of the labour force, making it a key pillar in supporting the national economy (Utami et al., 2024). The significant role of MSMEs makes them a crucial element in maintaining economic stability. However, amid increasing market competition, digital disruption, and global uncertainties such as the COVID-19 pandemic, the sustainability of MSMEs has become a serious challenge that requires attention.

Business sustainability refers to the ability of MSMEs to survive, grow, and develop sustainably by maintaining a balance between economic, social, and environmental aspects (Huda et al., 2025). According to the Triple Bottom Line concept (Elkington, dalam Temalagi & Borolla, 2021), business sustainability emphasizes not only profit but also responsibility towards people and the planet. In practice, many MSMEs, particularly in semi-urban areas such as Hamparan Perak

District (Deli Serdang Regency, North Sumatra), face significant obstacles in achieving business sustainability. Preliminary observations and interviews revealed that local MSME actors tend to run their businesses based solely on personal experience without proper planning or clear strategies, making them vulnerable to market changes and crises. Many MSMEs encounter problems in managerial practices, weak financial strategies, low product innovation, and limited access to markets and capital. These issues often result in stagnation or even business decline.

Several studies indicate that internal factors such as managerial capability and financial strategy have a significant influence on business sustainability (Hantono et al., 2025; Hutauruk et al., 2024). Managerial capability includes skills in planning, organizing, directing, controlling, decision-making, and adaptability (Al Gifari, 2025; Huda et al., 2025). MSME actors with high managerial capabilities tend to be better prepared to face market dynamics, innovate, and maintain business operations (Krisnantara & Dewi, 2023). Research by Kholison and Kartika also shows a positive influence of managerial capability on business sustainability, although contradictory findings by Nurdyanto suggest the need for further testing in different regional contexts (Kartika et al., 2025; Kholison et al., 2025; Nurdyanto et al., 2024).

In addition to managerial capability, financial strategy also plays a crucial role in maintaining MSME sustainability. Financial strategy involves working capital management, investment planning, cost control, cash flow management, and financial risk handling (Riani et al., 2025; Sutrisno et al., 2024). MSME actors with sound financial strategies are more likely to maintain business liquidity, optimize capital use, and withstand economic crises (Aminah et al., 2024). However, previous research (Suryani, 2025) suggests that the impact of financial strategy on business sustainability can be influenced by various external factors, hence necessitating further empirical studies across different regions.

Although there have been many studies on the influence of managerial capability and financial strategy on business sustainability, a research gap exists in the context of MSMEs in semi-urban areas such as Hamparan Perak District. Unique local economic characteristics, resource limitations, and varied levels of managerial literacy are important reasons to re-examine the relationships between these variables in a local context.

Based on this background, this study aims to: (1) analyze the influence of managerial capability on the business sustainability of MSMEs; (2) analyze the influence of financial strategy on the business sustainability of MSMEs; and (3) examine the simultaneous influence of both variables on the business sustainability of MSMEs in Hamparan Perak District.

1.1 Conceptual Framework

In managing a business, MSME actors are faced with various managerial and financial challenges that require adaptability and careful planning. Managerial capability plays a key role in formulating business strategies, managing resources, and making effective decisions. Meanwhile, an appropriate financial strategy is essential for maintaining business financial stability through working capital management, cost control, and access to adequate funding. According to Puspita and Dirgantari, MSME sustainability is significantly influenced by how well business actors possess managerial skills and their ability to implement financial strategies effectively (Puspita et al., 2024). MSME actors with strong management and well-planned financial strategies are not only able to survive in a competitive market but also have the potential to grow sustainably.

Based on this review, this study focuses on business sustainability as the dependent variable (Y), which is influenced by two independent variables, namely managerial capability (X_1) and financial

strategy (X_2). Using systematic measurement and analysis, this research aims to identify and test the extent of the influence of these two variables on the sustainability of MSMEs, particularly in the Hamparan Perak District, Deli Serdang Regency.

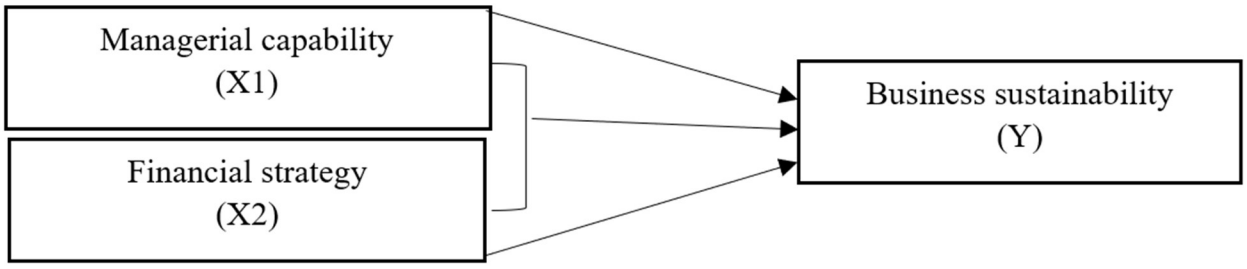


Fig. 1. Conceptual Framework

Hypotheses

The hypotheses in this study are as follows:

- H^1: There is a positive and significant influence of Managerial Capability (X_1) on Business Sustainability (Y) among MSMEs in Hamparan Perak District.
- H^2: There is a positive and significant influence of Financial Strategy (X_2) on Business Sustainability (Y) among MSMEs in Hamparan Perak District.
- H^3: There is a positive and significant simultaneous influence of Managerial Capability (X_1) and Financial Strategy (X_2) on Business Sustainability (Y) among MSMEs in Hamparan Perak District.

2. Methodology

2.1 Participants

The participants in this study were owners or managers of Micro, Small, and Medium Enterprises (MSMEs) operating in Hamparan Perak District. Population data were obtained from official sources, including the Office of Cooperatives and MSMEs, as well as local business associations and entrepreneurship communities. The inclusion criteria for this study were: (1) MSMEs that had been operating for at least one year, and (2) enterprises domiciled in or actively operating within the Hamparan Perak District. Based on the data collected, a total of 66 MSME actors met these criteria. Given the relatively small population size, the sampling technique employed was total sampling (also known as a census method), whereby the entire population was included as research respondents. This approach enabled the researchers to obtain more representative and comprehensive findings regarding the influence of managerial capability and financial strategy on the business sustainability of MSMEs in the region.

2.2 Procedures

Data collection was conducted through structured questionnaires distributed directly to the respondents during the period of February to March 2025. The questionnaires were distributed through in-person visits and digital platforms (such as WhatsApp and email), depending on each respondent's accessibility. Prior to participation, respondents were provided with a clear explanation of the research objectives and were asked to give their informed consent.

2.3 Measures and Materials

The primary instrument used in this study was a structured questionnaire, adapted and developed from previous research by Puspita & Dirgantari (2024), Huda & Wijaya (2024), dan Septrina et al. (2023). These questionnaires were selected based on the validity and reliability of their indicators within the context of MSMEs in Indonesia. The instruments were also considered to be highly relevant to the objectives of this study, which aim to assess the influence of managerial capability and financial strategy on MSME business sustainability. Compared to similar instruments developed by other researchers, this questionnaire was deemed the most suitable as it covers both managerial and financial aspects tailored to the characteristics of MSME actors in semi-urban areas such as Hamparan Perak.

Each variable in this study was operationalized into dimensions and indicators measured using a 5-point Likert scale, with response options ranging from:

1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree.

The operational definitions and indicators for each variable are as follows:

a. Managerial Capability, refers to the ability of an individual or MSME owner to plan, organize, direct, and control business resources to achieve business objectives. This was measured using 10 items covering the following five key aspects:
   i. Business planning
   ii. Organizing
   iii. Control and supervision
   iv. Decision-making
   v. Adaptability
b. Financial Strategy, refers to the policies and systematic approaches employed by business actors in managing finances to ensure business stability, efficiency, and growth. This was measured using 9 items covering:
   i. Working capital management
   ii. Financial planning
   iii. Cost control
   iv. Access to funding
   v. Investment and expansion
   vi. Financial risk management
c. Business Sustainability, refers to the ability of MSMEs to survive and grow over the long term through stable financial performance, innovation, and customer relationship management. This was measured using 6 items covering:
   i. Financial sustainability
   ii. Business competitiveness
   iii. Product/strategy innovation
   iv. Business growth
   v. Operational continuity
   vi. Customer relationship management

The questionnaire was developed based on validated instruments and adapted to the context of MSMEs in Hamparan Perak District. A preliminary pilot test was conducted to ensure the clarity of item statements and internal consistency before the full-scale distribution.

2.4 Statistical Analysis

The data collected through the questionnaire were analysed using quantitative methods, specifically through multiple linear regression analysis. The primary objective of this analysis was to examine the influence of the independent variables (Managerial Capability (X_1) and Financial Strategy (X_2)), on the dependent variable, Business Sustainability (Y). The analysis was conducted using SPSS version 22 as a supporting tool for statistical computation, while the interpretation of results was based on theoretical and empirical considerations rather than solely on software outputs. Prior to conducting the regression analysis, a series of data feasibility tests was performed to ensure that the measurement instruments were valid and reliable, and that the regression model met the required statistical assumptions. These preparatory stages included the following:

a. Validity Test, this test assessed the extent to which individual questionnaire items accurately measured the intended construct or variable. Validity testing was conducted using Pearson Product Moment Correlation Analysis, where each item was correlated with the total score of its respective variable. An item was considered valid if its Significant value (Sig.) was less than 0.05 and the correlation coefficient (r) exceeded the critical value of r-table at the 5% Significant level. Only valid items were retained for further analysis.
b. Reliability Test, this test measured the internal consistency of the questionnaire, specifically whether the items within a variable produced consistent results. Reliability was assessed using Cronbach's Alpha coefficient. An instrument was considered reliable if Cronbach's Alpha ≥ 0.70, indicating a high degree of internal consistency among the items.
c. Descriptive Statistics, Descriptive statistics were used to summarize respondent profiles and to provide a general overview of score distributions for each research variable. Mean values, standard deviations, and frequency distributions were used to illustrate respondents' tendencies regarding managerial capability, financial strategy, and business sustainability.
d. Classical Assumption Tests, to ensure that the resulting regression model was valid and unbiased, a series of classical assumption tests was conducted, including:
    i. Normality Test, assessed whether the residuals (prediction errors) were normally distributed. The Kolmogorov-Smirnov test was used for this purpose. The model was considered to meet the normality assumption if the Significant value > 0.05.
    ii. Multicollinearity Test, examined the degree of correlation between independent variables to detect multicollinearity. This was evaluated using the Tolerance value and Variance Inflation Factor (VIF). The absence of multicollinearity was indicated by VIF < 10 and Tolerance > 0.10.
    iii. Heteroscedasticity Test, determined whether the variance of the residuals was constant across all levels of the independent variables. This was tested using the Glejser Test. The model was considered free from heteroscedasticity if the Significant value (Sig.) > 0.05.
e. Multiple Linear Regression Analysis, After the data were confirmed to be valid, reliable, and met the classical assumptions, multiple linear regression analysis was conducted. The primary objective of this analysis was to measure the influence of Managerial Capability (X_1) and Financial Strategy (X_2) on Business Sustainability (Y), both simultaneously and partially. The multiple linear regression equation used in this study is formulated as follows:

$$Y=\beta0+\beta1X1+\beta2X2+\varepsilon$$

Where:
Y : Business Sustainability
X1 : Managerial Capability
X2 : Financial Strategy
β0 : Constant
β1, β2 : Regression coefficients of the independent variables

ε : Error term

The partial effects of each independent variable were tested using t-statistics and their corresponding Significant values (Sig.). A variable was considered to have a statistically significant partial effect on the dependent variable if Sig. < 0.05.

Meanwhile, the simultaneous effect of both independent variables on the dependent variable was tested using the F-statistic, which was compared to the critical F-value (F-table), or by examining the Significant level of the F-test. The regression model was considered to be statistically significant if the Sig. value < 0.05.

This analytical approach was expected to provide a clear understanding of the extent to which managerial capability and financial strategy influence the business sustainability of MSMEs in the Hamparan Perak District.

3. Results and Discussion

3.1 Respondent Characteristics

The descriptive analysis of respondent characteristics aims to provide an overview of the demographic profile and business characteristics of Micro, Small, and Medium Enterprise (MSME) actors in Hamparan Perak District, Deli Serdang Regency, North Sumatra Province. MSME population data in this area were obtained from the Office of Cooperatives and MSMEs of North Sumatra Province, accessible via the official website (https://diskopukm.sumutprov.go.id/data-ukm/). Based on the available data, a total of 62 active MSMEs were recorded in Hamparan Perak District. From this total, the researchers successfully contacted 58 MSME actors who were willing to participate in the data collection process. To ensure the data collected was more representative and aligned with the study objectives, additional inclusion criteria were applied:

a. Respondents must be active business owners or managers (not passive owners only);
b. The business must have been operating for at least one year.

Considering these criteria and using snowball sampling and referral sampling techniques through local MSME associations and entrepreneurial communities, the researchers successfully recruited 66 respondents who met the inclusion criteria. Consequently, 66 questionnaires were distributed, all of which were returned fully completed and deemed valid for analysis. This reflects a high participation rate among MSME actors in Hamparan Perak, indicating a strong interest in the research topic concerning the influence of managerial capability and financial strategy on business sustainability.
All descriptive and inferential analyses in this study were therefore based on data from these 66 qualified respondents, with the expectation that the results would provide an accurate and representative reflection of the local MSME conditions.

a. Gender
The data show that the majority of MSME actors in Hamparan Perak District are women, totalling 40 individuals or 60.6%, while male respondents account for 26 individuals or 39.4%.

Table 1. Gander

Gender	Frequency	Percent (%)
Male	26	39.4

Female	40	60.6
Total	66	100

This finding highlights the dominant role of women in MSME management within the region.

b. Age
Most respondents were under the age of 25, totalling 32 individuals (48.5%). The next largest group was aged 26–35 (24 respondents or 36.4%), followed by those aged 36–45 (8 respondents or 12.1%), and 46–55 (2 respondents or 3.0%).

Table 2. Age

Age Range	Frequency	Percent (%)
< 25 years	32	48.5
26 – 35 years	24	36.4
36 – 45 years	8	12.1
46 – 55 years	2	3
Total	66	100

This indicates that the MSME sector in this region is largely dominated by younger entrepreneurs, particularly those under 35 years old.

c. Educational Background
The majority of MSME owners or managers (55 respondents or 83.3%) had completed senior high school (SMA/SMK). Respondents with a bachelor's degree (S1) accounted for 10 individuals (15.2%), and only one respondent (1.5%) held a diploma (D1/D2/D3).

Table 3. Education Level

Education Level	Frequency	Percent (%)
Diploma (D1/D2/D3)	1	1.5
Bachelor's Degree (S1)	10	15.2
Senior High School (SMA/SMK)	55	83.3
Total	66	100

This suggests that most MSME actors have a moderate level of formal education.

d. Type of Business
The culinary sector was the most dominant among respondents, accounting for 37 individuals (56.1%). This was followed by other business types (17 respondents or 25.8%), clothing retail (7 respondents or 10.6%), and service-based businesses such as salons or laundries (5 respondents or 7.6%).

Table 4. Type of Business

Type of Business	Frequency	Percent (%)
Service (salon, laundry)	5	7.6
Clothing Retail	7	10.6
Culinary	37	56.1
Others	17	25.8

Total	66	100

This data indicates that the culinary sector is the most prevalent among MSMEs in Hamparan Perak District.

e. Duration of Business Operation
Most MSMEs had been in operation for 1–3 years (52 respondents or 78.8%). Meanwhile, 10 respondents (15.2%) had operated their businesses for 4–7 years, 2 respondents (3.0%) for 8–10 years, and another 2 respondents (3.0%) for more than 10 years.

Table 5. Duration of Business Operation

Duration of Business	Frequency	Percent (%)
> 10 Years	2	3
1 – 3 Years	52	78.8
4 – 7 Years	10	15.2
8 – 10 Years	2	3
Total	66	100

This indicates that most MSMEs in the region are still in the early stages of business development.

f. Number of Employees
The majority of MSMEs employed only 1–2 workers (56 respondents or 84.8%). A total of 8 respondents (12.1%) employed 3–5 workers, while 1 respondent each (1.5%) reported having 6–10 employees and more than 10 employees.

Table 6. Number of Employees

Number of Employees	Frequency	Percent (%)
> 10 Employees	1	1.5
1 – 2 Employees	56	84.8
3 – 5 Employees	8	12.1
6 – 10 Employees	1	1.5
Total	66	100

This supports the classification of most businesses as micro-enterprises with limited human resources.

g. Monthly Business Income
MSME income levels varied. Most respondents (26 individuals or 39.4%) reported earning less than IDR 5 million per month. The next group (23 respondents or 34.8%) earned between IDR 5–10 million, followed by 10 respondents (15.2%) earning IDR 10–20 million, and 7 respondents (10.6%) earning between IDR 20–50 million.

Table 7. Monthly Business Income

Monthly income	Frequency	Percent (%)
< IDR 5 million	26	39.4
IDR 5 – 10 million	23	34.8
IDR 10 – 20 million	10	15.2
IDR 20 – 50 million	7	10.6
Total	66	100

This indicates that most MSMEs in the region are still operating with relatively low income levels.

3.2 Validity Test

The validity test was conducted using the Pearson Product Moment correlation to assess whether each item in the research instrument accurately measured the intended construct. With a Significant level of α = 0.05 and a critical r-value of 0.244 (N = 66), the results are presented as follows:

a. Managerial Capability (X_1), This variable was measured using 10 indicators labeled KM1 through KM10. To ensure that each item accurately represents the intended variable, a validity test was conducted on each statement. The results are summarized in the following table:

Table 8. Validity Test Results for Managerial Capability (X_1)

Item	Correlation Coefficient (r)	Sig. (p)	Decision
KM-1	0.773	0	Valid
KM-2	0.901	0	Valid
KM-3	0.819	0	Valid
KM-4	0.816	0	Valid
KM-5	0.878	0	Valid
KM-6	0.853	0	Valid
KM-7	0.81	0	Valid
KM-8	0.928	0	Valid
KM-9	0.843	0	Valid
KM-10	0.878	0	Valid

All items for the Managerial Capability variable have high correlation coefficients ranging from 0.773 to 0.928, indicating a strong relationship between each item and the total score of the variable. In addition, the Significant values (p-values) for all items are less than 0.05, confirming statistical validity. Therefore, all ten items are declared valid and suitable for further analysis.

b. Financial Strategy (X_2), To evaluate how well each item measures the Financial Strategy variable, a validity test was conducted on 9 indicators labelled SK1 to SK9. The results are presented below:

Table 9. Validity Test Results for Financial Strategy (X_2)

Item	Correlation Coefficient (r)	Sig. (p)	Decision
SK-1	0.869	0	Valid
SK-2	0.916	0	Valid
SK-3	0.864	0	Valid
SK-4	0.903	0	Valid
SK-5	0.876	0	Valid

SK-6	0.851	0	Valid
SK-7	0.874	0	Valid
SK-8	0.904	0	Valid
SK-9	0.877	0	Valid

The correlation coefficients for all Financial Strategy indicators range from 0.851 to 0.916, reflecting a strong and consistent relationship between each item and the overall construct. With all Significant values below 0.05, all nine indicators are confirmed to be statistically valid and thus eligible for further analysis.

c. Business Sustainability (Y), was measured using six indicators (KU1–KU6). A validity test was conducted to ensure that each item accurately reflects the construct. The results are as follows:

Table 10. Validity Test Results for Business Sustainability (Y)

Item	Correlation Coefficient (r)	Sig. (p)	Decision
KU-1	0.879	0	Valid
KU-2	0.891	0	Valid
KU-3	0.899	0	Valid
KU-4	0.926	0	Valid
KU-5	0.914	0	Valid
KU-6	0.773	0	Valid

All six items demonstrate high correlation values ranging from 0.773 to 0.926, with p-values less than 0.05, confirming their statistical validity. Hence, all items used to measure Business Sustainability are considered valid and appropriate for use in further analysis.

3.3 Reliability Test

To assess the internal consistency of each research instrument, a reliability analysis was conducted using Cronbach's Alpha. A Cronbach's Alpha value greater than 0.70 is considered acceptable, indicating that the items within the instrument exhibit a high degree of reliability. The results of the reliability tests for the three variables in this study are presented in the table below:

Table 11. Reliability Test Results of Research Instruments

Variable	Number of Items	Cronbach's Alpha	Decision
Managerial Capability (X_1)	10	0,971	Reliabel
Financial Strategy (X_2)	9	0,977	Reliabel
Business Sustainability (Y)	6	0,966	Reliabel

The following are the results of the reliability test for each research variable using the Cronbach's Alpha method. This test was conducted to determine the extent to which the items within each variable produce consistent results. A Cronbach's Alpha value above 0.70 indicates that the instrument is reliable. The results are as follows:

a. Managerial Capability (X_1): Comprising 10 items, this variable obtained a Cronbach's Alpha value of 0.971, indicating that the instrument is highly reliable.
b. Financial Strategy (X_2): With 9 items, this variable achieved a Cronbach's Alpha value of 0.977, which also reflects a very high level of reliability.
c. Business Sustainability (Y): Consisting of 6 items, this variable recorded a Cronbach's Alpha value of 0.966, indicating strong internal consistency and reliability.

Therefore, all instruments used in this study are deemed reliable and are suitable for further analysis.

3.4 Normality Test

The normality of the dependent variable was tested using both the Kolmogorov–Smirnov and Shapiro–Wilk methods. The test results are as follows:

a) Kolmogorov–Smirnov: Sig. = 0.060
b) Shapiro–Wilk: Sig. = 0.074

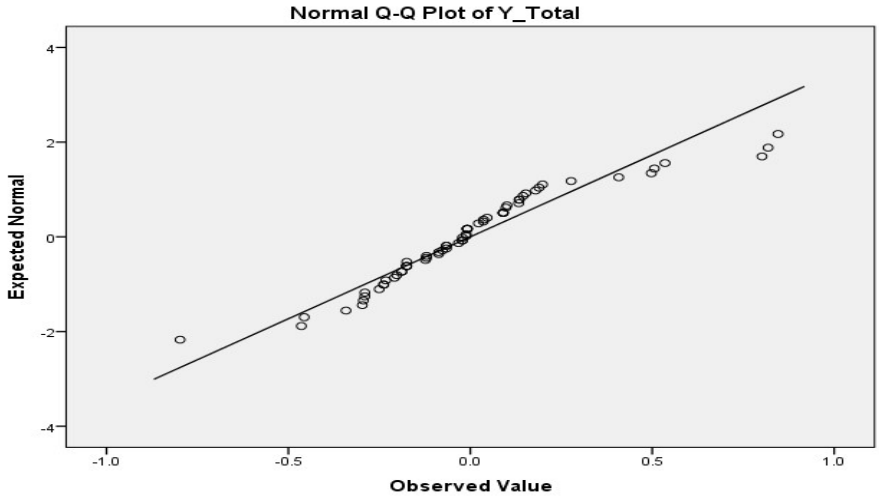


Fig.2. Q-Q Plot

Since both Significant values are greater than 0.05, the null hypothesis stating that the data are normally distributed is accepted. Additionally, the Q–Q Plot shows that the data points are closely clustered, indicating that the assumption of normality has been fulfilled.

3.5 Multiple Linear Regression Analysis

To examine the influence of Managerial Capability (X_1) and Financial Strategy (X_2) on Business Sustainability (Y), a multiple linear regression analysis was conducted.

a. Model Summary

Table 12. Model Summary

No	Type of Correlation	Correlation Value
1	R	0.956
2	R^2	0.914
3	Adj R^2	0.912

The correlation coefficient (R) of 0.956 indicates a very strong relationship between the independent variables (managerial capability and financial strategy) and the dependent

variable (business sustainability). The coefficient of determination (R^2) of 0.914 suggests that 91.4% of the variance in business sustainability can be explained by the two independent variables. This implies that the regression model has a very high explanatory power. Additionally, the Adjusted R^2 value of 0.912 confirms the model's stability, indicating that it remains strong even after accounting for the number of predictors and sample size.

b. Simultaneous Test (F-Test)

Table 13. F-Test

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2089.015	2	1044.508	336.411	.000[b]
	Residual	195.606	63	3.105		
	Total	2284.621	65			

Note. a. Dependent Variable: Y_Total
b. Predictors: (Constant), X2_Total, X1_Total

The ANOVA results show an F-value of 336.411 with a Significant level of 0.000. At a 5% Significant level (α = 0.05) and degrees of freedom ($df_1 = 2$, $df_2 = 63$), the critical F-table value is approximately 3.15. Since the calculated F-value (336.411) is much greater than the F-table value, the regression model is statistically significant. This confirms that Managerial Capability (X_1) and Financial Strategy (X_2) have a significant simultaneous effect on Business Sustainability (Y).

c. Partial Test (t-Test)

Table 14. t-Test Results

Variable	Coef. (B)	t-value	Sig.	t-table (df = 63)	Interpretation
Constant	1.773	1.843	0.07	1.998	Not significant
X_1 (Kemampuan Manajerial)	0.327	4.606	0	1.998	Significant positive effect
X_2 (Strategi Keuangan)	0.265	3.555	0.001	1.998	Significant positive effect

At a Significant level of α = 0.05 and degrees of freedom df = 63, the critical t-value is 1.998. Since the t-values for X_1 and X_2 are greater than the t-table value and their respective p-values are below 0.05, it can be concluded that both Managerial Capability (X_1) and Financial Strategy (X_2) have a positive and statistically significant effect on Business Sustainability (Y). Among the two variables, Managerial Capability (X_1) exerts a slightly stronger influence.

d. Regression Equation

Based on the regression results, the multiple linear regression equation is formulated as follows:

$$Y=1.773+0.327X1+0.265X2+e$$

Where:

Y = Business Sustainability
X_1 = Managerial Capability
X_2 = Financial Strategy
E = Error Term (at α = 0.05)

The regression analysis shows that the constant value of 1.773 represents the baseline level of business sustainability when both independent variables are set to zero. In other words,

even without the influence of managerial capability and financial strategy, there is a foundational level of sustainability. Furthermore, an increase of one unit in Managerial Capability (X_1) contributes to an increase of 0.327 units in business sustainability, while a one-unit increase in Financial Strategy (X_2) contributes to an increase of 0.265 units. All regression coefficients in the model are statistically significant at the 5% level, confirming that both variables have a meaningful influence on business sustainability.

3.6 Discussion

The results of the multiple linear regression analysis indicate that Managerial Capability (X_1) and Financial Strategy (X_2) have a significant effect on Business Sustainability (Y) among MSME actors in Hamparan Perak District, both simultaneously and partially. The ANOVA Significant value of 0.000 ($p < 0.05$) confirms that the regression model used is valid and appropriate for explaining the relationship between the independent and dependent variables. Furthermore, the R Square value of 0.914 demonstrates that 91.4% of the variability in business sustainability can be explained by the two predictor variables, while the remaining 8.6% is influenced by other factors not included in this model.

Individually, Managerial Capability shows a significant and positive effect on business sustainability (Sig. = 0.000), indicating that MSMEs with stronger managerial skills tend to be more capable of sustaining and developing their businesses. This finding aligns with the studies conducted by Apsari & Rofiaty and Oktaria & Hairudin, which emphasize the importance of managerial ability in improving business performance and continuity (Cahyono et al., 2024). Similarly, Aminah & Prasetyo, in the context of MSMEs in Yogyakarta, identified managerial competence as a key success factor for small enterprises (Aminah et al., 2024). However, contrasting evidence was found in the study by Alexandra, which reported no significant relationship between managerial capability and business sustainability (Kang & Arikrishnan, 2024). discrepancies may be attributed to contextual differences, such as regional business environments, types of businesses, or entrepreneurial backgrounds.

Financial Strategy also exhibits a significant positive effect on MSME sustainability (Sig. = 0.001), suggesting that effective financial planning and control contribute to long-term business viability. These results support the findings of Arifandi et al., who emphasized the importance of financial strategy, financial literacy, and financial management in sustaining MSME operations (Arifandi et al., 2024). Conversely, Usmayanti et al. found that financial strategy does not have a direct impact on sustainability, instead highlighting the roles of business model innovation and financial resilience. This implies that, in certain contexts, the effect of financial strategy may be mediated or moderated by other variables (CH & Fitria, 2024).

Overall, the findings of this study affirm that managerial capability and financial strategy collectively have a significant impact on business sustainability. This supports prior research by Rahmawati & Setiawan and Linawati & Nursolikin, which assert that the synergy between managerial skills and financial resource management is essential for the growth of micro-enterprises (Linawati, n.d.; Rahmawati & Setiawan, 2024). Nonetheless, opposing evidence also exists, such as in studies by Setyowati & Widhy and Nurdyanto, which suggest that under certain conditions, these two variables may not significantly influence sustainability due to external factors such as market dynamics, access to capital, policy support, technological adaptation, and changes in consumer behavior (Nurdyanto et al., 2024; Setyowati et al., 2024).

In summary, this research reinforces the notion that enhancing managerial capability and financial strategy should be a strategic priority for MSMEs in Hamparan Perak District. Managerial

competence involves the ability to plan, organize, lead, and evaluate business activities, while sound financial strategy supports efficient resource allocation, investment decision-making, and risk management. Therefore, the interaction between these two dimensions forms a foundational pillar for building sustainable and competitive MSMEs in an ever-evolving business environment.

4. Conclusion

This study aimed to examine whether Managerial Capability and Financial Strategy have a significant influence on Business Sustainability among MSMEs in Hamparan Perak District. Based on the results of multiple linear regression analysis, it can be concluded that both variables exert a positive and significant impact, both simultaneously and partially, on business sustainability. Accordingly, the research question is answered affirmatively: stronger managerial skills and well-planned financial strategies contribute meaningfully to the sustainable operation of MSMEs. The R^2 value of 0.914 indicates that 91.4% of the variation in business sustainability can be explained by the combined influence of managerial capability and financial strategy. Among the two, managerial capability exerts a slightly stronger influence, highlighting the critical importance of leadership, planning, organization, and evaluation in ensuring long-term business success. Financial strategy also plays an essential role, particularly in helping business actors allocate resources effectively and manage financial challenges.

This research contributes new insights by emphasizing the importance of synergy between internal managerial competencies and financial decision-making in the context of small enterprises in developing regions. The findings demonstrate that business sustainability is not solely determined by market conditions but also by the internal capacity of business owners to manage and strategize effectively.

Future studies are encouraged to explore additional variables such as digital literacy, innovation capability, or external support mechanisms, which may also influence MSME sustainability. Moreover, qualitative approaches could offer a deeper understanding of how managerial and financial strategies are formulated and implemented in real-world business practice. Ultimately, this study underscores that empowering MSME owners through targeted training in management and finance represents a practical and essential step toward building resilient and sustainable enterprises.

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ANALYSIS OF SPARE PARTS SUPPLIER SELECTION AT APIN WORKSHOP USING THE SIMPLE ADDITIVE WEIGHTING (SAW) METHOD

Eria Teresia Lonika Br. Bangun*, Mesran

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, North Sumatra, Indonesia

*Corresponding author e-mail address: eriateresia735@gmail.com

Abstract

Apin Workshop faces challenges in selecting spare parts suppliers due to subjective and unsystematic decision-making, which complicates the accurate selection of suppliers. To address this issue, the Simple Additive Weighting (SAW) method was implemented as part of a decision support system using five main evaluation criteria: price (0.30), product quality (0.25), delivery time (0.20), availability (0.15), and service (0.10). Data were collected through direct measurement and observation, then processed using the SAW method to generate preference scores for each supplier. The evaluation results identified Muda Medan Sparepart as the best supplier with a score of 0.83, followed by Cemerlang Motor and Katamso Jaya Motor, each with a score of 0.78. The application of the SAW method improves objectivity, transparency, and efficiency in the supplier selection process, thereby facilitating management in making more accurate and data-driven decisions.
Keywords: Spare Parts Supplier; Simple Additive Weighting; Decision Support System

1. Introduction

In the automotive service industry, selecting the right spare parts supplier plays a vital role in maintaining service quality, customer satisfaction, and operational continuity. At Apin Workshop, the absence of a structured supplier selection system has led to subjective decision-making, resulting in inefficiency and inconsistent outcomes.

To overcome this issue, the implementation of a Decision Support System (DSS) is highly important. DSS is designed to assist decision-makers in evaluating various alternatives based on relevant criteria, thereby improving the quality, accuracy, and transparency of decisions (Ramadhan & Supatman 2022). In the context of supplier selection, DSS enables workshops to assess suppliers not only based on price but also on aspects such as quality, delivery speed, availability, and service responsiveness.

One of the most widely used methods within DSS is the Simple Additive Weighting (SAW) method. As stated by Bintang Putra Dwi Pamungkas et al., (2024), SAW simplifies the decision-making process by converting multiple criteria into a single composite score, making it easier to objectively compare alternatives.

The usefulness of the SAW approach in supplier selection is still being shown by recent studies. For example, SAW was effectively implemented in a decision support system for assessing suppliers in the MSME sector by (Suryadi et al., 2025). Their results demonstrated that SAW successfully increased transparency and impartiality throughout the selecting procedure. Furthermore, a study conducted by George & Balaguru(2024) presented a hybrid strategy that combines AHP and SAW to improve the accuracy of supplier selection decisions. These new

developments demonstrate SAW's continued applicability and usefulness in a range of industries, including auto repair shops. Given these developments, it is crucial to investigate how SAW might be customized for certain operational contexts, like the Apin Workshop, which hasn't been thoroughly examined in earlier research. This method has been effectively applied across various fields, including supplier selection in both manufacturing and service sectors.

Several previous studies support the effectiveness of SAW in multi-criteria decision-making. Adidtyawan (2024) implemented SAW for vendor selection in IT procurement at PT Bank Rakyat Indonesia, demonstrating its reliability in structured vendor assessments. Diana dan Dwi Achadiani, (2022) combined SAW and the Analytical Hierarchy Process (AHP) to evaluate automotive workshop suppliers, proving that SAW improves objectivity. Similarly, Sipayung et al., (2022) showed that SAW facilitates fair and data-driven decisions in supplier selection for construction material distribution.

Motivated by these findings, this research applies the SAW method to assist Apin Workshop in selecting the most suitable spare parts supplier. The objective is to develop a structured and transparent DSS-based model that enhances decision-making accuracy and operational efficiency in supplier selection.

2. Methodology

2.1 Research Stages

The research framework describes the systematic flow used to improve the effectiveness of spare parts supplier selection at Apin Workshop by utilizing a Decision Support System (DSS) based on the Simple Additive Weighting (SAW) method. The process begins with the collection of data on supplier alternatives as candidates, followed by determining relevant assessment criteria based on the workshop's needs. Subsequently, the data are processed using the SAW method to assign weights and scores to each criterion, thereby producing an objective supplier ranking. The results of these calculations then serve as the basis for decision-making in selecting the best supplier. This framework aims to ensure that the supplier selection process is more efficient, transparent, and results in accurate decisions in accordance with needs.

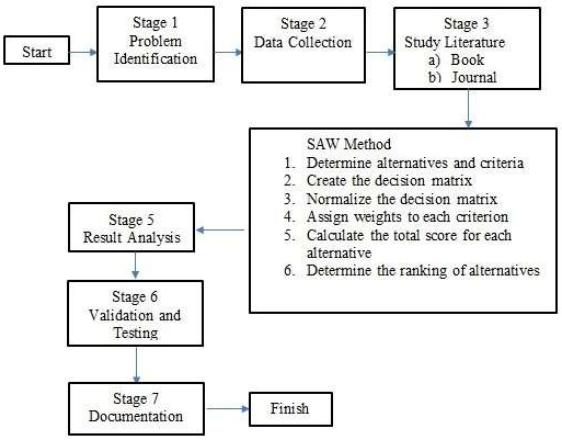


Fig. 1. Research Framework

Description of Figure 1. Research Framework

i. Problem Identification
ii. Identify and understand the issues and their limitations so that the research objectives are clear.
iii. Data Collection
iv. Collecting data through observation, interviews, and documentation as the basis for analysis.
v. Literature Review
vi. Reviewing references to strengthen the theoretical basis and identify relevant previous research.
vii. SAW Method
    a. Determining criteria and alternatives according to requirements
    b. Assigning weights based on the level of importance
    c. Constructing and normalizing the decision matrix
    d. Calculating final scores based on values and weights
    e. Ranking alternatives according to the highest scores
viii. Result Analysis
ix. Analyzing data to identify patterns and decision recommendations
x. Validation and Testing
xi. Testing the system to ensure the accuracy and relevance of results.
xii. Documentation
xiii. Recording the entire process and results as an official report and for future development materials.

2.2 Decision Support System

A Decision Support System (DSS) is a computer-based system designed to assist decision-makers in semi-structured or unstructured decision-making processes (Proboningrum & Sidauruk, 2021). DSS integrates data, analytical models, and an interactive interface that enables users to systematically and effectively evaluate various alternative solutions (Satria, 2023). Further, SPK modern has been widely developed using artificial intelligence (AI) and big data, which assist in analyzing large amounts of data, providing predictive analysis, and operational tools that can increase accuracy, trust, and efficiency, particularly in the manufacturing, logistics, and financial sectors (Soori et al., 2024). With DSS, decision-making becomes more directed and supported by relevant information and comprehensive analysis, thereby enhancing the quality and speed of decisions in various fields, including management and operations (Ranisa & Kirman, 2022), (Lubis et al., 2023).

A Decision Support System (DSS) not only serves as a tool for data processing and analysis, but also facilitates interaction between the user and the system, thus enabling faster and more precise decision-making (Harianto et al., 2022). By integrating various mathematical models and analytical techniques, DSS can handle the complexity and uncertainty inherent in decision-making processes, particularly in situations involving multiple alternatives and criteria. Moreover, the implementation of DSS can improve consistency and objectivity in evaluating alternatives, thereby helping organizations achieve their strategic goals more effectively and efficiently across diverse sectors such as business, manufacturing, healthcare, and public services (Sihombing et al., 2024).

2.3 Simple Additive Weighting (SAW) Method

The Simple Additive Weighting (SAW) method is a decision-making technique used to evaluate and select alternatives based on multiple predetermined criteria. According to Sari & oktaga,

(2024), this method works by assigning weights to each criterion and calculating the total value of each alternative to determine the best choice. SAW is particularly useful in situations where decisions must be made based on various interacting factors.

In the context of supplier selection, the SAW method enables companies to analyze various supplier alternatives based on criteria such as price, quality, delivery time, and after-sales service. By using this method, companies can make more objective and measurable decisions, thus increasing the likelihood of choosing the most suitable supplier for their needs. An effective implementation of the SAW method can contribute to improved operational efficiency and customer satisfaction, as well as support the company's long-term success (Nandes & Yunus, 2021).

The basic concept of the SAW method is to seek the weighted sum of performance ratings for each alternative across all attributes. The Simple Additive Weighting (SAW) method requires the process of normalizing the decision matrix (X) to a scale that can be compared across all available alternative ratings (Manik et al., 2022).

The steps in the Simple Additive Weighting (SAW) method are as follows:

i. Preparing the decision matrix.
   The decision matrix is formed from the alternative scores and the criteria values, using the following matrix equation:

$$X_{ij} \begin{bmatrix} X_{11}\, X_{12} \cdots X_{1n} \\ X_{21}\, X_{22} \cdots X_{2n} \\ X_{31}\, X_{32} \cdots X_{3n} \\ X_{m1}\, X_{m2} \cdots X_{mn} \end{bmatrix} \quad (1)$$

   Explanation:
   Xij = Decision matrix
   i = Alternative (row)
   j = Attribute or criterion (column)
   n = Number of attributes
   m = Number of alternatives

ii. This step converts the value of each attribute into a scale from 0 to 1, considering the type of criterion, using the following equation (Rachman & Daru, 2021).

$$R_{ij} = \begin{cases} \frac{Min\, X_{ij}}{X_{ij}} \rightarrow if\ j\ is\ a\ cost\ attribute\ (cos \\ \frac{Min\, X_{ij}}{X_{ij}} \rightarrow if\ j\ is\ a\ cost\ attribute\ (cos \end{cases} \quad (2)$$

   Explanation:
   Rij = Normalized matrix
   Max Xij = Highest value in column j
   Min Xij = Lowest value in column j
   Xij = Decision matrix

iii. Calculating preference values. This is the main stage, where all attributes are multiplied by the criteria weights for each alternative using the following equation (Wijaya & Farisi, 2024):

$$V_1 = \sum_{j=1}^{n} W_j\, R_{ij} \quad (3)$$

Explanation:
VI = Preference value
Wj = Weight
Rij = Normalized matrix
j = Criteria/attribute
n = Number of criteria/attributes

2.4 Supplier

A supplier are strategic partners who have significant control over quality, costs, and service delivery, in addition to fulfilling their role as product providers. Research shows that strategic alliances with suppliers significantly improve overall organizational performance and supply chain responsiveness (Malik et al., 2023). In a business context, choosing the right supplier is critical to ensuring smooth operations and overall company success.

Proper supplier relationship management can help companies improve operational efficiency and reduce risks associated with supply. Reliable suppliers can deliver high-quality products, ensure timely deliveries, and provide adequate after-sales support. Therefore, a thorough understanding of supplier characteristics and performance becomes key in making strategic decisions, as well as in planning and managing the supply chain effectively.

2.5 Supplier Selection

Supplier selection is the process of evaluating and selecting the most suitable goods or service providers for a company's needs. Finding the right suppliers is crucial to ensuring product quality, cost efficiency, and operational efficiency in the supply chain. This process involves analyzing several criteria, such as price, quality, delivery time, reputation, and after-sales service. Additionally, maintaining long-term relationships with selected suppliers plays a key role in enhancing collaboration, innovation, and the competitiveness of the supply network (Shi & Zhang, 2023).

An effective supplier selection process does not focus solely on cost aspects but also takes into account long-term relationships that can be developed with suppliers. Good relationships with suppliers can enhance collaboration, innovation, and responsiveness to changing market demands. Therefore, choosing the right supplier is key to creating a competitive advantage and ensuring the long-term success of a company’s operations.

3. Results and Discussion

3.1 Data Alternative

The alternatives in this study are candidate spare parts suppliers to be selected by Apin Workshop. Each alternative represents one supplier that will be assessed and compared based on the criteria established in the SAW method. Data regarding these supplier alternatives can be seen in Table 1 below, which contains complete information about each supplier as the basis for evaluation in the decision-making process.

Table 1. Alternative Data

Supplier	Price	Product Quality	Delivery Time	Availability	Service

Muda Medan Sparepart	Below standard	Standard	8 hours	Minimal	Less responsive
Cemerlang Motor	Standard	High	3 hours	Minimal	Responsive
Nitto Motor	Above standard	Premium	1.5 hours	High	Less responsive
Katamso Jaya Motor	Standard	Standard	2.5 hours	Minimal	Less responsive
Remaja Motor	Above standard	Economical	6 hours	Standard	Highly responsive
Sinar Jaya Sparepart	Standard	High	4 hours	Standard	Responsive
Medan Jaya Motor	Below standard	Economical	7 hours	Low	Less responsive
Prima Motor	Above standard	Premium	2 hours	High	Highly responsive
Surya Motor	Standard	Standard	5 hours	Standard	Responsive
Bintang Sparepart	Below standard	High	3.5 hours	High	Less responsive

Table 1 shows the initial data of ten suppliers assessed based on five main criteria: price, product quality, delivery time, availability, and service. This data was used as the basis for the assessment process using the SAW method.

3.2 Criteria Data

Criteria are factors or aspects used to evaluate and compare alternatives (spare parts suppliers) in the decision-making process. In this study, the criteria are tailored to the needs of Apin Workshop to ensure the selection of qualified and reliable suppliers. The criteria points include:

Table 2. Criteria Data

Criteria	Weight	Type	Priority
Price	0.30	Benefit	1
Product Quality	0.25	Benefit	2
Delivery Time	0.20	Benefit	3
Capacity and Availability	0.15	Benefit	4
Service and Responsiveness	0.10	Benefit	5

Table 2 shows the five assessment criteria used in the SAW method, complete with their weights, type (benefit), and priority order. The weights reflect the importance of each criterion in the decision-making process.
Next, to determine the weights for each criterion, the following values are used:

i. Price (C1)
   Price is one of the main criteria in supplier selection because it directly affects the workshop's operational cost efficiency. Suppliers offering more competitive prices will be more advantageous for the workshop, but must still be balanced with good product quality.

Table 3. Weight Value for Price (C1)

Category	Price Category
Below standard	5
Standard/competitive	4
Slightly above standard	3
Above standard	2
Far above standard	1

Table 3 explains the assessment weights for the price criterion (C1). The lower the price offered by the supplier, the higher the weight given, as it is considered more beneficial for the workshop.

ii. Product Quality (C2)
The quality of spare parts is crucial to ensure the reliability and customer satisfaction of the workshop. Products with premium quality are certainly prioritized, even though they may come at a higher price.

Table 4. Weight Value for Product Quality (C2)

Product Quality Category	Criteria Weight
Premium	5
High	4
Standard	3
Economical	2
Low	1

Table 4 shows the assessment weights for the product quality criterion (C2). The higher the product quality offered, the greater the weight given, as it is considered to better support the workshop's performance.

iii. Delivery Time (C3)
Fast delivery time is crucial to reduce workshop downtime and maintain smooth operations. Suppliers who can deliver spare parts in a short time will receive higher weights.

Table 5. Weight Value for Delivery Time (C3)

Delivery Time Category	Criteria Weight
Less than 2 hours	5
2 to 3 hours	4
3 to 5 hours	3
5 to 7 hours	2
More than 7 hours	1

Table 5 explains the assessment weights for the delivery time criterion (C3). The faster the delivery time offered by the supplier, the higher the weight assigned, since it directly impacts the operational efficiency of the workshop.

iv. Availability (C4)
The stock availability of spare parts at the supplier greatly affects the smooth operation of the workshop. Suppliers with high and consistent stock availability will be prioritized.

Table 6. Weight Value for Availability (C4)

Availability Category	Availability Category
Standard	5
Standar	4
Low	3
Minimal	2

Table 6 presents the assessment weights for the stock availability criterion (C4). The higher the stock availability from the supplier, the greater the weight assigned, as this supports the continuity of the ordering process.

v. Service (C5)
Supplier service, particularly in terms of responsiveness and ease of communication, is essential to ensure the workshop's needs are quickly and accurately met.

Table 7. Weight Value for Service (C5)

Service Category	Service Category
Very responsive	5
Responsive	4
Less responsive	3
Very unresponsive	2

Table 7 shows the assessment weights for the service criterion (C5). The more responsive the service provided by the supplier, the higher the weight assigned, as this reflects speed and quality of communication.

3.3 Discussion

The five criteria used to evaluate spare parts suppliers at Apin Workshop consist of price (C1), product quality (C2), delivery time (C3), stock availability (C4), and service responsiveness (C5). Price is a primary consideration to ensure cost efficiency, with lower prices being more favorable. Product quality reflects the reliability and durability of the components provided. Delivery time assesses how quickly suppliers can fulfill orders. Stock availability determines whether suppliers can consistently provide the required goods. Finally, service responsiveness evaluates how quickly and effectively suppliers respond to communications and complaints. These criteria serve as the basis for objectively evaluating and ranking suppliers using the Simple Additive Weighting (SAW) method.

Table 8. Description of Evaluation Criteria

Criteria	Description
Price (C1)	Lower prices receive higher scores
Product Quality (C2)	Higher durability and performance score higher
Delivery Time (C3)	Faster delivery is preferred
Availability (C4)	Consistency and readiness of stock
Service (C5)	Supplier responsiveness and communication effectiveness

Table 8 explains the meaning of each evaluation criterion used in the SAW method. Each criterion has a specific focus that reflects its contribution to the effectiveness of supplier selection.

This study involved ten spare parts suppliers as alternatives in the evaluation process at Apin Workshop. Each supplier was coded from A1 to A10 to simplify the assessment and calculation process in the SAW method. The complete list of these supplier alternatives is presented in Table 9.

Table 9. Supplier Alternatives

Code	Supplier Name
A1	Sparepart Muda Medan
A2	Cemerlang Motor
A3	Nito Motor
A4	Katamso Jaya Motor
A5	Remaja Motor
A6	Sinar Jaya Sparepart
A7	Medan Jaya Motor

A8	Prima Motor
A9	Surya Motor
A10	Bintang Sparepart

Table 9 contains the list of supplier alternatives evaluated in this research. Each supplier is given a code to facilitate the assessment and calculation process using the SAW method.

After the supplier alternatives were determined, the next step was to assign initial scores to each supplier based on the five established evaluation criteria. These scores were obtained through direct observation and assessment of each supplier's performance. Each criterion was rated on a scale of 1 to 5, where a score of 5 indicates the best performance. These raw scores served as the foundation for the normalization process in the SAW method, as shown in Table 10.

Table 10. Raw Scores for Each Supplier

Code	C1 (Price)	C2 (Quality)	C3 (Delivery)	C4 (Availability)	C5 (Service)
A1	5	5	5	5	5
A2	4	5	5	4	4
A3	4	4	4	5	5
A4	4	5	4	4	4
A5	4	4	4	4	4
A6	4	4	3	4	4
A7	3	4	3	4	4
A8	3	3	3	3	3
A9	3	3	3	3	3
A10	2	3	2	2	2

Table 10 shows the raw scores assigned to each supplier based on the five main assessment criteria: price (C1), product quality (C2), delivery time (C3), availability (C4), and service (C5). Each criterion was rated on a scale of 1 to 5, with 5 indicating the best performance and 1 the lowest. These values were obtained through observation and initial evaluation before the normalization process in the SAW method. These scores serve as the initial basis for determining supplier preferences quantitatively.

After obtaining the raw scores for each supplier across the five defined criteria, the next step in the SAW method is normalization. This process aims to equalize the value scales so that each criterion can be fairly compared. Normalization is performed by dividing the value of each alternative by the maximum value in each criterion. These normalized values will then be used in the final calculation to determine the total preference score for each supplier.

Table 11. Normalized Scores

Code	C1	C2	C3	C4	C5
A1	1.00	1.00	1.00	1.00	1.00
A2	0,80	1.00	1.00	0,80	0,80
A3	0,80	0,80	0,80	1.00	1.00
A4	0,80	1.00	0,80	0,80	0,80
A5	0,80	0,80	0,80	0,80	0,80
A6	0,80	0,80	0.60	0,80	0,80
A7	0.60	0,80	0.60	0,80	0,80
A8	0.60	0.60	0.60	0.60	0.60
A9	0.60	0.60	0.60	0.60	0.60
A10	0.40	0.60	0.40	0.40	0.40

Table 11 presents the normalized scores for each supplier based on the five criteria: price (C1), product quality (C2), delivery time (C3), availability (C4), and service (C5). Normalized values

range from 0 to 1, with 1 indicating the best performance on each criterion. These values form the basis for the final calculation of each alternative's preference score (Vi).

After normalization in Table 11, each score was multiplied by its corresponding criterion weight and then summed to obtain the final preference score (Vi). The Simple Additive Weighting (SAW) formula was used to generate objective preference values. Supplier A1 – Muda Medan Sparepart obtained the highest score of 0.830, indicating the best performance across all criteria. Suppliers A2 – Cemerlang Motor and A4 – Katamso Jaya Motor followed with identical scores of 0.780, demonstrating strong and consistent quality. These Vi values serve as the basis for ranking and selecting the most suitable suppliers.

a. Supplier A1 - Sparepart Muda Medan
   Vi = (1,00 × 0,30) + (0,80 × 0,25) + (0,60 × 0,20) + (1,00 × 0,15) + (0,60 × 0,10) Vi = 0,300 + 0,200 + 0,120 + 0,150 + 0,060 = 0,830
b. Supplier A2 - Cemerlang Motor
   Vi = (0,40 × 0,30) + (1,00 × 0,25) + (0,80 × 0,20) + (1,00 × 0,15) + (1,00 × 0,10) Vi = 0,120 + 0,250 + 0,160 + 0,150 + 0,100 = 0,780
c. Supplier A3 - Nitto Motor
   Vi = (0,80 × 0,30) + (0,80 × 0,25) + (0,60 × 0,20) + (0,80 × 0,15) + (0,80 × 0,10) Vi = 0,240 + 0,200 + 0,120 + 0,120 + 0,080 = 0,760
d. Supplier A4 - Katamso Jaya Motor
   Vi = (0,40 × 0,30) + (1,00 × 0,25) + (1,00 × 0,20) + (1,00 × 0,15) + (0,60 × 0,10) Vi = 0,120 + 0,250 + 0,200 + 0,150 + 0,060 = 0,780
e. Supplier A5 - Remaja Motor
   Vi = (0,80 × 0,30) + (0,60 × 0,25) + (0,60 × 0,20) + (0,80 × 0,15) + (0,80 × 0,10) Vi = 0,240 + 0,150 + 0,120 + 0,120 + 0,080 = 0,710
f. Supplier A6 - Sparepart Sinar Jaya
   Vi = (0,80 × 0,30) + (0,80 × 0,25) + (0,80 × 0,20) + (0,40 × 0,15) + (0,80 × 0,10) Vi = 0,240 + 0,200 + 0,160 + 0,060 + 0,080 = 0,740
g. Supplier A7 - Medan Jaya Motor
   Vi = (1,00 × 0,30) + (0,60 × 0,25) + (0,20 × 0,20) + (0,40 × 0,15) + (0,60 × 0,10) Vi = 0,300 + 0,150 + 0,040 + 0,060 + 0,060 = 0,610
h. Supplier A8 - Prima Motor
   Vi = (1,00 × 0,30) + (0,40 × 0,25) + (0,40 × 0,20) + (0,60 × 0,15) + (0,60 × 0,10) Vi = 0,300 + 0,100 + 0,080 + 0,090 + 0,060 = 0,630
i. Supplier A9 - Surya Motor
   Vi = (0,80 × 0,30) + (0,60 × 0,25) + (0,80 × 0,20) + (0,40 × 0,15) + (0,60 × 0,10) Vi = 0,240 + 0,150 + 0,160 + 0,060 + 0,060 = 0,670
j. Supplier A10 - Sparepart Bintang
   Vi = (0,40 × 0,30) + (0,40 × 0,25) + (0,40 × 0,20) + (0,80 × 0,15) + (1,00 × 0,10) Vi = 0,120 + 0,100 + 0,080 + 0,120 + 0,100 = 0,520

After completing the normalization and preference score calculations with the Simple Additive Weighting (SAW) method, the final ranking of each supplier based on the total Vi score was obtained. These scores reflect the suitability of each supplier against the five predetermined criteria, and serve as the basis for making objective supplier selection decisions at Apin Workshop.

Table 12. Final Supplier Rankings

Rank	Code	Supplier Name	Vi Score
1	A1	Sparepart Muda Medan	0.83

2	A2	Cemerlang Motor	0,78
2	A3	Nito Motor	0,78
4	A4	Katamso Jaya Motor	0.76
5	A5	Remaja Motor	0,74
6	A6	Sinar Jaya Sparepart	0.71
7	A7	Medan Jaya Motor	0.67
8	A8	Prima Motor	0.63
9	A9	Surya Motor	0.61
10	A10	Bintang Sparepart	0.52

Table 12 shows the final ranking of all suppliers based on the Vi scores. The first rank was achieved by Muda Medan Sparepart (A1) with the highest score of 1.00, followed by Cemerlang Motor (A2) in second place with a score of 0.89. Nitto Motor (A3) and Katamso Jaya Motor (A4) occupied the third and fourth positions with identical scores of 0.85, while Bintang Sparepart (A10) placed last with a score of 0.45, indicating a need for improvement in several assessment aspects. This table serves as the main reference for objectively and measurably determining the best supplier.

Based on the table above, a supplier ranking chart is presented to visually illustrate the performance of each supplier at Bengkel Apin.



Fig. 2. Apin Workshop Supplier Ranking Chart

The graph in Fig. 2 shows the ranking of Bengkel Apin's spare parts suppliers based on the final score calculated using the Simple Additive Weighting (SAW) method, taking into account five main criteria: price, product quality, delivery time, availability, and service. Muda Medan Sparepart (A1) ranks first with the highest score of 0.83, reflecting excellence across all aspects, particularly in price and delivery accuracy. Cemerlang Motor (A2) and Katamso Jaya Motor (A4) are in second place with a score of 0.78, showing strong and consistent performance, followed by Nitto Motor (A3) in fourth place with a score of 0.76, and Remaja Motor (A5) in fifth place with a score of 0.74. In the middle to lower rankings are Sinar Jaya Sparepart (A6) with a score of 0.71, Medan Jaya Motor (A7) with 0.67, Prima Motor (A8) with 0.63, and Surya Motor (A9) with 0.61, indicating the need for improvement in certain areas. The supplier with the lowest score is Bintang Sparepart (A10), with a score of 0.52, indicating a gap in meeting evaluation standards. This ranking provides a comprehensive overview for Apin Workshop management in selecting the best supplier partners, while also serving as strategic input for suppliers to enhance their quality and competitiveness.

Based on the evaluation results, the supplier assessment process for spare parts at Apin Workshop was conducted using the Simple Additive Weighting (SAW) method as part of the decision support system, involving ten suppliers evaluated based on five main criteria: price (0.30), product quality (0.25), delivery time (0.20), availability (0.15), and service (0.10). Data was collected through direct observation and measurement, then processed using the SAW method to calculate each supplier's preference score. The calculation results showed that Muda Medan Sparepart achieved the highest score of 0.83 due to its best performance across most aspects, thus recommended as the primary supplier. Followed by Cemerlang Motor and Katamso Jaya Motor with a score of 0.78, as well as Nitto Motor (0.76) and Sinar Jaya Sparepart (0.74). The SAW method has proven to provide objective, measurable, and transparent results, thereby improving the accuracy and efficiency of decision-making. By applying this method, Bengkel Apin can select the best suppliers according to their needs in a more systematic manner and reduce subjectivity, making it suitable for continuous application in the supplier selection process in the future.

4. Conclusion

The application of the Simple Additive Weighting (SAW) method in this study proved to be effective and systematic in the process of selecting spare parts suppliers at Apin Workshop, by evaluating ten suppliers based on five main criteria—price, product quality, delivery time, stock availability, and service responsiveness—thereby enabling objective comparisons and measurable rankings. The final results show that Muda Medan Sparepart achieved the highest Vi score of 0.83, followed by Cemerlang Motor and Katamso Jaya Motor, both of which scored 0.78, demonstrating the SAW method's ability to integrate multi-criteria assessments into clear and actionable outcomes. In addition to improving the efficiency and accuracy of selection, this method also strengthens transparency and accountability in decision-making, and opens up opportunities for integration into digital decision support systems in the future for more real-time and scalable evaluations. Thus, SAW is not only relevant to current needs, but also adaptive to strategic procurement and organizational decision-making in the future.

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SYSTEMATIC LITERATURE REVIEW ON THE CHALLENGES OF ADOPTING SMART GREEN COMPUTING IN MALAYSIAN HIGHER EDUCATION BRIDGING SUSTAINABILITY AND TECHNOLOGY

Mohamad Hafizi bin Masdar[1], Engku Mohamad bin Engku Abdullah[2*], Nurfarhana binti Hamdan[1]

[1]Information Technology Department, Bentong Community College, 28600 Karak, Pahang, Malaysia

[2]Faculty of Economics and Management, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

*Corresponding author e-mail address: engkumohamadea@gmail.com

Abstract

The integration of sustainable and intelligent technologies in computing has gained global traction, especially in the context of higher education (HE). Smart green computing presents a promising approach to reduce environmental impact while enhancing digital learning and technological efficiency. However, its implementation in Malaysian higher education institutions (HEI) remains limited due to various challenges. The core objective of this study is to conduct a systematic literature review aimed at exploring and analyzing the key challenges hindering smart green computing adoption in Malaysian HE settings. By synthesizing existing literature, this review seeks to bridge the gap between sustainability goals and technological advancement in academia, providing valuable insights for implementing effective and environmentally responsible information and communication technology (ICT) strategies in HEI. The review will draw from major academic databases including Scopus and Web of Science (WoS) and will be guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. A thematic analysis will be employed to identify and categorize recurring issues within organizational, technical and social aspects. The result for thematic has been identified in three main themes: (i) infrastructural limitations; (ii) lack of policy support; and (iii) low awareness of green ICT benefits. By synthesizing existing literature, this study seeks to bridge the gap between sustainability goals and technological advancement in academia. The findings provided valuable insights for policymakers, university administrators and researchers aiming to implement effective and environmentally responsible ICT strategies in higher education institutions.

Keywords: Smart Green Computing; Higher Education Malaysia; Information and Communication Technology.

1. Introduction

The worldwide necessity for sustainability has progressively infiltrated many industries, with Information and Communication Technology (ICT) becoming a crucial yet contradictory field (Sfhea & Calzada, 2021). Although ICT drives innovation and communication, its swift proliferation markedly increases energy consumption and electrical waste (Memić et al., 2022). The notions of "Green Computing" and "Smart Computing" have merged into "Smart Green Computing", promoting the application of intelligent technology to improve environmental sustainability and operational efficiency (Ahmed, 2018; Kamarudin et al., 2021; Okewu et al., 2017). Higher education institutions (HEI), as essential hubs for research, education and social

advancement, are well equipped to advocate for these initiatives due to their comprehensive digital infrastructures and substantial energy use (Caird et al., 2015; Ranjan & S, 2020).

Notwithstanding the acknowledged advantages of incorporating green and smart technology, their actual implementation in HEI is sometimes intricate (Parashar et al., 2024), encompassing distinct technological, organizational and human elements (Trenerry et al., 2021). In Malaysia, a nation dedicated to enhancing its digital economy and sustainability objectives (Jasni et al., 2020), comprehending these particular obstacles is essential. A thorough and systematic synthesis of the issues associated with the adoption of Smart Green Computing in Malaysian HEI constitutes a notable research vacuum, in spite of various studies examining facets of green ICT or smart campus projects. Current work frequently emphasizes technical elements or broad organizational implementation (Dahwan et al., 2022; Androshchuk et al., 2021), neglecting the distinctive interaction of sustainability, technology and localized educational contexts.

To comprehensively address this research vacuum and support sustainable digital transformation, this systematic literature review is guided by a central research inquiry: What are the principal obstacles impeding the implementation of smart green computing in Malaysian higher education institutions? Accordingly, the primary objectives of this study are precisely defined as follows: (1) to systematically explore and analyse the key challenges hindering the adoption of smart green computing within Malaysian higher education settings; and (2) to synthesize existing literature to bridge the gap between sustainability goals and technological advancement in academia.

2. Methodology

2.1 Identification

The systematic review followed a three-step process to identify relevant publications. First, we identified keywords and explored related terms using thesauri, dictionaries, encyclopaedias and current research. We then formulated search queries for the Scopus and Web of Science (WoS) databases, as detailed in Table 1. This initial search yielded 290 articles from Scopus and 282 from WoS.

Table 1. Search Strings

Scopus	TITLE-ABS-KEY (("smart comput*" OR "green comput*" OR "sustainable comput*" OR "eco-friendly technolog*" OR "energy-efficient ICT" OR "green ICT" OR "green IT" OR "smart technolog*" OR "sustainable ICT") AND ("challeng*" OR "barrier*" OR "obstacle*" OR "issue*" OR "limitation*" OR "difficult*" OR "constraint*" OR "impediment*") AND ("higher education*" OR "universit*" OR "college*" OR "tertiary education*" OR "post-secondary education*" OR "academic institution*" OR "HEIs")) AND (LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
Web of Science (WoS)	ALL FIELDS=(("smart comput*" OR "green comput*" OR "sustainable comput*" OR "eco-friendly technolog*" OR "energy-efficient ICT" OR "green ICT" OR "green IT" OR "smart technolog*" OR "sustainable ICT") AND ("challeng*" OR "barrier*" OR "obstacle*" OR "issue*" OR "limitation*" OR "difficult*" OR "constraint*" OR "impediment*") AND ("higher education*" OR "universit*" OR "college*" OR "tertiary education*" OR "post-secondary education*" OR "academic institution*" OR "HEIs")) AND (LIMIT-TO (SUBJAREA , "COMP")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))

2.2 Screening

In the initial screening phase, the aim was to eliminate duplicate papers. Consequently, all 572 selected articles underwent a thorough examination using pre-established selection criteria and the database's sorting features. This process resulted in the removal of 512 items, leaving 60 articles for meticulous scrutiny. The researcher then applied defined inclusion and exclusion criteria to guide the subsequent screening. A primary criterion for selection was the article type, with a focus on research articles as the main source of practical information. Furthermore, to uphold the rigor of the evaluation, only publications containing empirical data and published in recognized journals were considered for inclusion.

This evaluation specifically excluded scholarly publications such as systematic reviews, literature reviews, conceptual analyses, meta-analyses, meta-syntheses, bibliometric studies, book series, novels, chapters and conference proceedings. Additionally, the investigation was limited to scientific articles published in English. The timeframe for the included research spans a decade, from 2015 to 2025.

To ensure alignment with the analytical objectives, only research conducted within the domain of higher education was selected. This stringent selection method was critical for maintaining the study's focus on smart green technology implementation in higher education, thereby excluding works that did not directly contribute to the investigation within this specific context. As a result, 512 publications were eliminated based on these specific criteria. The remaining 60 articles then proceeded to the third stage of eligibility evaluation.

2.3 Eligibility

During the eligibility assessment, an initial set of 60 articles was compiled. A rigorous evaluation of each publication's title and substantive content was conducted to verify adherence to the stipulated inclusion criteria and alignment with the current study's research objectives. Consequently, 37 papers were excluded due to their failure to present empirical evidence within the higher education context. This screening process resulted in a final corpus of 23 articles, which are available for subsequent investigation as presented in Table 2.

Table 2. Searching Criteria Based on Selection Criterion

Criterion	Inclusion	Exclusion
Language	English	Other than English
Timeline	2015 - 2025	< 2015
Literature Type	Journal (Article)	Conference, Book Review, Chapter in Book
Publication Stage	Final	In Press
Subject Area	Computer Science	Other than Computer Science

2.4 Data Abstraction and Analysis

The current study utilized an integrative analysis approach to synthesize diverse research methodologies, encompassing qualitative, quantitative and mixed methods. The primary objective of this academic inquiry was to identify important themes and their underlying subcategories. The initial phase of thematic development involved comprehensive data collection. This study meticulously examined 23 academic articles, systematically extracting all remarks and content pertinent to the investigated research subject. Subsequently, the researcher critically evaluated the key challenges impeding the adoption of smart green computing within Malaysian higher education settings, thereby identifying and constructing coherent categories. The research ultimately illuminated three primary themes: infrastructural limitations, lack of policy support and low awareness of green ICT benefits.

The first phase of the thematic analysis centred on theme generation, which involved discerning recurring patterns within the abstracted data from all reviewed publications. Similar or related data were then systematically organized into three comprehensive groups. Following this, these emergent themes underwent rigorous assessment to confirm their precision and practical relevance. All discrepancies or conceptual variations pertaining to data interpretation were deliberated and resolved until a unanimous consensus was achieved regarding any necessary modifications to the overall thematic framework. The researcher also provided a thorough analysis of each overarching theme, delineating any interdependencies, underlying thoughts or associated concepts.

Throughout the data analysis process, a detailed record was precisely maintained to document all relevant analyses, evolving perspectives, encountered difficulties and other noteworthy observations that contributed to a deeper understanding of the data. Furthermore, the researcher conducted a comparative assessment of the findings to address any potential inconsistencies that may have arisen during the theme identification process. It is crucial to acknowledge that whenever conceptual misunderstandings emerged, the researcher engaged in focused discussions to thoroughly address and resolve them. Ultimately, the established patterns were refined to ensure their internal coherence and robustness.

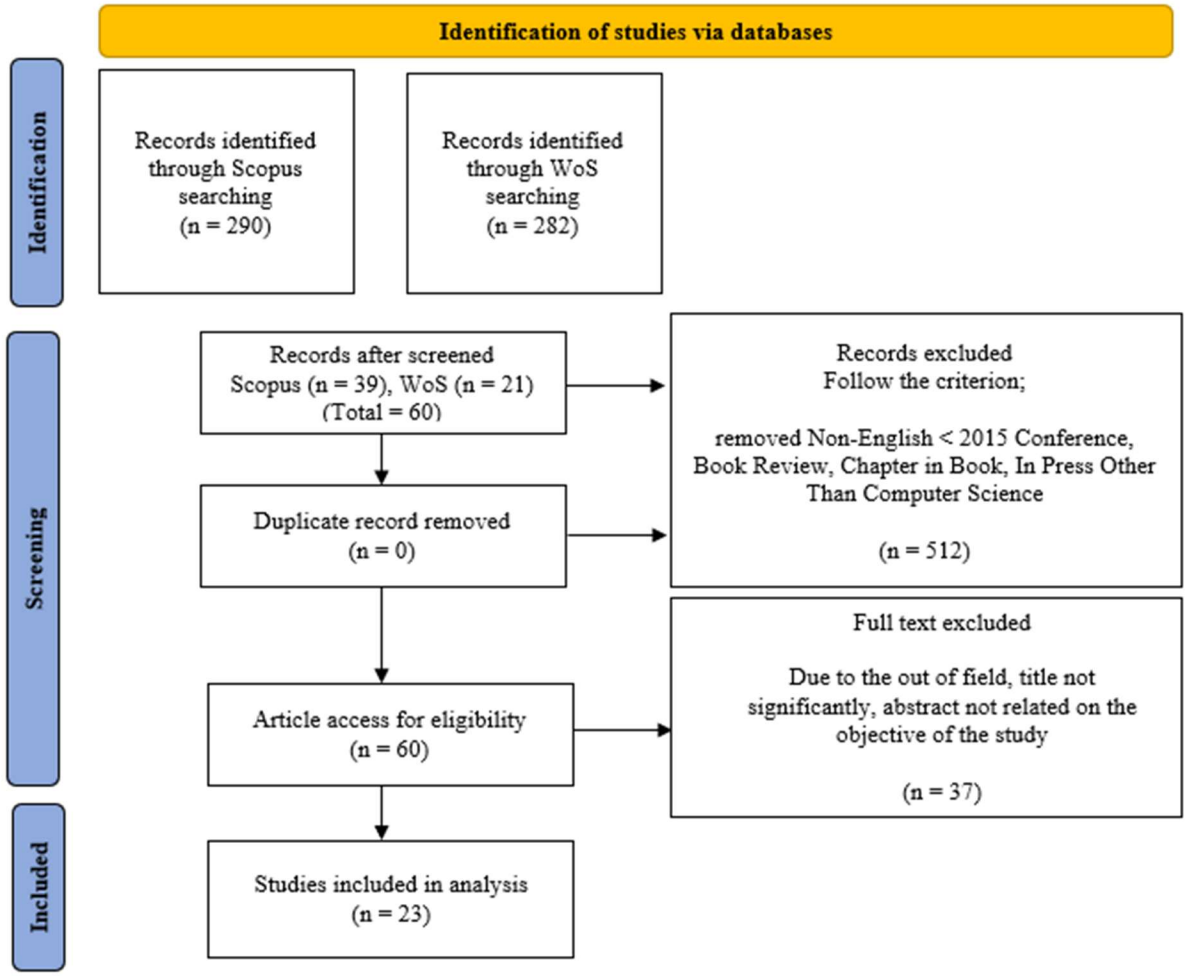


Fig. 1. Flow diagram of the proposed search study

3. Results and Discussion

3.1 Background of the Selected Articles

The review obtained 23 meticulously chosen articles. The topic analysis yielded the discovery of three (3) primary themes: infrastructural limitations, lack of policy support and low awareness of green information and communication technology (ICT) benefits. Out of the 23 chosen articles, the European Union (Italy, Switzerland, United Kingdom) was the location for five (5) studies, China for three (3) studies, the combined region of North America and China for two (2) studies, Southeast Asia (Malaysia, Thailand) for three (3) studies, Africa (Botswana) for one (1) study, India for one (1) study, Australia for one (1) study, North America for one (2) studies, East Asia (Taiwan, Korean) for two (2) studies and United Arab Emirates for one (1) study. Two (2) articles were designated as "Not Specified" for a specific region. The articles and themes are condensed and presented in Table 3.

Table 3. Themes Summary

Studies	Region	Infrastructural Limitations	Lack of Policy Support	Low Awareness of Green ICT Benefits
Giacobbe et al., (2023)	European Union	√		
Xie (2023)	China	√		
Yue et al. (2024)	China	√		
Almshari et al. (2020)	European Union	√		
Cheng et al. (2016)	North America, China	√		
Cheng et al. (2019)	North America, China	√		
Badie et al. (2015)	Southeast Asia	√	√	
Hajeer & Dasgupta (2019)	North America	√		
Mutula et al. (2006)	Africa	√		
Rashmi et al. (2021)	India	√		
Townsend & Mohammadian (2017)	Australia	√		
Haddadi et al. (2025)	North America	√		
Rehan et al. (2018)	Not Specified	√		
Frischer et al. (2020)	European Union	√		
Kang (2012)	East Asia		√	
Muangnak et al. (2022)	Southeast Asia		√	
Al-Madhagy et al. (2015)	Southeast Asia		√	√
Xin (2021)	China			√
Roblek et al. (2019)	European Union			√
Stevenson et al. (2015)	Not Specified			√
Jeong (2017)	East Asia			√
Chowdhury (2015)	United Arab Emirates			√
Priporas et al. (2017)	European Union			√

i. Theme 1: Infrastructural Limitations

The successful integration of advanced smart green computing solutions, such as intelligent energy systems (Giacobbe et al., 2023) and efficient Internet of Things (IoT) deployments in campus environments, fundamentally relies on robust technological infrastructure. Challenges in

this domain include the limited computational capacity and battery life of IoT terminals, which often necessitate the adoption of mobile edge computing to offload tasks and minimize latency (Xie, 2023). Furthermore, the deployment of sophisticated Artificial Intelligence (AI) -driven applications, such as lightweight convolutional neural networks for industrial defect detection, underscores the critical need for optimizing computational resources on devices with constrained power and memory, like digital signal processors (Yue et al., 2024). Therefore, in order for Malaysian HEI to effectively adopt smart green computing, significant investment and strategic planning are required to enhance their foundational digital infrastructure.

The implementation of data-intensive and energy-conscious smart green computing initiatives in higher education demands a sophisticated and resilient power and data centre infrastructure. Monitoring and managing power consumption data are essential, not only for detecting anomalies in computer nodes (Almshari et al., 2020) but also for optimizing resource utilization. Data centres, especially those striving for self-sustainability through renewable energy, face complexities in elastic power-aware resource provisioning due to dynamic power supply (Cheng et al., 2016). Moreover, effectively managing heterogeneous workloads across distributed sustainable data centres requires advanced strategies to maximize system throughput and reduce the environmental impact of energy consumption (Cheng et al., 2019). These infrastructural demands highlight a significant barrier for universities aiming to implement comprehensive smart green computing solutions.

The transition to more efficient and sustainable computing models in Malaysian HE is often hindered by inherent infrastructural limitations, particularly concerning cloud adoption and big data management. While cloud computing offers a cost-efficient alternative to traditional data centres, its adoption is frequently impacted by issues related to security, policy and standardization (Badie et al., 2015). Furthermore, the proliferation of cyber-enabled systems generates massive and diverse datasets, which legacy big data solutions like Hadoop's distributed file system struggle to handle efficiently, leading to increased space requirements and wasted resources (Hajeer & Dasgupta, 2019). These challenges suggest that institutions must not only consider the technological upgrade but also address the complexities of managing and securing large, dynamic data environments for the successful integration of advanced computing paradigms.

The effective implementation of smart green computing within Malaysian HEI is significantly constrained by existing infrastructural limitations, particularly concerning data management, security and resource optimization. Surveillance video analysis for student action recognition in smart campuses generates vast amounts of data, necessitating robust processing and storage capabilities that current computer laboratories might struggle to provide (Rashmi et al., 2021). Concurrently, the drive towards green ICT mandates a strategic approach to manage increasingly complex data centres, where virtualization has proven effective in rationalizing dispersed environments and enhancing cost and energy efficiency (Townsend & Mohammadian, 2017). Furthermore, ensuring the security of these interconnected systems against threats like denial-of-service attacks is paramount, requiring sophisticated detection mechanisms to maintain service availability (Haddadi et al., 2025). These interconnected challenges highlight the critical need for substantial upgrades in digital infrastructure, encompassing not only advanced processing and storage but also comprehensive security protocols and energy-efficient management strategies to fully realize the potential of smart green computing.

The widespread integration of smart green computing, including advanced ICT solutions in HE is heavily reliant on the robustness and accessibility of network protocols and end-user infrastructure. In wireless sensor networks, addressing issues such as bandwidth insufficiency, interference and high energy consumption is critical for achieving Quality of Service (QoS), often

necessitating the adoption of multichannel MAC protocols (Rehan et al., 2018). Beyond core network capabilities, the usability and cost-effectiveness of smart solutions for end-users are also vital. For instance, commercial ICT smart solutions, particularly in areas like smart furniture, emphasize the need for flexible, low-cost, easy-to-install and widely available options to ensure broader acceptance and utility (Frischer et al., 2020). These elements collectively highlight the need for a comprehensive infrastructural approach that supports both technical performance and user adoption in the educational setting.

In summary, infrastructural limitations emerge as a paramount challenge to the adoption of smart green computing within HEI. Core issues encompass inadequate computational capacity for advanced AI and IoT systems, alongside the critical need for robust data center infrastructure capable of handling intensive workloads and dynamic energy demands. Universities also face significant hurdles with cloud adoption, efficient big data management while ensuring system security. Ultimately, widespread smart green computing hinges upon substantial investment in digital infrastructure upgrades, including network protocols, advanced processing and user-friendly solutions, prioritizing both efficiency and security.

ii. Theme 2: Lack of Policy Support

The successful integration of smart green computing initiatives within Malaysian HEI is frequently hampered by an insufficient framework of policy support. Even in highly collaborative environments like living labs, such as the Suan-Lien Living Lab focused on elderly welfare, clear protocols and a sustainable operational model are identified as critical for launching and managing projects, underscoring the need for well-defined institutional policies (Kang, 2012). Similarly, the implementation of smart waste management systems, even those driven by social enterprises and leveraging advanced technology like deep learning, benefits significantly from formal policies that encourage participation and data utilization for analysis (Muangnak et al., 2022). Without explicit policy frameworks and guidelines, the widespread and sustained adoption of smart green computing initiatives remains challenging.

A significant barrier to the widespread adoption of smart green computing in Malaysian HE stems from the absence of comprehensive policy and regulatory support. Studies on cloud computing data centre adoption factors frequently highlight the lack of proper policy and standardization as key impediments, even when numerous benefits like cost reduction and flexibility are present (Badie et al., 2015). Similarly, research into individuals' perceptions and behaviours towards green ICT in Malaysia, specifically within a university context, identifies perceived usefulness, ease of use and environmental awareness as predictors of adoption; however, the implicit need for policies to foster these perceptions and encourage behavioural intention remains crucial (Al-Madhagy et al., 2015). Therefore, institutional and governmental policy development is essential to create an enabling environment that incentivizes and standardizes green ICT practices, addressing concerns beyond individual perceptions and technological capabilities.

Collectively, the adoption of smart green computing in Malaysian HEI significantly hampered by an insufficient framework of policy support. The absence of comprehensive and explicit policies, along with a lack of standardization, creates substantial barriers to implementation and sustained growth. Formal institutional and governmental policy development is crucial, as it fosters an enabling environment, incentivizes participation and shapes positive perceptions and behaviours towards green ICT practices, addressing concerns that extend beyond mere technological capabilities.

iii. Theme 3: Low Awareness of Green ICT Benefits

A prevalent challenge in adopting smart green computing in Malaysian HE is the limited understanding among stakeholders regarding the multifaceted benefits of advanced technologies. While multimedia AI can significantly enhance English teaching practices by stimulating student engagement (Xin, 2021) and smart technologies are perceived by Generation Z as time-saving innovations (Roblek et al., 2019), a broader awareness of their sustainable aspects and long-term implications remains underexplored. Similarly, although mobile applications are acknowledged as powerful tools for fostering creativity and productivity in learning, there is a call for a shift from infrastructure-led to learner-led solutions (Stevenson et al., 2015), implying a gap in institutional awareness of how to strategically leverage these tools for holistic benefits, including their environmental footprint. This suggests that without a clear articulation of comprehensive benefits beyond immediate pedagogical gains, the full potential of smart green computing may not be realized.

The integration of educational technologies within HE can be hampered by an insufficient awareness of their broader benefits, extending to green ICT. While university students readily engage with online learning management systems like Moodle to facilitate flipped learning, perceiving benefits in promoting a learner-centred environment (Jeong, 2017) and engineering students frequently utilize smart technologies aligning with their preferred learning styles (Chowdhury, 2015) the focus often remains on direct pedagogical outcomes. This narrow perception can overshadow the wider advantages of green ICT as long-term cost savings, reduced environmental impact and enhanced resource efficiency. Consequently, a lack of comprehensive awareness among educators and administrators regarding these deeper benefits can impede strategic decisions that prioritize and invest in truly sustainable technological adoptions within the educational ecosystem.

Crucially, the behavioural intention to adopt green ICT in Malaysian HEI is directly influenced by the level of awareness among educated individuals. Research explicitly demonstrates that perceived usefulness, perceived ease of use and environmental awareness are significant positive predictors of green ICT adoption (Al-Madhagy et al., 2015). This highlights that if students, faculty and staff are not adequately informed about the tangible advantages and ease of using green ICT or its positive environmental impact, their willingness to embrace such practices will be low. Furthermore, while Generation Z consumers exhibit high expectations for innovative smart technologies in various sectors, they simultaneously emphasize the necessity of training to fully utilize new applications and express scepticism about broader societal implications (Priporas et al., 2017). These collective evidence underscores that a targeted approach to education and awareness campaigns is indispensable to foster a culture that recognizes and values the comprehensive benefits of smart green computing, thereby driving its wider adoption.

To summarize, the integration of smart green computing in Malaysian higher education faces significant hurdles primarily due to inadequate policy frameworks. The absence of clear, explicit guidelines and standardized approaches creates substantial obstacles to its successful implementation and sustained expansion. Therefore, developing formal policies at both institutional and governmental levels is vital. Such policies would establish a supportive environment, encourage engagement and positively influence attitudes and actions toward green ICT, addressing challenges that extend beyond technical capabilities alone.

The article titled “Cloud Computing Data Center Adoption Factors Validity By Fuzzy AHP" (Badie et al., 2015) is categorized under both Theme 1 (Infrastructural Limitations) and Theme 2 (Lack of Policy Support) due to its comprehensive exploration of adoption challenges. It highlights how existing data centres face inherent infrastructural limitations like physical constraints, high energy

consumption and performance issues. Concurrently, the study explicitly identifies that adopting cloud computing is severely hindered by the lack of proper policy and standardization, aligning directly with the defined scope of inadequate policy frameworks.

Furthermore, "Exploring the underlying factors of individual's perception and behaviour towards green IT in Malaysia" written by Al-Madhagy et al. (2015) is classified under both Theme 2 and Theme 3 due to their inherent interconnectedness. It directly investigates how factors like Perceived Usefulness, Perceived Ease of Use and Environmental Awareness influence individuals' behavioural intention towards green ICT adoption, explicitly addressing low awareness of green ICT benefits. Furthermore, the study implicitly highlights that the absence of robust institutional policies and strategic frameworks often contributes to this limited awareness as formal support and guidance are crucial for fostering positive perceptions and driving green ICT adoption among individuals.

Table 4. Regional Distribution of Identified Challenges

Region	Infrastructural Limitations	Lack of Policy Support	Low Awareness of Green ICT Benefits
European Union	3	0	2
China	4	0	1
North America	4	0	0
Southeast Asia	1	2	1
Africa	1	0	0
India	1	0	0
Australia	1	0	0
East Asia	0	1	1
United Arab Emirates	0	0	1
Not Specified	1	0	1

Analysis of the thematic patterns presented in Table 4 clearly indicates varying regional profiles for smart green computing adoption challenges. Infrastructural limitations, for instance, stand out as the most pervasive global issue, notably emphasized in studies originating from China (4 studies), North America (4 studies) and the European Union (3 studies), highlighting its widespread nature. Yet, within the specific context of Malaysia, the lack of policy support emerges as a particularly critical barrier. This challenge finds significant focus in Southeast Asia (2 studies), the region encompassing Malaysia, as well as in East Asia (1 study), a striking contrast to its notable absence as a primary theme in research from the European Union, North America, Africa, India and Australia. This distinct regional emphasis strongly implies that inadequate policy frameworks pose a more significant hurdle for Malaysian higher education institutions compared to their global counterparts. Meanwhile, low awareness of green ICT benefits, though less dominant, remains a consistent concern across diverse settings, including Southeast Asia (1 study), China (1 study), and the European Union (2 studies), underscoring its relevance for improving understanding, particularly in Malaysia.

4. Conclusion

In conclusion, infrastructural limitations critically impede smart green computing adoption in Malaysian HE. These challenges encompass insufficient computational capacity, unreliable power and insecure network protocols. Issues with cloud integration, big data management and the crucial need for robust, user-friendly end-user infrastructure collectively demand substantial investment for sustainable digital transformation within these institutions.

Beyond infrastructural concerns, a critical barrier to smart green computing adoption in Malaysian HE is the widespread lack of comprehensive policy support. The absence of clear institutional guidelines and formal frameworks resulting in hindering successful project implementation and standardization. Consequently, effective policy development is essential to incentivize green ICT practices, foster positive perceptions and create an enabling environment that extends beyond individual awareness.

Compounding these challenges, low awareness of green ICT benefits critically impedes smart green computing adoption in Malaysian higher education. Stakeholders often overlook the sustainable aspects, focusing narrowly on immediate gains. This limited understanding, coupled with insufficient information and training, ultimately hinders behavioural intention to adopt. As a result, targeted awareness campaigns are essential to foster appreciation for green ICT's comprehensive advantages, thereby accelerating its wider adoption across Malaysian higher education.

This paper aims to explore and analyse the key challenges hindering the adoption of smart green computing in Malaysian HEI through a comprehensive thematic analysis guided by the PRISMA framework and successfully identify and classify three main themes of infrastructural limitations, lack of policy support and low awareness of green information and communication technology (ICT) benefits. By synthesizing existing literature, this study effectively bridged the gap between sustainability goals and technological advancement in academia. The findings thus provide valuable insights for policymakers, university administrators and researchers, guiding them in developing effective and environmentally responsible ICT strategies for higher education institutions in Malaysia.

Despite its thoroughness, this systematic literature review has a few limitations. Primarily, it only included articles from the Scopus and Web of Science (WoS) databases, meaning some relevant studies from other sources or unpublished works might have been missed. Secondly, only English-language journal articles published between 2015 and 2025 were considered. This might have excluded important research in other languages or foundational studies published before 2015, introducing a potential linguistic and time-based bias. Lastly, while the review identified global challenges, it couldn't specifically assess how these challenges uniquely impact Malaysian higher education. That would require direct, on-the-ground research, which was beyond the scope of this review.

Based on these findings, several areas for future research emerge. First, it's recommended to conduct empirical studies (quantitative or qualitative) specifically within Malaysian HEI. These studies could directly verify the challenges identified, such as the extent of infrastructure limitations, the influence of policy gaps and the actual level of green ICT awareness among students, faculty and administrators. Second, future research could focus on creating and evaluating specific solutions. This might involve developing custom policy frameworks, launching awareness campaigns or piloting smart green computing projects to address these challenges in Malaysian HEIs. Finally, comparative studies between Malaysian institutions and those in other developing nations facing similar adoption barriers could offer valuable insights into effective strategies and adaptable solutions from different contexts.

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THE INFLUENCE OF GENERAL MANAGER'S MOTIVATION AND POLICY ON GUEST RESIDENCE INCREASE AT THE ASTON PLUIT JAKARTA HOTEL

David Gordon Tambunan, Dian Purnama Sari*

Management, Sukma College of Management Sciences, Medan, North Sumatra, Indonesia

*Corresponding author e-mail address: dianpurnama047@gmail.com

Abstract

The aim of this study was to explore how employee motivation and the general manager's policies influence the increase in guest visits at Aston Pluit Hotel Jakarta. The research was conducted at Aston Pluit Hotel Jakarta, involving a total of 55 employees as respondents. The sample was chosen using a probability sampling method, specifically through random sampling. This study focused on two independent variables motivation and general manager policies and one dependent variable, namely guest increase. Data were collected through questionnaires measured on a Likert scale ranging from 1 to 5. The data analysis was carried out using multiple linear regression to assess both the partial and simultaneous influence of the independent variables, employing t-tests and F-tests, respectively. The data processing was conducted using SPSS version 26. The results showed a coefficient of determination (R^2) of 0.788, meaning that 78.8% of the variation in guest increases could be explained by motivation and general manager policies. The remaining 21.2% was attributed to other factors not examined in this study. Further analysis revealed that both motivation and general manager policies had a positive and significant individual (partial) effect, as well as a joint (simultaneous) positive impact on the increase in guests.

Keywords: Motivation; General Manager Policy; Guest Improvement.

1. Introduction

The hospitality industry is one of the key sectors supporting the development of tourism and the economy in Indonesia. Jakarta, as the nation's capital, serves as both a business hub and a destination for domestic and international travelers. According to data from the Central Statistics Agency (BPS), the number of star-rated hotels in DKI Jakarta continues to increase, reaching more than 300 units in 2023. Competition has become increasingly intense due to the presence of various accommodation options such as serviced apartments and online platforms like Airbnb, which offer price flexibility and complete home-like facilities. This situation requires every hotel to develop the right strategies to maintain occupancy rates, particularly from the long-stay guest segment.

An interesting phenomenon that has emerged recently is the shift in consumer lifestyle driven by technological advancements and increasingly flexible work patterns. Concepts like remote working and digital nomadism have become global trends, including in Indonesia. Many professionals can now work from anywhere, leading them to seek accommodations that are not only comfortable for rest but also support work productivity. This trend creates new opportunities for the hospitality industry: attracting guests who stay for longer periods, also known as guest residences. These guests usually stay for business projects, training, temporary relocation, or simply to find a new working environment outside their home.

However, this opportunity also comes with significant challenges. Long-stay guests have higher expectations compared to regular guests. They do not only consider price but also the

completeness of facilities, such as a stable internet connection, the availability of a comfortable workspace, flexible housekeeping services, and varied dining options. Several hotels in Jakarta have adapted by offering more affordable long-stay packages, adding amenities such as kitchenettes, and providing co-working spaces. Some hotels even offer discounts of up to 30% for stays of at least seven nights, complete with complimentary laundry services and gym access.

As a star-rated hotel strategically located in the Pluit area, close to the port and with access to Soekarno-Hatta International Airport, Aston Pluit has great potential to attract this guest segment. However, industry data shows that long-stay occupancy rates remain volatile. Some guests opt to move to alternative accommodations because they feel the facilities provided do not fully meet their needs.

Two key factors that can influence a hotel's success in attracting and retaining guest residences are employee motivation and the policies of the General Manager. In the hospitality industry, excellent service is the main competitive advantage, which depends heavily on the employees who interact directly with guests. According to Herzberg's Two-Factor Theory, work motivation is influenced by motivator factors (recognition, opportunities for growth, responsibility) and hygiene factors (salary, working conditions, company policies). Motivated employees will provide the best service friendly and responsive creating positive guest experiences. Conversely, a lack of motivation can lower service quality, ultimately affecting guest satisfaction and their decision to extend their stay.

The role of the General Manager is highly strategic in setting the hotel's policy direction. Policies related to pricing, additional facilities, loyalty programs, and personalized services can become differentiators in a competitive market. General Managers who can read market needs typically implement adaptive policies, such as offering discounts for long-stay packages, providing private workspaces, and even free shuttle services to nearby business locations. These policies not only attract new guests but also increase the retention of existing ones.

Research conducted by Anggraini and Ermawati (2024) The findings indicates that a democratic leadership style has a significant impact on positive relationship with employee work motivation and service quality at the Horaios Malioboro Hotel. Priyadi et al. (2022) found that work motivation and leadership have a significant effect on employee job satisfaction at the COMO Uma Canggu Hotel. Previous research supports the assumption that managerial policies and employee motivation play an important role in improving hotel performance. Although there are several studies that discuss the effect of work motivation and leadership on employee performance, there are still few studies that specifically examine the relationship between general manager policies, employee motivation, and increasing the number of guests at the hotel.

2. Methodology

This research was carried out at Aston Pluit Hotel Jakarta during the period of May to June 2024. The data collected comprised both primary and secondary sources. Primary data were obtained directly through interviews, observations, and questionnaires distributed to hotel employees. Secondary data were obtained from relevant company records, books, and journals. Data collection methods include documentation studies from the company, questionnaires to respondents, direct observation at the hotel, and library research through journals, theses and books. The study population was 122 hotel employees, the study involved a sample of 55 respondents taken using the Slovin formula. Data analysis was carried out using quantitative descriptive methods and multiple linear regression.

3. Results and Discussion

3.1 Validity Test

The validity test was conducted to assess the accuracy and appropriateness of the research instrument. An instrument is considered valid if the calculated correlation value (r count) is equal to or greater than 0.266. The results of the validity test for each research variable are presented as follows:

Table 1 Validity of Motivation Variable Instrument (X1)

Instrument	Validity Value		Description
	rhitung	Rtable	
Motivation1	0.578		valid
Motivation2	0.655		valid
Motivation3	0.744		valid
Motivation4	0.406		valid
Motivation5	0.544		valid
Motivation6	0.423		valid
Motivation7	0.577		valid
Motivation8	0.409		valid
Motivation9	0.574	0.266	valid
Motivation10	0.497		valid
Motivation11	0.668		valid
Motivation12	0.608		valid
Motivation13	0.464		valid
Motivation14	0.602		valid
Motivation15	0.555		valid
Motivation16	0.716		valid
Motivation17	0.493		valid

Based on Table 1, it can be seen that all items in the motivation variable have an r count value ≥ 0.266. This indicates that each statement used to measure the motivation variable is valid and suitable for use in this study.

Table 4.2 Validity of the General Manager Policy Variable Instrument (X2)

Instrument	Validity Value		Description
	rhitung	Rtable	
GM Policy1	0.545		valid
GM Policy2	0.586		valid
GM Policy3	0.459		valid
GM Policy4	0.771		valid
GM Policy5	0.694		valid
GM Policy6	0.428		valid
GM Policy7	0.824		valid
GM Policy8	0.717		valid
GM Policy9	0.688	0.266	valid
GM Policy10	0.701		valid
GM Policy11	0.516		valid
GM Policy12	0.499		valid
GM Policy13	0.767		valid
GM Policy14	0.691		valid
GM Policy15	0.746		valid
GM Policy16	0.579		valid

Referring to Table 2, the test results show that all items related to the general manager policy variable have an r count value ≥ 0.266. This means that each statement used to measure this variable is valid and appropriate for use in the research.

Table 3. Validity of Guest Increase Variable Instrument (Y)

Instrument	Validity Value		Description
	rhitung	Rtable	
Guest Increase1	0.705	0.266	valid
Guest Increase2	0.642		valid
Guest Increase3	0.658		valid
Guest Increase4	0.702		valid
Guest Increase5	0.697		valid
Guest Increase6	0.743		valid
Guest Increase7	0.711		valid
Guest Increase8	0.706		valid
Guest Increase9	0.604		valid
Guest Increase10	0.794		valid
Guest Increase11	0.665		valid
Guest Increase12	0.643		valid
Guest Increase13	0.736		valid
Guest Increase14	0.773		valid

From Table 3, it can be seen that the testing of each guest increases the variable instrument (Y) has an r count ≥ 0.266, concluding that overall, the guest increase variable instrument used is valid.

3.2 Reliability Test

A reliability test was conducted to ensure that the research instrument produces consistent and stable results when used repeatedly over time. An instrument is considered reliable if it has a Cronbach's Alpha value of ≥ 0.60. The results of the reliability test are presented as follows:

Table 4.4. Reliability Results

No	Variables	Cronbach's Alpha	Decision
1	Motivation (X1)	0.857	Reliable
2	General Manager Policy(X2)	0.906	Reliable
3	Guest Increase(Y)	0.912	Reliable

The results of the reliability test indicate that the Cronbach’s Alpha values for all variables exceed 0.60. This suggests that the questionnaire used in this study is reliable and capable of producing consistent measurements.

3.3 Partial Test (t-Test)

A partial test is carried out to examine the effect of each independent variable on the dependent variable individually. This test uses the t-test statistic, where the decision is made by comparing the significance value (Sig. t) to the alpha level of 0.05, as well as comparing the t-count with the t-table value. The following criteria serve as the basis for drawing conclusions.

Table 4.5. Partial Test Results

Coefficients a						
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,770	4,557		.608	.546
	Motivation	.444	.111	.452	3.993	.000
	GM Policy	.369	.087	.477	4.221	.000

Note. a. Dependent Variable: IncreaseVisitor

For the motivation variable, the t-count value of 3.993 is greater than the t-table value of 2.006, and the significance value of 0.000 is less than the alpha level of 0.05. Based on these results, H_0 is rejected and H_1 is accepted. This indicates that motivation has a positive and significant partial effect on the increase in guest numbers.

Meanwhile, for the general manager policy variable, the t-count value is 4.221, which is also greater than the t-table value of 2.006, and the significance value is 0.000, which is below 0.05. Thus, H_0 is rejected and H_1 is accepted, meaning that the general manager's policy also has a positive and significant partial effect on the increase in guest numbers.

3.4 Simultaneous Test (F Test)

Simultaneous testing is conducted to determine the influence of several independent variables simultaneously on one dependent variable, the basis for decision making.

Table 4.6. Simultaneous Test Results

ANOVA						
Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1480.139	2	740,070	96,620	.000b
	Residual	398,297	52	7,660		
	Total	1878.436	54			

Note. a. Dependent Variable:Guest IncreaseGuests

b. Predictors: (Constant),GM Policy, Motivation

Based on the table above, the F-count value of 96.620 is greater than the F-table value of 3.18, and the significance value of 0.000 is less than the alpha level of 0.05. These results indicate that H_0 is rejected and H_3 is accepted. Therefore, it can be concluded that motivation and the general manager's policy simultaneously have a positive and significant effect on the increase in guest numbers at Aston Pluit Hotel Jakarta.

3.5 Multiple Linear Regression Analysis

This test was carried out to examine the influence of motivation and the general manager's policy on guest increase at Aston Pluit Hotel Jakarta. The following table presents the results of the multiple linear regression analysis for each variable:

Table 4.7. Multiple Linear Regression Results

Coefficients a				
Model	Unstandardized Coefficients	Standardized Coefficients	t	Sig.

		B	Std. Error	Beta		
1	(Constant)	2,770	4,557		.608	.546
	Motivation	.444	.111	.452	3.993	.000
	GM Policy	.369	.087	.477	4.221	.000

Note. a. Dependent Variable: IncreaseVisitor

Based on the results of the test above, the following multiple linear regression equation was derived:

Y= 2.770+0.444X1+0.369X2

In the multiple linear regression model, the constant value for the guest increase is 2.770. This means that if both independent variables motivation and general manager policy are assumed to be zero, the baseline value of the guest increase would be 2.770. Furthermore, the regression coefficients for both independent variables are positive, indicating that improvements in employee motivation and the general manager's policy contribute positively to the increase in guest numbers at Aston Pluit Hotel Jakarta.

3.6 Coefficient of Determination

The coefficient of determination (R^2) is used to measure how well the regression model explains the variation in the dependent variable. The value ranges from 0 to 1, where a value closer to 1 indicates a stronger influence of the independent variables on the dependent variable. The results of the R^2 analysis are shown in the table below.

Table 4.8. Determination Coefficient Results

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.888[a]	.788	.780	2,768

Note. a. Predictors: (Constant),GM Policy, Motivation

b. Dependent Variable:Guest Increase

The coefficient of determination (R^2) obtained was 0.788 or 78.8%, indicating that motivation and the general manager's policies collectively explain 78.8% of the variation in the increase in guest numbers at Aston Pluit Hotel Jakarta. The remaining 21.2% is attributed to other factors beyond the scope of this study, such as leadership style, work environment, and other external variables.

From the results of the study above, we can see that the increase in guests at the Aston Pluit Hotel Jakarta can be influenced by motivation variables and also the general manager's policies. This can be input for the company to maintain the motivation and policies of the existing general manager, but it is also important to continue to improve it to a better level. This supports earlier studies that found high work motivation has an impact on improving the performance of front office employees, which in turn increases guest satisfaction and has an impact on increasing the number of guests who return to stay at the XYZ Hotel Jakarta (Indriani, 2020). The results of previous research conducted by Nugroho (2021) stated that strategic policies from the general manager, such as guest loyalty programs, providing seasonal discounts, and improving services, have a significant effect on increasing room occupancy and the number of guests at Five-Star Hotels in Jakarta. Other research results according to Wulandari (2022), at a Four-Star Hotel in South Jakarta in terms of both employee motivation and managerial leadership style (in the form

of policies, approaches, and service decisions) have a simultaneous effect on guest loyalty, which has an impact on increasing the number of returning guests.

4. Conclusion

Based on the results of testing and data analysis obtained by the author regarding the motivation and policies of the general manager towards increasing guests at the Aston Pluit Hotel Jakarta, it can be concluded that the results of the first hypothesis test show that the motivation and policies of the general manager are able to influence the increase in guests at the Aston Pluit Hotel Jakarta, as evidenced by the coefficient of determination (R2) value obtained of 78.8%.

The results of the second hypothesis test show that simultaneously the F-count value of 96,620 ≥ the F-table value of 3.18 and the significant value of 0.000.≤from alpha 0.05 and partially the t-value for the motivation variable 3.993 ≥ t-table 2.006 and the significant value 0.000≤from alpha 0.05 (5%) and the calculated t value for the general manager policy variable 4.221 ≥ t table 2.006 and a significant value of 0.000≤from alpha 0.05 (5%) so that motivation and general policies are able to provide a positive and significant influence on increasing guests at the Aston Pluit Hotel Jakarta.

Hotel Aston Pluit should focus on optimizing attractive long-stay packages, such as offering progressive discounts and additional services like complimentary laundry, gym access, and breakfast for specific periods. Productivity-supporting facilities should also be enhanced by providing rooms equipped with kitchenettes, ergonomic workspaces, and co-working areas with high-speed internet access to align with the current trend of flexible work arrangements. The implementation of personalized services and adaptive policies is essential to increase guest loyalty. The hotel can introduce loyalty programs, welcome packages, and flexible pricing policies for long-stay guests, along with partnerships with companies that require long-term accommodation. Employee motivation should also be improved through service excellence training, performance-based incentives, and career development support. Leveraging technology is another key strategy, such as implementing an internal service booking application and utilizing guest data analysis to create a more personalized and efficient experience.

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THE INFLUENCE OF BRAND IMAGE ON BUYING INTEREST AT D'GRAND SM RAJA

Jeffri Mulia[1], **Anggia Arif** [2]*

[1]Management,Study Program, Stim Sukma Medan,Indonesia

[2]International Marketing Management,Study Program, Cendana Polytechnic,Medan,Indonesia

*Corresponding author e-mail address: arifanggia13@gmail.com

Abstract

This study aims to determine how brand image influences Purchase Intention at D'Grand SM Raja. The subjects of this study were residential consumers at D'Grand SM Raja. The population in this study was unknown and the sample was 110 people from the population with a sampling technique using census sampling. With the realization of consumer decisions, the company's hopes will continue to exist and grow easily. The achievement of image improvement can lead to a decision by consumers and consumers who have made a purchase will tell the experience to others, so that it is likely to attract new consumers. Data collection techniques used questionnaires, documentation, and observation, where the research method used is a quantitative method. Based on the t-test, the value obtained is 0.687. The significance value for the Purchase Intention variable is 0.000, meaning that this variable has a significant effect on the level of consumer satisfaction, where the significance value is <0.05. Therefore, it can be concluded that Brand Image influences Purchase Intention at D'Grand SM Raja.
Keywords: Brand Image; Purchase Intention; Consumer Behavior.

1. Introduction

Every company today is required to know its market and consumers as much as possible in order to successfully compete in the business world. Competition is getting tighter, where more and more companies are involved in fulfilling consumer needs and desires. The choice, especially for companies to continue to exist, requires them to better understand consumer needs to decide to buy the company's services. The importance of knowing consumer decisions will make it easier to gain profits for the company.

Decision making is making an assessment and making a choice. Decisions are made after going through several alternative calculations. Making decisions with knowledge, experience, and data obtained or collected is very important in determining Purchase Interest. The factors that influence decisions are: cultural, social, personal and psychological factors Decision making is making an assessment and making a choice. Decisions are made after going through several alternative calculations. Making decisions with knowledge, experience, and data obtained or collected is very important in determining Purchase Interest. The factors that influence decisions are: cultural, social, personal and psychological factors (Kotler and Keller, 2017).

D'Grand SM Raja is a company engaged in the construction and sale of housing. Driven by the same desire to advance in realizing dreams as young entrepreneurs who can participate in driving the wheels of the economic development of the Republic of Indonesia, we then with a joint initiative to form a company organization called "D'Grand SM Raja". The target market for this

housing is consumers with middle to upper income from young people and decision makers. The developer provides a different concept in offering housing products where the cluster concept is equipped with large garden facilities. Although the price offered is relatively expensive, the quality of the house design and the advantage of access are added values offered by the developer. However, the various attractions given to buyers were not responded to well by the market, this can be seen from the housing sales target which always decreases every year, and the sales figures have decreased drastically in the last six months, as seen in Table 1.1 below

Table 1. Sales Targets and Actual Units Sold at D'Grand SM Raja in the Last Six Months of 2024

Month	Sales Target (Unit)	Number Sold (Unit)
July	15	5
August	19	6
September	20	11
October	20	12
November	21	9
December	22	8

The data above shows that the level of the number of housing offered and sold at D'Grand SM Raja in July 2024, which had a sales target of 15 units and only 4 housing units were sold. In August 2024, the sales target increased to 19 units and only 6 housing units were sold. In the following month, September, the sales target became 20 units and 11 housing units were sold. Furthermore, in October, the sales target remained at 20 and 12 housing units were sold. In November, with a sales target of 21 units, the number of housing units sold was 9 housing units. And the last month in 2024, with a sales target of 22 and the number of units sold was only 8 housing units.

Sales are closely related to Purchase Interest. In the concept of sales, consumers buy a product because of various considerations that are adjusted to the conditions and character of the consumer. The decline in home sales in the D'Grand SM Raja housing complex was caused by various factors. In general, it is divided into 2 (two) factors, namely internal factors such as marketing mix, segmentation policy, target market and positioning. External factors are influenced by the level of competition, economic conditions, and market trends. In this study, the factors that cause the decline in sales are seen from internal factors which are part of the marketing mix, namely products, prices, facilities, location and environment.

The results of the study (Fauziah and Mubarok, 2019) with the research title "The Influence of Brand Image on Purchase Interest: A Study on Beauty Products" stated that the results of the study explain that brand image influences consumer purchase interest. (Veronika, 2016) in a study entitled The Influence of Advertising and Brand Image on Consumer Purchase Interest, with Brand Trust as a Mediating Variable, the results of her study stated that Brand Image has a positive effect on Purchase Interest of Dove shampoo in Yogyakarta.

The achievement of image improvement can lead to a decision by consumers and consumers who have made purchases will tell the experience to others, so that it is likely to attract new consumers. Based on the description of the problems above, the author is interested in conducting a study with the title "The Influence of Brand Image on Purchase Interest at D'Grand SM Raja".

2. Methodology

2.1 Research Framework

In this study, the data collection technique used was a questionnaire, which is a data collection technique carried out by giving a set of written questions or statements to respondents to be answered according to the circumstances, conditions, reality, or facts that actually occur. In this study, the respondents were 238 Prospect Custommer D'Grand SM Raja.

2.2 Identification of Research Variables

The types of data used in this study are primary data and secondary data. The primary data in this study are all Prospect Customers who save at D'Grand SM Raja who fill out the research questionnaire. While the secondary data of this study are in the form of theoretical books used to support the research. The data sources in this study are internal data sources, namely data and organizational structure of this company, and data sourced from the company.

Population is a generalization area consisting of objects/subjects that have certain quantities and characteristics that researchers expect to study and then draw conclusions from (Sugiyono, 2017).

The population in this study is Prospect Custommer who has the potential to buy a house through D'Grand SM Raja, as many as 110 Prospect Custommer. This study uses the Census Sampling type, where the author takes the entire population in this study as a research sample.

2.3 Operational Research Variables

Table 2. Operational Definition of Research Variables

No	Variable	Operational definition	Indicator
1.	Brand Image (X)	the results of observations about brands as a form of replication of customer relationships with brands that are held within themselves. (Kotler and Keller, 2017)	a. Recognition b. Reputation c. Affinity loyalty d. Domains
2.	Purchase Interest (Y)	Purchase interest is the tendency of consumers to buy a brand or take action related to a purchase which is measured by the level of likelihood of consumers making a purchase (Lin, & Hsiung in (Ningrum and Nilowardono, 2016)	a. Attention b. Interest c. Desire d. Action

2.4 Brand Image

The definition of a brand according to (Kotler and Keller, 2017), is a name, term, sign, symbol or design, or communication of these attributes that identify the maker or group of sellers and differentiate them from their competitors, while brand image is the public's perception of a company or its products. The image can be formed through stimuli that come from outside as a touching message or what is called information received by someone.

2.5 Purchase Interest

Purchase interest is considered as a measurement of the possibility of consumers buying a particular product, where a high purchase interest will have an impact on the possibility of a fairly large Purchase Interest. Considering what methods consumers

2.6 Research result

2.6.1 Validity Test Results

Validity test is conducted by using the correlation between each statement item score and with total score. The correlation value obtained (rcount) is compared with (rtable). If rcount> rtable at a certain level of confidence, then it is concluded that the instrument meets the criteria. validity so that the item is declared valid. With the degree of freedom (df) in this study is 100 and a significance level of 5%, the rtable is obtained, namely 0.175. The results of the data validity test are as follows:

i. Product

Based on the test results, it can be seen that 8 product variable statement items have a greater rcount value than rtable, so all statement items are considered valid and can be used in this study (Ghozali, 2018b).

Table 3. Results of Brand Image Validity Test (X1)

Statement Items	r_{hitung}	r_{tabel}	Information
1	0,644	0,175	Valid
2	0,731	0,175	Valid
3	0,611	0,175	Valid
4	0,737	0,175	Valid
5	0,677	0,175	Valid
6	0,790	0,175	Valid
7	0,738	0,175	Valid
8	0,533	0,175	Valid

ii. Purchase Interest

Based on the test results, it can be seen that 10 Purchase Interest variable statement items have a greater rcount value compared to rtable, so all statement items are considered valid and can be used in this study.

Table 4. Purchase Interest Validity Test Results (Y)

Statement Items	r_{hitung}	r_{tabel}	Information
1	0,456	0,175	Valid
2	0,662	0,175	Valid
3	0,172	0,175	Tidak Valid
4	0,779	0,175	Valid
5	0,762	0,175	Valid
6	0,726	0,175	Valid
7	0,684	0,175	Valid
8	0,644	0,175	Valid
9	0,680	0,175	Valid
10	0,724	0,175	Valid

2.7 Correspondent characteristics

2.7.1 Gender

Description of respondent characteristics based on gender is presented in the table below:

Table 5. Respondent Characteristics Based on Gender

Gender	Frequency	Percentage (%)
Male	85	77,3%
Female	15	13,7%
Number	110	100%

The table above shows that there are 85 male respondents (77.3%) and 15 female respondents (13.7%). This shows that the majority of respondents are male, 85 people (77.3%).

2.7.2 Age

Description of respondent characteristics based on age is presented in the table below:

Table 6. Respondent Characteristics Based on Age

Age	Frequency	Percentage (%)
20-25 years	5	4,5%
26-30 years	10	9,1%
31-40 years	65	59,1%
>40 years	30	27,2%
Number	125	100

The table above is divided into 4 age categories which show that respondents aged between 20-25 years, namely 5 people (4.5%), respondents aged between 26-30 years, namely 10 people (9.1%), respondents aged between 31 - 40 years, namely 65 people (59.1%), and respondents aged >40 years, namely 30 people (27.2%). This data shows that the majority of respondents are aged 28-32 years, namely 76 people (60.8%).

2.7.3 Last Education

Description of respondent characteristics based on the last education used is presented in the table below:

Table 7. Respondent Characteristics Based on Last Education

Education	Frequency	Percentage (%)
SMA	30	27,3%
D3	2	1,8%
S1	70	63,6%
S2	7	6,4%
S3	1	0,7%
Number	125	100%

The table above shows that respondents with high school education level were 30 people (27.3%), respondents with D3 education level were 2 people (1.8%), respondents with S1 education level were 70 people (63.6%), respondents with S2 education level were 7 people (6.4%), and respondents with S3 education level were 1 person (0.7%). It can be concluded that the majority of respondents with S1 education level were 70 people (63.6%).

2.7.4 Income

Description of respondent characteristics based on income is presented in the table below:

Table 8. Respondent Characteristics Based on Income

Income	Frequency	Percentage (%)
<Rp3.000.000,00	3	2,8%
Rp3.000.000,00-Rp5.000.000,00	26	23,6%
Rp5.000.000,00-Rp10.000.000,00	50	45,4%
>Rp10.000.000,00	31	28,2%
Number	125	100

The table shows that respondents with income less than Rp3,000,000.00 are 3 people (2.8%), respondents with income between Rp3,000,000.00- Rp5,000,000.00 are 26 people (23.6%), respondents with income between Rp5,000,000.00-Rp10,000,000.00 are 50 people (45.4%), and respondents with income more than Rp10,000,000.00 are 31 people (28.2%). This shows that the majority of respondents with income between Rp5,000,000.00-Rp10,000,000.00 are 50 people (45.4%).

2.7.5 Occupation

Description of respondent characteristics based on occupation is presented in the table below:

Table 9. Respondent Characteristics Based on Occupation

Income	Frequency	Percentage (%)
PNS	1	0,9%
Private Employee	46	41,8%
Self-Employed	58	52,7%
Other	5	4,5%
Number	110	100

The table above shows that respondents consist of 5 types of jobs, namely working as a civil servant as many as 1 person (0.9%), respondents who work as private employees as many as 46 people (41.8%), respondents who work as self-employed as many as 52 people (52.7%), respondents with other jobs as many as 5 people (4.5%). It can be concluded that the majority of respondents with jobs as self-employed as many as 58 people (52.7%).

3. Results and Discussion

3.1. Data Analysis Results

a. Normality Test

The normality test aims to praise one of the basic assumptions of simple regression analysis, namely that the independent and dependent variables must be normally distributed or close to normal (Ghozali, 2018a).

Table 10. Normality Test Results

One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		125
Normal Parameters[a,b]	Mean	,0000000
	Std. Deviation	3,65002324
Most Extreme Differences	Absolute	,047
	Positive	,029
	Negative	-,047
Test Statistic		,047
Asymp. Sig. (2-tailed)		,200[c,d]

Note. a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

The results of the normality test show that the sig. value of 0.200 has a significance value greater than 0.05 at (0.200>0.05), so it can be concluded that the research data is normally distributed.

b. Linearity Test

The Linearity test also aims to determine whether there is a linear relationship or not significantly. This test is used to see whether the model specifications used are correct or not (Ghozali, 2018a).

Table 11. Linearity Test Results

ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Minat Beli * Citra Merek	Between Groups	(Combined)	1100,487	20	55,024	4,220	,000
		Linearity	804,661	1	804,661	61,706	,000
		Deviation from Linearity	295,826	19	15,570	1,194	,258
	Within Groups		1356,185	104	13,040		
	Total		2456,672	124			

The results of the linearity test in the table above show that the sig. deviation from linearity value has a significance value of 0.258 which is greater than 0.05 (0.258>0.05), this indicates that all research variables are linear.

3.2 Hypothesis Test Results

3.2.1 Simple Linear Regression

Based on the results of data processing through data processing software, the following results were obtained:

Table 12. Simple Linear Regression Test Results

Coefficients[a]

Model	Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.

´ (Constant)	12,378	2,381		5,534	,000
Citra Merek	,687	,076	,572	7,740	,000

Note. a. Dependent Variable: Minat Beli

Based on the table above, it can be seen that the regression equation formed is:

$$Y = a + bX$$
$$Y = 12{,}378 + 0{,}687x$$

Description:
Y = dependent variable
a = constant
b = regression coefficient

From the equation, it can be explained that the Brand Image variable has a positive coefficient direction towards Purchase Interest:

i. The constant of 12.378 states that if there is no X then the product quality is 0.687.
ii. The Product Quality Coefficient gives a value of 0.867 which means that if the Product Quality is getting better then consumer satisfaction will increase.

3.2.2 t- Test Results

The t-test is used to determine the effect of independent variables partially, shown in the Coefficients Table below:

Table 13. t-Test Results

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	12,378	2,381		5,534	,000
	Citra Merek	,687	,076	,572	7,740	,000

Note. a. Dependent Variable: Minat Beli

Based on the Unstandardized coefficients B value for the Brand Image variable, it affects Purchase Interest by 0.687. This result is positive, meaning that the better the Brand Awareness, the greater the level of Purchase Interest. The significance of the influence of the independent variable on the dependent variable can be seen from the Sig value in the last column. The significance value for the Purchase Interest variable is 0.000, meaning that this variable has a significant effect on the level of consumer satisfaction, where the significance value is <0.05, so the conclusion is that Ha is accepted, namely Brand Image has a significant effect on Purchase Interest.

3.2.3 Test the Determinant Coefficient (R2)

The coefficient of determination is a quantity that shows the magnitude of the variation of the dependent variable that can be explained by the independent variable. This coefficient of determination is used to measure how far the independent variable explains the dependent variable. The value of the coefficient of determination is determined by the R square value as can be seen in the table below.

Table 14. Results of Determination Coefficient Test

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,572[a]	,476	,322	3,665

Note. a. Predictors: (Constant), Citra Merek
a. Dependent Variable: Minat Beli

The results of the regression calculation show that the coefficient of determination (R2) obtained is 0.476. This means that 47.6% of the variation in the Purchase Interest variable can be explained by the Brand Image variable, while the remaining 52.4% is explained by other variables not proposed in this study.

3.3 Discussion

The results of the study indicate that the Brand Image variable obtained a t-value of 0.597 with a significance value of 0.000 smaller than 0.05 (0.000 <0.05), and the regression coefficient has a positive value of 0.687; so this study proves the alternative hypothesis which states that "There is a positive influence of Brand Image on Purchase Interest at D'Grand SM Raja". Furthermore, it is known that the coefficient of determination (R2) value obtained is 0.476. This means that 47.6% of the variation in the Purchase Interest variable can be explained by the Brand Image variable, while the remaining 52.4% is explained by other variables not proposed in this study.

The results of this study support previous research conducted by (Fauziah and Mubarok, 2019) with the research title The Influence of Brand Image on Purchase Interest: Study on Beauty Products, which shows that brand image significantly influences purchase interest. The theoretical implication of this study is that brand image influences purchase interest with a very strong (positive) and unidirectional relationship, namely the calculated t of 7.109 is greater than the t table of 2.017 and the significance value of 0.000 is smaller than the confidence level α = 5 percent (0.05).

4. Conclusion

The conclusion of the research results entitled "The Influence of Brand Image on Purchase Interest at D'grand Sm Raja" is as follows:

i. The Brand Image variable has a positive coefficient direction on Purchase Interest with a value of 0.597, which means that if the Brand Image is getting better, Purchase Interest will increase. The significance value for the product quality variable is 0.000, meaning that this variable has a significant effect on the level of consumer satisfaction, where the significance value is <0.05 so that the conclusion is that Ha is accepted or in other words Brand Image has a significant effect on Purchase Interest.
ii. The results of the regression calculation show that the coefficient of determination (R2) obtained is 0.476. This means that 32.8% of the variation in the Purchase Interest variable can be explained by the Brand Image variable, while the remaining 52.4% is explained by other variables not proposed in this study.

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PRODUCT QUALITY AND SERVICE QUALITY ON CUSTOMER LOYALTY AT PADANG INDONESIA VEGETARIAN RESTAURANT

Zeslina Veronika, Yuliana Yuliana*

International Marketing Management Study Program, Polytechnic Cendana, Medan, Indonesia

*Corresponding author e-mail address: yuliana_njo@yahoo.com

Abstract

This study examines the effect of product and service quality on customer loyalty at Padang Indonesia restaurant. It uses associative quantitative research methods, which are used to examine a specific population or sample and test the hypothesis. The Incidental Sampling technique and the Slovin Formula, with a 10% or 0.1 margin of error, were used to obtain 80 respondents for this study. The research instruments used in the study were validity and reliability tests, normality, linearity, and classical assumption tests. The data analysis techniques used are correlation, coefficient of determination, and multiple linear regression. Using SPSS version 22, the researchers found that the correlation between product quality and customer loyalty is 0.556. The correlation between service quality and customer loyalty is 0.520, which indicates that the variable product quality and customer loyalty have a positive and strong enough relationship, and the variable service quality and customer loyalty have a positive and strong enough relationship. The regression analysis calculation obtains the regression equation Y = 3.662 + 0.487.X1 + 0.357.X2.
Keywords: Product Quality; Service Quality; Customer Loyalty.

1. Introduction

In the era of globalisation and the development of the digital world, many business ventures have begun to experience greater competition. To succeed, food sector companies must aim for a high profit. People's busy lives mean they do not have time to prepare their own food at home and thus prefer ready-to-eat food. Therefore, the food business can be profitable because people must eat daily.

One way a food business can succeed in a competition is to create loyalty and retain customers (F. Sanjaya et al., 2024). To achieve this goal, each company must strive to produce and deliver the goods and services consumers want with appropriate product quality (E. Kusidy et al., 2023), (E. Kusidy et al., 2024). Product quality is one factor known to influence customer loyalty significantly.

Product quality is an important attribute that influences consumer perceptions of a brand or product (Putra, 2022). Product quality is one way to increase competitiveness, but it must be appropriate and meet consumer expectations (F. A. Rizky et al., 2023). In addition, product quality is also an important variable related to service quality.

Service quality includes interactions between businesses and consumers during and after purchase, including speed, responsiveness, reliability, security, and after-sales activities (Liu et al., 2023). Companies conduct service quality activities to meet consumer expectations (Ilahi & Arifuddin, 2022). Previous research shows that consumers who are satisfied with service quality tend to remain loyal to the brand or company.

Customer loyalty is a high level of commitment from customers to make repeat purchases in the market, even in the face of potential influences and marketing efforts that can cause switching behaviour (Halim, 2019).

Product quality and service quality significantly influence the customer loyalty variable (Warganegara & Alviyani, 2020). This means that both product and service quality considerably influence customers to be loyal in purchasing.

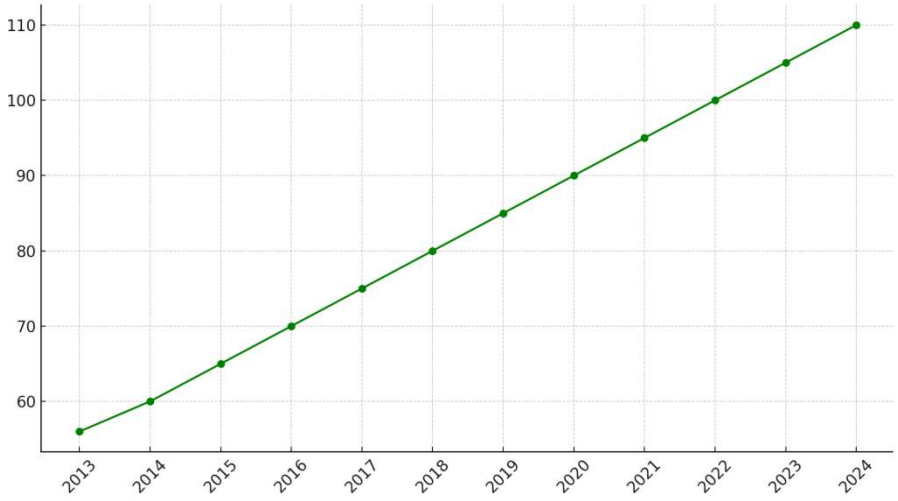


Fig. 1. Growth of vegetarian restaurants in Medan, 2013–2024
(Source: Dini Lestrina et al. (2013) & Data Business Listing from Rentech Digital)

Based on the graph above, from 2013 to 2024, the number of vegetarian restaurants in Medan increased from around 56 to 110, or almost doubled in about a decade. This data also suggests that more and more people are interested in vegetarian food and that vegetarian restaurants have good prospects in the future.

Padang Indonesia Vegetarian CemaraAsri, Medan, or Padang Indonesia Vegetarian Restaurant is located at Jl. Durian No.02, Medan Estate, Kec. Percut Sei Tuan, Deli Serdang Regency, North Sumatra. This restaurant serves a variety of low-priced rice menu items, drinks, and snacks. The name Padang Indonesia Vegetarian is interesting, so it has received much attention from the community. Padang Indonesia Vegetarian has several branches in other cities, including Medan.

Based on interviews, customer loyalty at Padang Indonesia Vegetarian is low. Customers who dined in at Padang Indonesia Vegetarian had numerous complaints. First, they complained that they were not well taken care of and that the food quality was not worth the slightly expensive price. Second, the food served was less varied and not tasty, such as vegetables that were no longer fresh. Third, customers also said that the portion of food was too small, making them less satisfied. Fourth, the food quality cannot last more than one day. Finally, the dish's image in the menu book and the menu served were not always the same. On the other hand, the positive side is that the various kinds of food and drinks at Padang Indonesia Vegetaria do not contain processed products derived from animals.

Based on this phenomenon, the researchers were interested in conducting research entitled "Product Quality and Service Quality on Customer Loyalty Padang Indonesia Restaurant."

2. Methodology

According to Hoy and Adam (2022), quantitative research is a systematic scientific study of parts and phenomena and their relationships. According to M. Y. Balaka (2022), the quantitative research method uses data, namely numbers, emphasising the objective measurement of results. It is accompanied by statistical analysis/numbers used in statistical analysis from an objective scale to measure units of analysis called variables.

In this study, the researchers focus on associative quantitative methods that ask about the relationship between variables or more. They want to know whether there is a relationship between product and service quality and customer loyalty at Padang Indonesia Restaurant.

3. Results and Discussion

3.1 Validity Test

The validity test aims to see how appropriate the variables used in the study are (H. S. Said et al. 2023, p. 252). A study can be valid if it provides results on what the researchers want to measure. The research results use the following criteria to compare r-count with r-table. If r-count is greater than r-table, then the instrument item can be said to be valid. Table 1 shows the validity test results.

Table 1. Validity Test Results

Product Quality				Service Quality				Customer Loyalty			
No	R-Count	R-Table	Validitas	No	R-Count	R-Table	Validitas	No	R-Count	R-Table	Validitas
1	0,588	0,443	Valid	1	0,492	0,443	Valid	1	0,649	0,443	Valid
2	0,749	0,443	Valid	2	0,545	0,443	Valid	2	0,631	0,443	Valid
3	0,697	0,443	Valid	3	0,563	0,443	Valid	3	0,494	0,443	Valid
4	0,775	0,443	Valid	4	0,741	0,443	Valid	4	0,816	0,443	Valid
5	0,699	0,443	Valid	5	0,764	0,443	Valid	5	0,500	0,443	Valid
6	0,604	0,443	Valid	6	0,617	0,443	Valid	6	0,722	0,443	Valid
7	0,45	0,443	Valid	7	0,658	0,443	Valid	7	0,552	0,443	Valid
8	0,844	0,443	Valid	8	0,762	0,443	Valid	8	0,679	0,443	Valid
				9	0,663	0,443	Valid				
				10	0,479	0,443	Valid				

Based on Table 1, it can be seen that eight items from the product quality variable (X1), service quality (X2) and 10 statement items from the customer loyalty variable (Y) are declared valid because the calculated r value is greater than the r table value.

3.2 Reliability Test

The reliability test aims to see the extent of the consistency of the results of a study when carried out repeatedly (Said et al., 2023, p. 255). The higher the level of reliability, the more reliable the research. The indicator of reliability is when it reaches a minimum of 0.70. With the decision-making criteria, namely if the Cronbach's Alpha coefficient> 0.70, the question is declared reliable or a construct or variable is declared reliable. Conversely, the question is declared unreliable if Cronbach's Alpha coefficient <0.70.

Table 2. Reliability Test Results

Variable	Cronbach's Alpha	N of items	Description
Product Quality (X1)	0,801	8	Reliable
Service Quality(X2)	0,818	10	Reliable
Customer Loyalty(Y)	0,783	8	Reliable

Based on Table 2, Cronbach's Alpha of the product quality variable (X1) is 0.801; Cronbach's Alpha of the service quality variable (X2) is 0.818; and the Cronbach's Alpha of the customer loyalty variable (Y) is 0.783. Thus, all instruments have an Alpha value> 0.70 and can be declared reliable.

3.3 Normality Test

The Normality Test determines whether the data distribution follows or approaches a normal distribution, namely the data distribution with a bell-shaped shape (R. A. Permata et al. 2023, p. 21).

Table 3. Normality Test Results

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		80
Normal Parameters[a,b]	Mean	,0000000
	Std. Deviation	3,95907175
Most Extreme Differences	Absolute	,077
	Positive	,035
	Negative	-,077
Test Statistic		,077
Asymp. Sig. (2-tailed)		,200[c,d]

Note. a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

Table 3 shows the significance of product quality, service quality, and customer loyalty, with a value of 0.200, which is greater than 0.05. This indicates that the data is normally distributed and can be used for further research.

3.4 Multicolonierity Test

The multicolonierity test assesses the correlation between the independent variables in the regression model (Iqlal Muhammad Luthfi & Wijaya, 2024, p. 707).

Table 4. Multicolonierity Test Results

Coefficients[a]			
Model		Collinearity Statistics	
		Tolerance	VIF
1	(Constant)		
	Product_Quality	,706	1,416
	Service_Quality	,706	1,416

Note. a. Dependent Variable: Customer_Loyalty

Table 4 shows that the data does not show symptoms of multicollinearity because the tolerance value of product quality and service quality is 0.706> 0.010, and the VIF value is 1.416 < 10.

3.5 Heteroscedasticity Test

The heteroscedasticity test aims to identify the presence of non-uniform variation of the residual variance between observations in a regression model (Iqlal Muhammad Luthfi and F. Wijaya, 2024). In an ideal regression model, the presence of homoscedasticity indicates the absence of heteroscedasticity.

Table 5. Heteroscedasticity Test Results

Model		Coefficients[a] Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5,120	2,756		1,858	,067
	Product_Quality	-,077	,085	-,121	-,902	,370
	Service_Quality	,008	,079	,014	,103	,918

Note. a. Dependent Variable: ABS

Table 5 shows that the data does not show symptoms of heteroscedasticity because product quality and service quality show a significance value of more than 0.05, which means that the data does not experience symptoms of heteroscedasticity.

3.6 Correlation *Test*

The Correlation test aims to test the amount of correlation between two variables (K. Syafitri & M. Waluyo, 2023, p. 50). This study aims to regress two or more exogenous variables on one or more endogenous variables, so the condition that must be met is that the correlation between exogenous variables is not significant.

Table 6. Colleration Test Results

Correlations

		Product_ Quality	Service_ Quality	Customer_ Loyalty
Product_Quality	Pearson Correlation	1	,542**	,556**
	Sig. (2-tailed)		,000	,000
	N	80	80	80
Service_Quality	Pearson Correlation	,542**	1	,520**
	Sig. (2-tailed)	,000		,000
	N	80	80	80
Customer_Loyalty	Pearson Correlation	,556**	,520**	1
	Sig. (2-tailed)	,000	,000	
	N	80	80	80

Note. **. Correlation is significant at the 0.01 level (2-tailed).

From Table 6, it can be concluded that variable X1 (Product Quality), Variable X2 (Service Quality), and variable Y (Customer Loyalty) are related because the values show a positive relationship. The correlation value (r) of product quality with customer loyalty is 0.556, which

means that product quality has a fairly strong relationship with customer loyalty. The correlation value of service quality with customer loyalty is 0.520, which means that service quality has a fairly strong relationship with customer loyalty.

3.7 Coefficient of Determination Test

Determination Coefficient test R2 is a statistical tool used to measure how well the linear regression model fits the observed data (Agusriadi, 2023, p. 34).

Table 7. Coefficient Test Results

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,614[a]	,377	,361	4,010

Note. a. Predictors: (Constant), Service_Quality, Product_Quality

From the above calculations, it can be seen that the result of the Adjusted R Square = 0,361. To calculate the coefficient of determination, researchers use the formula:

$D = (r)^2 x\ 100\%$
$D = 0{,}361 \times 100\%$
$D = 36{,}1\%$

The results above suggest that product and service quality influence customer loyalty by 36.1%, and other factors not tested in this study, such as purchasing decision factors, influence the remaining 63.9%.

3.8 Multiple Linear Regression Test

Multiple linear regression analysis is used to determine the effect of Product Quality and Service Quality on Customer Loyalty (A. T. Nurani, et al. 2023, p. 40). In addition, regression analysis is also used to test the truth of the hypothesis proposed in the study.

Table 8. Multiple Linear Regression Test Results

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	3,662	4,322		,847	,399
	Product_Quality	,487	,134	,389	3,632	,001
	Service_Quality	,357	,124	,309	2,888	,005

Note. a. Dependent Variable: Customer_Loyalty

Based on the above results, it can be predicted how the value of the dependent variable changes if the value of the independent variable increases or decreases using the formula:

$Y = a + b1.X1 = b2.X2$
$Y = 3.662 + 0.487.X1 + 0.357.X2$

The explanation of the equation is as follows:
From this equation, the constant value is 3.662, which means that if there is no increase in product or service quality, the customer loyalty value will be 3.662. The coefficient of the product quality variable (X1) is 0.487, meaning that every 1-unit increase in product quality will increase customer

loyalty by 0.487. The coefficient of the service quality variable (X2) is 0.357, meaning that every 1-unit increase in service quality will increase customer loyalty by 0.357.

3.9 T-test

The T-test measures whether the independent variable partially affects the dependent variable (F. Ayu Ningrum et al, 2023). It is based on a significance level of 0.05.

Table 9. T-test Results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	3,662	4,322		,847	,399
	Product_Quality	,487	,134	,389	3,632	,001
	Service_Quality	,357	,124	,309	2,888	,005

Note. a. Dependent Variable: Customer_Loyalty

Table 9 shows that the significance value of product quality is 0.001, which means it is smaller than 0.05, and the significance value of service quality is 0.005, which is smaller than 0.05. It can be concluded that the product quality variable (X1) influences the customer loyalty variable (Y), and the service quality variable (X2) influences the customer loyalty variable (Y).

3.10 F-test

The F-test tests the effect of all independent variables together (simultaneously) on the dependent variable (F. Ayu Ningrum et al, 2023).

Table 10. F-test results

ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	749,284	2	374,642	23,297	,000[b]
	Residual	1238,266	77	16,081		
	Total	1987,550	79			

Note. a. Dependent Variable: Customer_Loyalty

b. Predictors: (Constant), Service_Quality, Product_Quality

Based on Table 10, the significance value for the simultaneous influence of X1 and X2 on Y is 0.000 less than 0.05, which means that product quality (X1) and service quality (X2) simultaneously affect customer loyalty (Y).

4. Conclusion

Based on the results of testing and analysis of the influence of product quality and service quality on customer loyalty in Padang Indonesia Vegetarian CemaraAsri, the conclusions that can be drawn are as follows:

i. Product and service quality simultaneously influence customer loyalty, although other factors, such as product price, can also influence it.
ii. Product and service quality positively and significantly influence customer loyalty in Padang Indonesia Vegetarian CemaraAsri. Product and service quality influence 36.1% of customer

loyalty, while 63.9% is influenced by other factors not examined in this study, such as purchasing decisions, product prices, etc.

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REASSESSING THE CURRICULUM RELEVANCE OF HUMAN RESOURCE MANAGEMENT: A MIXED-METHODS NEEDS ANALYSIS FOR FUTURE-READY EDUCATION

Khairul Hafezad bin Abdullah*, Luqman bin Mahmud

Human Resource Management Programme, School of Business Management, Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia

*Corresponding author e-mail address: hafezad@uum.edu.my

Abstract

This study reassesses the relevance of the human resource management (HRM) curriculum, considering the increasing prominence of artificial intelligence (AI) in the workforce. The research evaluates how the syllabus aligns with contemporary human resource management practices and technological imperatives. The study combined quantitative data from a structured survey of 40 students and qualitative insights from semi-structured interviews with three academic experts by employing a mixed methods needs analysis. Thematic analysis of expert interviews revealed nine curriculum content selection criteria: self-sufficiency, significance, relevance to life, variety, suitability, validity, interest, utility, and learnability. These themes emphasise the syllabus's lack of strategic integration of digital tools and experiential learning. Findings suggest that although the reviewed subject meets traditional academic standards, it disappears to prepare graduates for AI-augmented HRM environments. The study advocates a curriculum redesign that embeds AI-related competencies, adopts blended and experiential pedagogies, and aligns assessment practices with industry-relevant performance measures. These insights align with national policy directions such as the Malaysia Education Blueprint (2015–2025) and the National AI Roadmap. Eventually, the study provides a data-driven foundation for modernising HRM education in Malaysia, ensuring its relevance, adaptability, and alignment with future workforce demands.
Keywords: Human resource management; Artificial intelligence in education; Higher education reform.

1. Introduction

In today's fast-evolving global landscape, higher education institutions face an urgent imperative to modernise and future-proof their academic programmes (Lytras et al., 2024). This necessity is primarily driven by the digital revolution, which continues to shape the trajectory of sustainable education management across the higher education sector (Mohamed Hashim et al., 2022). The urgency is particularly pronounced within human resource management (HRM) disciplines, where digital transformation and the rapid advancement of artificial intelligence (AI) technologies are fundamentally redefining the nature of work (Mossavar-Rahmani & Zohuri, 2024), altering organisational operations (Kitsios & Kamariotou, 2021), and transforming talent management strategies (Agnihotri et al., 2024).

The conventional pedagogical structures and course designs that were previously adequate for preparing students for traditional HR positions are becoming increasingly inadequate. This issue is identified as more challenging in equipping graduates with the necessary skills and competencies to effectively navigate the digitally driven workplace (Goulart et al., 2022). This illustrates that education providers face one of their most significant obstacles in guaranteeing that education aligns with the requirements of a constantly evolving society (Sibanda &

Marongwe, 2022). Thus, universities must critically reassess the structure, content, and delivery of HRM curricula to ensure alignment with current industry needs, global best practices, and technological imperatives.

The Malaysia Education Blueprint for Higher Education (2015–2025) articulates a clear vision of producing holistic, entrepreneurial, and balanced graduates. Central to this vision is a shift towards outcome-based education (OBE) and integrating technology and digital literacy across disciplines (Ministry of Education Malaysia, 2013). The HRM ABC course addresses foundational HRM knowledge and interpersonal skills, mapping well to learning outcomes focused on knowledge (PLO1), teamwork (PLO4), and communication (PLO5). Malaysian HRM curricula often lag in embedding contemporary tools and practices such as digital HR systems and AI (Lai et al., 2023). Compared to international counterparts such as the CIPD's Professional Map in the United Kingdom or the SHRM Competency Framework in the United States, there is a limited curricular emphasis on digital HRM, ethical AI, and data-driven decision-making (Hubschmid-Vierheilig et al., 2020). From a curriculum design perspective, Tyler's model defines clear objectives and aligns content and evaluation accordingly. The HRM ABC syllabus meets this structure through defined CLOs and mapped assessments. However, Taba's inductive model, which promotes learner input and flexibility and advocates for iterative feedback and responsiveness, suggests the need for broader stakeholder engagement and ongoing syllabus renewal.

Across the globe, curriculum design and development have undergone significant paradigmatic shifts, evolving from rigid, content-heavy frameworks to more flexible, learner-centred, and technology-integrated models. In the early stages of curriculum theory, models such as Ralph Tyler's Objectives Model dominated curriculum planning. This model emphasises the formulation of clear learning objectives, systematic organisation of content, and alignment with assessments (D'Souza et al., 2024). Tyler's approach, while foundational, is critiqued for its linearity and inflexibility in accommodating the nuanced needs of diverse learners and the dynamic nature of knowledge (Shamim, 2024). As curriculum studies matured, alternative frameworks emerged to challenge the limitations of prescriptive models. For instance, Hilda Taba's Grassroots Model advocated for curriculum development from the classroom upwards, emphasising teacher involvement, diagnostic assessment, and inductive thinking (Shandia Dewi, 2023). Taba's model is particularly relevant in democratic education contexts where stakeholder participation and contextual sensitivity are prioritised (Portillo et al., 2020).

Against this global backdrop, the HRM ABC course at the university represents a pivotal academic offering within the undergraduate business education portfolio. The course introduces students to fundamental HRM concepts and practices, encompassing legal frameworks, staffing procedures, training and development strategies, performance management, employee relations, and occupational safety and health (OSH). It is structured to develop students' theoretical understanding and practical awareness of the strategic role HRM plays in organisational success. The syllabus is anchored in traditional HRM education and aligns with national policies and institutional learning outcomes. It integrates core HRM literature, includes relevant Malaysian labour laws, and adopts standard assessment methods through continuous assessment and final examination.

Despite its comprehensive nature, the HRM syllabus exhibits critical shortcomings when evaluated against the demands of a technologically driven workforce. The course content does not explicitly address integrating digital technologies or AI in HRM functions, a notable omission given the growing significance of data-driven decision-making, AI-assisted recruitment, and digital performance monitoring in the contemporary HR landscape. This disconnect suggests that while

the syllabus meets conventional academic standards, it falls short in preparing students for emerging HRM roles that require digital competencies, technological fluency, and critical engagement with ethical and strategic dimensions of AI.

Moreover, the course design appears to mirror traditional curriculum planning models, notably Tyler's Objectives Model, which, although structured and goal-oriented, lacks the flexibility to incorporate rapid changes and stakeholder feedback. The absence of interactive or experiential learning components, such as simulations, digital labs, or AI-based case studies, further limits the pedagogical richness of the course (Shrotri et al., 2024). As a result, students may graduate with solid theoretical knowledge but insufficient preparedness to engage with real-world HRM challenges in the digital age.

In contrast, contemporary curriculum frameworks advocate for responsive, iterative, and inclusive approaches to curriculum development. Taba's model, for example, supports the inclusion of learner and industry feedback in shaping course content (Asuncion et al., 2023). The model offers valuable guidance for revising an HRM ABC subject to ensure that it reflects the realities of today's HRM environment and anticipates future trends. The justification for conducting a needs analysis for the HRM ABC subject syllabus at one of the public universities is multifaceted and anchored in policy, industry transformation, and educational theory. Firstly, from a policy alignment perspective, the Malaysia Education Blueprint for Higher Education (2015–2025) strongly advocates for outcome-based education (OBE), graduate employability, and curriculum modernisation aligned with the demands of the Fourth Industrial Revolution (IR4.0) (Sharef et al., 2024).

In order to meet these national imperatives, curriculum development must be informed by data-driven assessments of relevance and responsiveness. Secondly, technological advancements in human resource management, particularly the increasing application of artificial intelligence (AI) in talent acquisition, employee engagement, and succession planning (Kadirov et al., 2024), necessitate the inclusion of AI-related competencies in HRM education. Without such integration, graduates risk entering the workforce with outdated knowledge and insufficient digital literacy. Thirdly, and most critically, pedagogical accountability requires that curricula evolve through continuous stakeholder feedback (Cooper et al., 2014).

Needs analysis (NA), or needs assessment, is a foundational process in curriculum development, particularly in outcome-based and learner-centred frameworks. Several scholars have defined NA to capture its essential role in educational planning. For example, Brown (2016) describes it as the systematic collection and analysis of all relevant information necessary to satisfy the learning requirements of a defined group of students. Meanwhile, McKillip (1998) frames it as an evaluative process identifying discrepancies between current capabilities and desired learning outcomes. Multiple types of needs analysis have been proposed and utilised in educational contexts to fulfil different diagnostic purposes. These include Target Situation Analysis (TSA), which identifies the knowledge and skills required in specific professional settings, and Present Situation Analysis (PSA), which assesses learners' current abilities and preparation (Nhut, 2021).

This study has applied a combination of TSA and PSA to assess how well the HRM ABC syllabus prepares students for careers in technologically advanced HR environments. This needs analysis supports a more targeted and strategic curriculum revision by identifying the expected future demands of the HR profession and the current state of student preparedness. It also aligns with contemporary curriculum models that promote adaptability, relevance, and continuous improvement in higher education.

Therefore, this study aims to conduct a need analysis of the HRM ABC syllabus, focusing on its content structure and its capacity to integrate AI as a transformative element in HRM education. The study also adopts a formal needs analysis to assess the alignment of the syllabus with student expectations, industry requirements, and national education policy, particularly the Malaysia Education Blueprint for Higher Education (2015–2025). The study seeks to identify curriculum gaps, propose relevant enhancements, and contribute to the broader discourse on modernising HRM education in Malaysia through this dual approach.

2. Methodology

2.1 Research Strategy and Sample Selection

This study adopted a mixed-methods approach comprising a student survey and expert interviews at one of the public universities to conduct a comprehensive needs analysis of the HRM ABC syllabus. This study adhered to established ethical standards in educational research involving student participants and academic experts. Ethical clearance was obtained from the appropriate institutional research ethics committee before data collection. All participants were informed of the study's purpose, procedures, and their rights, including the right to withdraw at any time without penalty.

The first phase involved a quantitative survey administered to 40 undergraduate students enrolled in HRM ABC during Semester XYZ/2024. A sample of 40 students can provide valuable preliminary data on student perceptions, offering estimates precise enough to meet various exploratory research aims (Hertzog, 2008). The survey was conducted using Google Forms from 11 March to 14 March 2025. It consisted of 12 structured questions categorised into four key domains: Learning Objectives, Learning Content, Learning Experience, and Learning Evaluation (Bilbao et al., 2008). This instrument was designed to gauge students' perceptions of the syllabus regarding relevance, clarity, engagement, and effectiveness of assessment.

The second phase of the methodology entailed qualitative data collection through semi-structured interviews with three academic experts. Guest et al. (2006) conducted a seminal study demonstrating that data saturation often occurs within the first 12 interviews, with basic thematic elements present as early as six interviews. This finding is particularly relevant in studies involving homogeneous groups with specific expertise. In the current study, a smaller sample size is justifiable, focusing on a homogeneous group of academicians with extensive experience in Human Resource Management (HRM) education and curriculum development.

The panel comprised three academicians (Academician A, B, and C). These academicians were purposefully selected based on their extensive academic and administrative experience, each having over ten years of teaching expertise, at least five semesters of experience teaching HRM ABC, and a minimum of five years serving in academic leadership roles such as chairperson or course coordinator. Purposeful sampling, particularly criterion sampling, is widely recognised in qualitative research for identifying and selecting information-rich cases relevant to the phenomenon of interest (Palinkas et al., 2015). The interviews were held online via Webex on 18 March 2025 and lasted approximately one hour and thirty minutes.

The interview protocol was structured around nine curriculum content selection criteria derived from established curriculum models: (1) Self-sufficiency, (2) Significance, (3) Relevance to life, (4) Variety, (5) Suitability, (6) Validity, (7) Interest, (8) Utility, and (9) Learnability (Bilbao et al., 2008). These domains reflect the key elements often cited in curriculum evaluation literature and provide a comprehensive framework to assess the extent to which the HRM ABC syllabus meets

pedagogical standards and industry expectations. Data from the survey and interviews were triangulated to derive insights into curriculum strengths, gaps, and actionable areas for improvement.

2.2 Need Analysis

A comprehensive needs analysis was conducted as the foundational step of this study to evaluate the relevance, effectiveness, and alignment of the HRM ABC syllabus with contemporary academic and industry expectations. This initiative was prompted by growing concerns regarding the adequacy of the syllabus in addressing students' learning needs, employability skills, and the dynamic nature of human resource practices. Informal feedback from students, coupled with observations from teaching staff, suggested potential gaps in content relevance, engagement, and assessment strategies. Moreover, as higher education institutions move towards outcome-based education and graduate employability, ensuring that course syllabi remain current and impactful becomes increasingly essential.

The justification for conducting the needs analysis was based on several compelling factors. Firstly, engaging students and academic experts provided a dual perspective on the syllabus. This is because students, as the primary beneficiaries of the course, are offered insights into their learning experiences and expectations (Silvola et al., 2021). In contrast, with their deep pedagogical knowledge and curriculum development experience, academic experts provided a more structured and theoretical evaluation of the content (Dankasa, 2015). Secondly, the needs analysis should align with institutional quality assurance efforts (Suleiman,2023), ensuring that the course meets the standards outlined in the Malaysian Qualifications Framework (MQF) and other relevant curriculum models. Thirdly, preliminary assessments indicated a potential gap between theory and practice, a common critique in HRM education (Negt & Haunschild, 2025). This analysis aimed to bridge that gap by identifying areas where practical elements could be strengthened.

2.3 Data Analysis Strategy

The data analysis process was designed to yield meaningful insights that would directly inform curriculum enhancement for the HRM ABC syllabus. As this study employed a mixed-methods approach, the analysis strategy was structured accordingly to reflect quantitative and qualitative components, emphasising data triangulation to ensure validity and depth of interpretation.

Quantitative data from the student survey were analysed using descriptive statistics to identify overall patterns and trends in student perceptions. Responses to the 12 structured items were examined across the four predefined domains: Learning Objectives, Learning Content, Learning Experience, and Learning Evaluation. Frequency distributions and measures of central tendency (mean, median) were computed to assess students' levels of agreement with each item. This analysis identified key areas where students expressed concerns or dissatisfaction, particularly in content relevance, engagement strategies, and the clarity of assessment criteria. The study also highlighted which syllabus components were perceived as strengths, offering a balanced view of what should be retained and what requires revision.

For the qualitative phase, interview transcripts from the three expert participants were subjected to thematic analysis. An inductive coding approach was used, guided by the nine curriculum content selection criteria: self-sufficiency, significance, relevance to life, variety, suitability, validity, interest, utility, and learnability. These criteria served as a conceptual framework to ensure consistency and theoretical alignment in interpreting expert responses. Coding was

conducted manually to ensure close engagement with the data, with themes emerging around curriculum gaps, redundancy in content, lack of real-world application, and the need for increased learner-centred pedagogical approaches. Particular attention was given to repeated points raised by all three experts, which were treated as key indicators of consensus.

Crucially, the quantitative and qualitative findings were then integrated through triangulation. For instance, expert observations about the lack of industry-aligned case studies and experiential learning opportunities in the syllabus reinforced students' concerns regarding limited practical application. Similarly, feedback about the lack of engagement in current teaching materials was echoed in expert critiques of outdated content and rigid delivery methods. This convergence of perspectives validated the credibility of the findings and strengthened the case for reform.

The data analysis, therefore, provided a robust evidence base to support the rationale for a revised HRM ABC syllabus. It revealed misalignments between learner needs, pedagogical intent, and curriculum design, justifying the need for a more integrated, relevant, and outcome-based approach. The insights gleaned from both students and experts identified areas requiring improvement. They offered constructive directions for future curriculum development, including incorporating industry-relevant content, more interactive teaching methods, and assessment practices that reflect authentic HRM challenges. This strategic and layered approach to data analysis ensured that the findings were both analytically rigorous and practically actionable, forming a sound basis for the proposed curriculum revision.

3. Results

3.1 Quantitative Findings

The quantitative data were collected through a structured online survey involving 40 undergraduate students enrolled in the HRM ABC course during Semester XYZ/2024. The survey explored student perceptions across four domains: Learning Objectives, Learning Content, Learning Experience, and Learning Evaluation. This study used a combination of structured items and open-ended responses to analyse these four domains. Descriptive analysis reveals generally positive perceptions, while the qualitative inputs embedded within the survey provide critical nuance for syllabus enhancement, particularly concerning the content structure and the integration of AI and experiential learning methods.

In the Learning Objectives domain, students reported high clarity and accessibility. A total of 97.5% of respondents agreed that they understood the learning objectives, while 100% confirmed they had achieved them and received sufficient guidance. However, in the open responses, a few students expressed challenges related to content overlap, the volume of materials, and language difficulties. For example, one student remarked, *"Penerangan tentang beberapa topik agak sama jadi berlakunya kekeliruan semasa mempelajarinya,"* [The explanation of several topics was quite similar, which led to confusion during the learning process] while another stated, *"There are too many notes to study."* These comments suggest a need to streamline thematic progression and improve content coherence.

Feedback within the Learning Content domain was overwhelmingly positive, with all students (100%) agreeing that the content was easy to understand, relevant to their needs, and supported by effective learning materials. Nevertheless, students proposed enhancing clarity through examples and contextual explanations when asked which content areas could be improved. A student suggested, *"Berikan huraian beserta contoh dalam setiap topik besar dan topik kecil,"* [Provide an explanation along with examples for each main topic and subtopic] while another

noted, *"Saya suka jika topik ' employee's right and discipline' difokuskan kerana ia akan dipraktikkan ketika bekerja."* [I prefer the topic of 'employee's rights and discipline' to be emphasised, as it will be applied in the workplace] These responses indicate a demand for more profound, practice-oriented content, particularly topics linked to industrial relations and legal frameworks in HRM.

The Learning Evaluation domain showed consistently positive results. All students (100%) felt that the assessments, such as projects, assignments, quizzes, and tests, effectively measured their understanding of the topics. Furthermore, 100% agreed that assessment feedback helped improve their comprehension and enabled them to identify strengths and weaknesses. However, suggestions for improvement included increasing the quizzes' frequency and simplifying the notes' volume. One respondent remarked, *"Need to reduce the notes from each topic,"* while another highlighted the value of out-of-classroom activities, stating, "*Saya harap Dr. dapat kekalkan aktiviti luar bilik darjah... kerana dapat menarik minat kami dan dapat belajar dengan santai tetapi bermakna."* [I hope Dr. will continue the outdoor class activities… as they successfully capture our interest and allow us to learn in a relaxed yet meaningful way]. This supports the need for experiential and blended learning approaches, mainly through activities that link course content to real-world scenarios and technologies, including AI applications.

The Learning Evaluation domain also received high scores, with 100% of students reporting that the assessments reflected their understanding and that the feedback helped them improve. Students also confirmed that evaluations enabled them to identify strengths and development areas. However, the open-ended feedback on assessment improvement offers valuable insights for future curriculum reform. Several students suggested increasing the frequency and variety of formative assessments, with one stating, *"Banyak quiz sebelum quiz 10%,"* [There were many quizzes before the 10% quiz] and another proposing, *"Pensyarah boleh menambahkan kuiz yang banyak."* [The lecturer can include more quizzes]. Others advocated more applied, experiential evaluations such *as "kajian kes dan simulasi sebenar,"* [Case studies and real-life simulations] including court case discussions or mock interviews to support practical understanding.

Some students called for greater incorporation of technology-enhanced and gamified learning, recommending, *"Pembelajaran berasaskan gamifikasi,"* [Gamification-based learning] and *"HR scenario-based games yang menguji pemahaman konsep."* [HR scenario-based games that test conceptual understanding]. These suggestions align with the increasing emphasis on active learning through simulation and integrating digital platforms to assess complex concepts. Additionally, one student commented, *"Tingkatkan pembelajaran AI dalam semua mata pelajaran,"* [Enhance AI learning across all subjects] directly supporting the research objective of enhancing the syllabus's capacity to integrate AI as a transformative educational element.

Students also expressed the importance of inclusive participation and social dynamics in assessments. One student suggested, *"Berinteraksi dengan murid yang mungkin kurang menyerlah dalam kelas,"* [Interact with students who may be less outstanding in class] highlighting the need for assessments that promote engagement among all learners. Others stressed group harmony and presentation-based evaluations, stating, *"Keharmonian antara pelajar dalam group assignment dijamin,"* [Harmony among students in group assignments is ensured] *and "Lakukan pembentangan assignment untuk mengenal pasti adakah pelajar faham tentang apa yang mereka pelajari."* [Conduct assignment presentations to identify whether students understand what they have learned]. Although many respondents indicated satisfaction with the current evaluation methods, with comments such as *"Semua sudah terbaik"* [Everything is already excellent] and *"Semuanya bagus dan boleh diteruskan,"* [Everything is good and can be

continued] the range of improvement-oriented suggestions reflects a collective aspiration for more dynamic, interactive, and digitally aligned assessment formats.

While the quantitative responses demonstrate a high degree of satisfaction across all learning domains, the accompanying qualitative feedback reveals meaningful opportunities for enhancement. Students strongly support the existing syllabus but envision it as more engaging, digitally integrated, and reflective of workplace realities, mainly through gamification, simulation, and AI applications. These findings provide a compelling basis for reimagining the HRM ABC syllabus to ensure its pedagogical robustness, technological relevance, and practical applicability.

3.2 Qualitative Findings

Thematic analysis of the expert interviews revealed nine significant themes related to the HRM ABC syllabus: (a) self-sufficiency, (b) significance, (c) relevance to life, (d) variety, (e) suitability, (f) validity, (g) interest, (h) utility, and 9i) learnability. These themes offer critical insights into how the syllabus can be restructured to better support HRM education in the digital era, mainly through the integration of AI and other transformative technologies.

The expert interviews revealed a strong consensus on the need to restructure the HRM ABC syllabus to enhance its practical relevance, pedagogical coherence, and digital responsiveness, particularly in integrating AI tools. The findings highlight the importance of flexible, student-centred curriculum design aligned with programme outcomes, responsive to technological change, and grounded in real-world contexts. These recommendations directly support transforming the HRM ABC syllabus into a future-proof HRM course that prepares graduates for dynamic and digitised work environments.

3.3 Self-Sufficiency: Enabling Independent and Digitally-Driven Learning

The analysis revealed that the current HRM ABC syllabus partially supports student self-sufficiency but lacks explicit strategies for nurturing autonomous learning in a digital context. Academician A stressed the importance of aligning course content with learning outcomes: *“Setiap kursus yang dibangunkan mestilah sejajar dengan CLO, PLO, dan PEO; baru kita bangunkan kandungan yang membolehkan pelajar belajar secara kendiri.”* [Each course developed must be aligned with the Course Learning Outcomes (CLO), Programme Learning Outcomes (PLO), and Programme Educational Objectives (PEO); only then should we design content that enables students to engage in self-directed learning]. However, she acknowledged that the integration of digital learning platforms such as Google Classroom and Webex is reactive, not strategic: *“Disebabkan perkembangan teknologi, kita terpaksa ubah kandungan kurikulum sejajar dengan keperluan digital.”* [Due to technological advancement, we are compelled to revise the curriculum content in line with digital requirements]. These insights suggest an urgent need to embed structured digital learning pathways and AI-based tools that support self-directed learning within the syllabus.

3.4 Significance: Bridging Theory, Industry, and Technological Application

Curriculum content was considered significant when it directly contributed to developing critical, transferable skills. Academician B emphasised, *“Kandungan perlu menyepadukan kekuatan teori dan amalan semasa industri... dan membangunkan transferable skills seperti komunikasi dan membuat keputusan.”* [The content must integrate the strengths of theoretical knowledge with current industry practices… while also developing transferable skills such as communication and decision-making]. He also raised concerns about over-reliance on AI tools in academic writing,

advocating for oral assessments to gauge deeper understanding. Academician A echoed this by stressing the need for constructive alignment between learning outcomes, teaching strategies, and assessment methods. Experts highlighted the curriculum's limited responsiveness to current HRM trends, particularly in technology adoption and skill relevance. Academician B remarked, *"Kita perlu seimbang antara kekuatan teori dan kesesuaian industri… dan semakan berkala untuk masukkan amalan terkini."* [We need to strike a balance between theoretical strength and industry relevance, with regular reviews to incorporate current practices]. He advocated for using AI not only in content delivery but also in assessment, stating, *"Di zaman AI ini, saya lebih cenderung ukur penguasaan pelajar melalui komunikasi, bukan penulisan."* [In this era of AI, I am more inclined to assess students' mastery through communication rather than writing]. This underscores the need for curriculum content incorporating AI as a subject matter and an assessment medium, enabling students to demonstrate their applied competencies beyond traditional written outputs.

3.5 Relevance to Life and Workplace: Anchoring Curriculum in Real-World Contexts

Experts agree that learning is more effective when connected to students' experiences. Academician C observed, *"Kaitan antara pengalaman pembelajaran dengan situasi sebenar semasa latihan industri memberikan impak yang tinggi terhadap kefahaman pelajar."* [The connection between learning experiences and real-world situations during industrial training has a significant impact on students' understanding]. She provided examples where students applied course concepts during internships, particularly in training units. Academician B added that structured group tasks often reflect students' personal discipline and time management skills, which are essential for future employment. The data strongly suggest that meaningful learning occurs when students connect classroom knowledge with workplace experiences. Academician C noted, *"Student praktikkan apa yang mereka belajar dalam unit latihan semasa intern... ini menunjukkan kaitan terus antara kandungan kursus dan kehidupan sebenar."* [Students apply what they have learned in training units during their internship, which demonstrates a direct connection between course content and real-life practice]. Academician B observed that students' assignment behaviour mirrors real-life time management and interpersonal dynamics. This finding supports the need to update the syllabus with applied learning components such as AI-driven case simulations, role-plays, and reflective practices that mirror workplace realities.

3.6 Variety in Content Delivery: Adapting Content for Diverse Learning Preferences

A recurring theme was the necessity for instructional variety to accommodate Generation Z learners. Academician A emphasised the value of flexible content: *"Pelajar Gen Z ini cenderung kepada gaya pembelajaran visual, auditori dan kinestetik… maka kita guna pelbagai kaedah dan teknologi."* [Generation Z students tend to favour visual, auditory, and kinaesthetic learning styles; therefore, a variety of methods and technologies are employed to support their engagement and understanding]. She also added, *"Pensyarah perlu mahir dalam teknologi terkini serta peka terhadap perubahan dalam industri."* [Lecturers must be proficient in current technologies and remain responsive to changes within the industry]. Academician B remarked, *"Topik seperti remuneration memerlukan pendekatan hands-on dan dua hala-syarahan tak cukup."* [Topics such as remuneration require a hands-on and interactive approach-lectures alone are not sufficient]. These findings support the integration of AI-enhanced learning environments, such as interactive chatbots, gamified modules, and AI-curated content delivery. Academician B criticised conventional lecture methods, particularly for technical subjects such as remuneration, recommending more interactive and experiential learning strategies. Academician C highlighted that active engagement requires mastering digital tools and designing high-interaction learning environments.

3.7 Suitability: Matching Content with Cognitive Readiness

The experts stressed the need for content to match students' cognitive readiness and disciplinary background. Academician B highlighted, *"Pelajar semester lima lebih matang... kandungan kursus harus disesuaikan dengan tahap penguasaan mereka."* [Fifth-semester students are more mature… and the course content should be aligned with their level of mastery]. He noted that students from finance-related disciplines more readily grasp HRM principles due to prior exposure. Hence, content scaffolding and differentiated instruction were deemed essential. Experts identified mismatches between content complexity and student readiness, particularly in early semesters. Academician B noted, *"Pelajar semester satu tak sesuai diajar struktur gaji yang mendalam… mereka belum cukup matang dari segi kognitif."* [First-semester students are not suited to learning in-depth salary structures… as they are not yet cognitively mature enough]. This indicates the need for curriculum scaffolding, starting with foundational content and gradually integrating more complex, AI-related concepts as students progress.

3.8 Validity of Content: Ensuring Rigour Through External and Internal Review

Ensuring the accuracy and currency of course material was a shared concern. Academician C advocated systematic programme audits and ISO-based documentation reviews supported by industrial feedback and student evaluations. Academician B highlighted the value of informal assessments, such as in-class reflections. At the same time, Academician A called for curriculum reviews to be conducted by panels comprising academic and industry experts to ensure relevance and rigour. These perspectives reinforce the need to develop a validation mechanism for AI-integrated content, ensuring alignment with evolving HRM industry practices.

3.9 Stimulating Student Interest

Capturing student interest was seen as increasingly challenging without diverse, interactive methods. Academician A shared, *"Saya sendiri uji soalan dalam ChatGPT sebelum beri kepada pelajar… sebab mereka memang guna AI dalam tugasan."* [I personally test the questions in ChatGPT before giving them to students, as they frequently use AI tools for their assignments]. She argued for shifting towards flexible media, such as podcasts, while ensuring pedagogical alignment. *"Bila diberi kebebasan buat podcast, pelajar lebih terlibat dan pembelajaran berlaku."* [When given the freedom to create podcasts, students became more engaged and meaningful learning took place]. This underscores the value of incorporating AI not only as a subject but also as a tool for engaging and co-creating content.

3.10 Utility of Curriculum in Skill Development

Experts linked curriculum utility to employability. Academician B stated, *"Ukuran kebergunaan ialah sejauh mana pelajar memperoleh kerjaya yang sesuai selepas tamat pengajian."* [Usefulness is measured by the extent to which students secure appropriate careers after graduation]. He recommended industry visits over one-off guest lectures to improve contextual learning. All experts agreed that curriculum components should translate directly into skills needed in the workplace, particularly in internships and early career roles. The findings suggest that the curriculum must embed employability-focused AI skills such as predictive analytics, HR software simulations, and automation tools to prepare students for AI-augmented HR roles.

3.11 Learnability: Structuring Content for Retention and Progression

The final theme addressed the learnability of content. Academician C emphasised the importance of building on students' existing knowledge and experiences through structured sequencing, noting, "*Strategi pengajaran perlu dimulakan dengan mengaitkan kandungan baharu dengan pengetahuan sedia ada pelajar."* [Teaching strategies should begin by connecting new content to students' prior knowledge]. She also stressed the role of scaffolding and ongoing review to prevent surface learning. The need for better sequencing of topics was emphasised as a foundation for long-term knowledge retention. Academician C explained, *"Pelajar Gen Z perlu bimbingan berstruktur… mereka cepat lupa sebab belajar untuk exam, bukan untuk ingat lama."* [Generation Z students require structured guidance, as they tend to forget easily due to learning primarily for examinations rather than long-term retention]. She advocated linking content to prior knowledge and authentic experiences, such as part-time jobs or workshop participation. This supports the development of AI-based personalised learning plans, intelligent tutoring systems, and adaptive assessments tailored to student learning histories. Academician B added that industrial transparency regarding HRM practices would allow students to understand the theory better.

4. Discussion

The findings from the quantitative phase of this study offer valuable insights into students' perceptions of the HRM ABC syllabus, with implications for content structure, pedagogical alignment, and the integration of digital innovations such as artificial intelligence (AI). The results demonstrate high satisfaction across all four learning domains: objectives, content, experience, and evaluation. Yet, the qualitative comments in the survey responses reveal a nuanced desire for enhancements that reflect evolving learner needs and industry demands.

Students firmly understood the course learning objectives, aligning with Biggs and Tang's (2011) advocacy for constructive alignment in outcome-based education. However, concerns over overlapping topics and information overload suggest revisiting thematic progression and streamlining syllabus content. These concerns are echoed by Gkintoni et al. (2025), who caution that excessive cognitive load can impede deep learning. This is particularly significant in HRM, where concept differentiation is critical for workplace application (Marescaux et al., 2021). Streamlining objectives into thematic modules and embedding clarity through AI-driven curriculum mapping tools may support better cognitive scaffolding.

The overwhelmingly positive feedback on learning content mirrors studies by Fish et al. (2025), which underscore the importance of content relevance in promoting student engagement and employability. Nevertheless, the students' call for more contextual examples and detailed explanations points to a gap between theoretical knowledge and applied HRM practice (Robertson, 2023). This is consistent with findings by Kolb (1984), who argues that experiential learning bridges theory-practice gaps. In particular, student recommendations to expand industrial relations and employee discipline topics suggest an awareness of HRM's legal and practical complexities areas where scenario-based AI tools could enhance realism and critical thinking.

The high ratings for the learning experience align with Nordin et al. (2021) work on Generation Z learning preferences, which favour interactivity, technology integration, and visual engagement. However, the limited classroom time hampers topic comprehension and calls for improved instructional design (Caskurlu et al., 2021). This resonates with literature on flipped classrooms and blended learning approaches, allowing content delivery outside class and in-class time to focus on application (Kang & Kim, 2021). Integrating AI technologies such as automated feedback

systems and adaptive learning platforms could enhance these strategies by tailoring instruction to individual learner progress (Aggarwal, 2023).

The learning evaluation domain also received favourable feedback, consistent with findings by Morris et al. (2021), who highlight the formative role of feedback in promoting metacognitive development. However, the qualitative data revealed a clear preference for assessment methods that go beyond traditional formats. Student recommendations to increase the frequency of quizzes, simplify learning materials, and include more simulations and real-world tasks reflect a shift in expectations toward more authentic, performance-based assessment. These findings are supported by Sokhanvar et al. (2021), who argue that authentic assessment improves transfer of learning. In HRM, incorporating simulations such as mock disciplinary hearings or AI-powered role-plays can enhance realism and deepen learning (Sainila, 2024).

Notably, the suggestion to incorporate gamification and AI into assessment reflects a growing body of research on digital engagement strategies. Shen et al. (2024) support the positive impact of gamification on motivation and learning outcomes, while other studies highlight the role of AI in personalising assessment and feedback (Hooda et al., 2022; Vashishth et al., 2024). The student proposal for "HR scenario-based games" and calls to *"tingkatkan pembelajaran AI dalam semua mata pelajaran"* signal a readiness to embrace such innovations. These suggestions align with current trends in HRM education, where AI is a subject of study and a pedagogical tool (Gârdan et al., 2025).

Students also highlighted social and interpersonal dimensions of learning, such as inclusive engagement and harmony in group assignments. These aspects are consistent with collaborative learning theory, which emphasises the importance of peer interaction for knowledge construction (Er et al., 2021). Suggestions to support "*murid yang kurang menyerlah"* and ensure equitable group dynamics indicate an awareness of effective learning environments, supporting the notion that curriculum design must address academic and socio-emotional dimensions.

Although some students reported that the current assessment approach was *"sudah terbaik,"* the breadth of suggestions for enhancement reflects an underlying aspiration for transformation. This echoes the call by Dumbuya (2023) for curricula to evolve beyond traditional boundaries and foster complex problem-solving, adaptability, and digital fluency. Integrating AI into learning and evaluation practices is no longer a luxury but a necessity, particularly in preparing graduates for HRM roles in a data-rich, automated workplace. When triangulated with the qualitative expert interviews, these student-driven insights present a strong case for a revised HRM ABC syllabus that is both future-ready and pedagogically robust.

While the current syllabus is positively received, the student feedback highlights the need for continuous improvement, especially in applied content, assessment diversity, and digital engagement. Integrating AI as content and a pedagogical tool is a critical recommendation (Alam & Mohanty, 2023). These findings affirm the relevance of student-centred design and provide empirical justification for curriculum reform efforts aimed at producing HRM graduates who are competent, adaptive, and digitally literate in a rapidly evolving world of work.

For the qualitative phase, the findings of this study highlight the urgent need to reform the HRM ABC syllabus, particularly to enhance its pedagogical alignment, practical relevance, and integration of Artificial Intelligence (AI) as a transformative element in HRM education. The expert insights obtained reflect a growing concern that the current curriculum is inadequately structured to meet the demands of a rapidly digitising HR landscape. This discussion explores these findings

in light of previous research, revealing both parallels and new contributions to curriculum design discourse in the context of higher education.

Experts agreed that while the current syllabus supports self-directed learning, it lacks strategic mechanisms to develop independent learning skills in a digital context. This aligns with previous literature on outcome-based education, underscoring the importance of aligning content with learning outcomes and enabling students to take ownership of their learning (Biggs & Tang, 2011). However, the experts' concern that digital platforms are used reactively rather than as part of a broader pedagogical vision resonates with Tarigan et al. (2021), who argue that digital tools must be purposefully integrated to truly enhance learner autonomy. Embedding AI-powered tools, such as adaptive learning systems or intelligent tutoring platforms, would thus support a more robust approach to learner self-sufficiency (Karimova et al., 2025).

The theme of curriculum significance also drew attention to the need for content that bridges theoretical foundations with industry practices and 21st-century competencies. Academician B's advocacy for balancing theory with real-world applications reflects the broader view in curriculum literature that emphasises the need for constructive alignment. Particularly salient is the concern over students' overreliance on AI tools for assignments, which mirrors findings by Cotton et al. (2023), who argue that traditional assessment methods must evolve in the era of generative AI (Khlaif et al., 2025). This supports the call for oral presentations, interactive assessments, and scenario-based evaluations as more authentic and future-proof alternatives.

Regarding real-world relevance, the findings affirm the value of experiential learning models. Students' application of course content during internships confirms Kolb's (1984) theory that knowledge is deepened through active engagement and reflection. The literature supports this, particularly Jackson and Dean (2023), who emphasise the role of work-integrated learning in enhancing graduate employability. In this regard, embedding AI-driven simulations and role-play into the syllabus would contextualise learning and prepare students for the AI-augmented workplace.

The need for instructional variety is well-documented in contemporary pedagogical literature. Azman et al. (2021) highlight the distinctive learning styles of Generation Z, who prefer visual, interactive, and digital forms of engagement. The experts' call for more hands-on and two-way teaching methods, especially for technical content, reflects this. Their recommendations to use gamified learning tools, real-time feedback mechanisms, and AI-curated resources align with Dwivedi et al. (2024) findings on the effectiveness of multimodal content delivery. Moreover, the mention of AI-enhanced content delivery systems, such as chatbots and adaptive platforms, echoes Singh (2024)., who advocates for integrating AI to personalise and enrich learning environments.

The issue of content suitability further supports the argument for differentiated instruction. Vygotsky's (1978) concept of the Zone of Proximal Development suggests that curriculum must be scaffolded to support learners as they progress from foundational to advanced content. The experts' observations that early-semester students struggle with complex HRM topics support this notion. A phased content structure that progressively introduces AI and other advanced topics would be pedagogically sound and cognitively appropriate.

The discussion on curriculum validity is consistent with broader quality assurance frameworks such as the Malaysian Qualifications Framework (MQF) and international standards (e.g., AACSB, CIPD). Ensuring the syllabus reflects current industry needs, particularly in applying AI in HRM, is critical for relevance and accreditation. Including formal audit processes, stakeholder

panels, and benchmarking practices aligns with the Organisation for Economic Co-operation and Development (OECD) recommendations on maintaining curriculum quality in dynamic professional fields (Boeskens et al., 2020).

Student interest was another area where the findings intersect with contemporary concerns about engagement in higher education. As noted by Academician A, the use of tools such as podcasts, Kahoot, and ChatGPT reflects a shift towards digital co-creation of learning materials. This aligns with Celik (2023), who suggests that educators must acknowledge students' use of AI and actively integrate such tools into pedagogical practice. This allows AI to function as content and medium, helping students build digital fluency while enhancing their intrinsic motivation.

The experts' emphasis on utility confirms that the ultimate goal of any curriculum is employability. Bae et al. (2022) highlight the persistent gap between academic preparation and industry expectations. The findings of this study reinforce this concern, particularly the suggestion to embed AI-relevant competencies such as predictive analytics, HR software simulations, and data-driven decision-making into the syllabus. These are increasingly becoming core components of HRM practice, and their integration would ensure that the syllabus is aligned with the expectations of future employers.

Lastly, the theme of learnability touches on fundamental principles of cognitive load theory (Sweller, 1988) and knowledge transfer (Bransford et al., 2000). The need for content to be logically sequenced, connected to prior knowledge, and structured through continuous feedback loops supports long-term learning retention. With Gen Z learners, whose motivation may decline in traditional lecture formats, using AI to personalise learning paths through intelligent analytics, adaptive feedback, and microlearning can significantly enhance learnability and performance.

The findings of expert opinion analysis are strongly aligned with global calls for educational transformation in the age of AI. The expert interviews revealed deficiencies in the HRM ABC syllabus and opportunities to leverage emerging technologies and pedagogical strategies to create a more relevant, responsive, and future-oriented curriculum. The proposed reforms are not merely content updates but a fundamental shift towards a digitally fluent, outcome-aligned, and learner-centred model of HRM education. As the discipline of human resource management evolves in response to technological disruption, so must the academic frameworks that prepare the next generation of HR professionals.

4.1 Suggestions for Improvement: Integrating AI into the HRM Curriculum

To better prepare graduates for the evolving demands of digital human resource management, the HRM ABC syllabus must undergo a strategic revision that reflects technological trends, particularly the integration of artificial intelligence (AI) in managing people at work. From a content perspective, relevant AI-related topics should be embedded into existing modules such as "Recruitment and Selection," "Performance Management," and "Training and Development." Specific subtopics may include AI-enabled candidate screening, algorithmic bias and fairness in selection, performance dashboards, and chatbot-assisted onboarding. Such inclusion aligns with Tyler's curriculum design model, which emphasises clarity in objectives and content alignment but must go further by engaging students in applied knowledge and future-facing skills.

Regarding pedagogy, the course would benefit significantly from adopting blended learning approaches, including using AI-based simulations and HR analytics platforms to foster experiential and interactive learning. Implementing case-based learning that simulates real-world HR digital transformation scenarios is consistent with constructivist learning principles.

Moreover, assessments should be reconfigured to validate theoretical knowledge and practical digital competencies. This may include digital assignments, reflective AI case analyses, and the incorporation of micro-credentials that certify competencies in areas such as AI ethics, digital HR tools, and HR data analytics. Aligning these assessments with the DigCompEdu framework would support the development of 21st-century skills, ensuring that students graduate with globally recognised digital proficiencies.

Finally, any proposed enhancements must be contextually grounded and aligned with national strategic directions. The inclusion of AI within the HRM syllabus supports the objectives of the Malaysia Education Blueprint for Higher Education (2015–2025) (Ministry of Education Malaysia, 2013), the National Artificial Intelligence Roadmap (Ministry of Science, Technology and Innovation, 2021), and the Malaysia Digital Economy Blueprint (Economic Planning Unit, 2021). These policy frameworks call for integrating digital and AI-related competencies into university curricula, emphasising graduate employability, technological agility, and creating a digitally empowered workforce. Therefore, improving HRM ABC through AI integration is pedagogically sound and strategically imperative to ensure Malaysia's higher education institutions remain globally competitive and nationally relevant.

5. Conclusion

This study provides compelling evidence for the urgent transformation of the HRM ABC syllabus to ensure its continued relevance in an era increasingly shaped by digital innovation and artificial intelligence (AI). Through a comprehensive mixed-methods approach, incorporating both student perceptions and expert insights, the findings reveal that while the current syllabus is well-structured and positively received, it lacks the depth, flexibility, and technological alignment required to fully prepare HRM graduates for the evolving demands of the profession.

The quantitative analysis confirms intense student satisfaction across key learning domains: objectives, content, experience, and evaluation, yet qualitative feedback reveals meaningful gaps in practice-oriented content delivery, assessment diversity, and integration of real-world HRM tools and technologies. Students advocated for more precise content progression, more applied examples, and increased use of AI-enabled learning approaches, including simulations, gamification, and scenario-based assessments. Expert recommendations complement and deepen these perspectives, underscoring the need for a more future-facing curriculum structure. The qualitative findings highlight that content must be scaffolded according to learners' cognitive readiness, aligned with programme learning outcomes, and validated through academic and industry benchmarks.

This study makes a significant contribution by reinforcing the imperative to embed artificial intelligence not merely as a topic of academic inquiry but as a transformative pedagogical tool. It demonstrates how AI can be harnessed to support personalised learning pathways, performance-based assessment, and heightened student engagement, thereby aligning pedagogy with the expectations of digitally native learners. The study's findings also strengthen the case for adopting contemporary curriculum models prioritising learner-centred design, authentic assessment practices, and flexible delivery formats, which mirror modern work environments' dynamic and complex nature. Furthermore, by aligning the revised HRM ABC syllabus with national policy frameworks, namely the Malaysia Education Blueprint and the National Artificial Intelligence Roadmap, this study ensures academic and industry relevance and strategic policy coherence, positioning the curriculum as future-ready and nationally responsive.

This study focused on conducting a mixed-methods needs analysis of the HRM ABC syllabus offered at a public university in Malaysia, evaluating its relevance, structure, and technological adaptability, particularly in the context of artificial intelligence (AI) integration. This research's scope encompassed student and academic expert perspectives, providing a dual-layered assessment of the curriculum's pedagogical alignment, content utility, and readiness for the evolving digital workforce.

Quantitative data were collected through a structured survey administered to 40 undergraduate students, while qualitative insights were obtained via semi-structured interviews with three academic experts in HRM education. Integrating Target Situation Analysis (TSA) and Present Situation Analysis (PSA) methodologies allowed for a comprehensive evaluation of current syllabus effectiveness against future professional expectations.

Several limitations must be acknowledged. The study was confined to one academic institution and one specific HRM course (HRM ABC). As such, the findings may not be generalisable to other universities or broader HRM programmes in Malaysia or globally. Future research could extend this inquiry across multiple institutions for comparative analysis. While the student survey and expert interviews yielded rich insights, the sample size (40 students and 3 experts) limits the statistical generalisability of the findings. Nonetheless, the purposive selection of experts with over a decade of academic and curriculum leadership experience enhances the data's qualitative depth and contextual relevance. The study did not include a broader benchmarking of HRM curricula from international institutions or professional bodies beyond references to frameworks such as SHRM and CIPD. Including detailed cross-institutional comparisons would enrich future syllabus reform efforts.

In essence, the conclusion of this study is clear: the future of HRM education demands a curriculum that is agile, applied, and AI-integrated. The HRM ABC syllabus must evolve from its current static format into a dynamic, responsive framework capable of producing HR professionals competent in HR theory and practice and fluent in digital technologies and data-driven decision-making. Such reform is not only pedagogically justifiable but imperative for preparing graduates to thrive in the fast-changing, AI-augmented world of work. This study thus serves as a critical foundation for guiding curriculum review, innovation, and strategic enhancement within HRM education in Malaysia and beyond.

Future research should expand the scope of inquiry by including industrial experts and programme alumni as key informants and respondents. Their perspectives would provide valuable insights into how well the HRM ABC syllabus prepares graduates for real-world challenges and evolving industry demands. The alumni reflections on their transition from classroom to workplace can reveal practical gaps in skills application. At the same time, industry practitioners can offer forward-looking expectations regarding digital competencies, especially in AI-driven HRM practices. Incorporating these stakeholder voices would support a more holistic and responsive curriculum development process, ensuring that the revised syllabus aligns with academic standards, workforce realities, and future employability trends.

5.1 Novelty and Contribution of the Study

This study offers a novel contribution by reassessing an undergraduate HRM syllabus through a dual-perspective needs analysis that combines student feedback and expert insights. It is among the first in the Malaysian context to critically evaluate how AI-related content and digital competencies can be embedded into HRM education. The study identifies apparent gaps in content relevance, teaching methods, and assessment design by integrating established

curriculum models with empirical data. It proposes practical reforms aligned with national policy frameworks, advocating for a shift towards learner-centred, AI-integrated, and industry-responsive HRM curricula that better prepare graduates for future workforce demands.

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KESEDARAN DAN AMALAN KESELAMATAN SIBER PENGGUNA DIGITAL DI MALAYSIA: IMPLIKASI TERHADAP LITERASI DIGITAL LESTARI

Elisnorazmaliza binti Ab Hamid[1]*, Eni Aryanti binti Yusoff[1], Ruzila binti Mat Ghani[2]

[1]Jabatan Teknologi Maklumat dan Komunikasi, Politeknik Besut Terengganu, 22200, Besut, Terengganu, Malaysia

[2] Jabatan kejuruteraan Mekanikal, Politeknik kota Bharu, KM24 kok Lanas 16450 Ketereh Kelantan, Malaysia

*Corresponding author: elis@polibesut.edu.my

Abstrak

Keselamatan siber semakin penting seiring dengan perkembangan teknologi digital dalam pelbagai aspek kehidupan seperti komunikasi, pendidikan dan urusan kewangan. Namun begitu, jurang antara tahap kesedaran dan amalan keselamatan siber masih ketara, khususnya dalam kalangan kumpulan rentan seperti warga emas, pelajar sekolah dan peniaga kecil. Kajian ini dijalankan bagi menilai tahap kesedaran dan amalan keselamatan siber dalam kalangan pengguna digital di Malaysia serta mengkaji hubungannya dengan literasi digital lestari. Seramai 392 responden pelbagai latar belakang telah terlibat melalui pendekatan kuantitatif menggunakan soal selidik berstruktur atas talian berasaskan kerangka NIST yang merangkumi lima fungsi keselamatan utama. Data dianalisis menggunakan perisian SPSS versi 26 melalui kaedah statistik deskriptif, korelasi Pearson, ujian-t bebas dan ANOVA. Hasil kajian menunjukkan bahawa tahap kesedaran (Min = 4.15) dan amalan keselamatan (Min = 4.27) adalah tinggi, manakala korelasi antara kedua-dua pemboleh ubah adalah sangat kuat dan signifikan ($r = 0.73$, $p < 0.001$). Pendidikan didapati mempengaruhi tahap kesedaran, manakala wanita menunjukkan tahap amalan keselamatan yang lebih tinggi berbanding lelaki. Namun, kelemahan dikenal pasti dari segi amalan kemas kini perisian serta kefahaman terhadap serangan sosial seperti *social engineering*. Kajian ini menyumbang kepada pembangunan strategi literasi digital yang lebih inklusif dan responsif terhadap keperluan sebenar pengguna. Secara tidak langsung, ia menyokong Matlamat Pembangunan Mampan SDG 4 (Pendidikan Berkualiti), SDG 9 (Industri, Inovasi dan Infrastruktur) melalui pengukuhan kapasiti keselamatan dalam ekosistem digital negara, serta SDG 16 (Keamanan, Keadilan dan Institusi Kukuh) melalui penekanan terhadap akses selamat kepada maklumat dan perlindungan data pengguna. Cadangan utama merangkumi pembangunan modul latihan digital berasaskan komuniti serta pengukuhan peranan institusi TVET sebagai pusat latihan keselamatan siber negara.
Kata kunci: Keselamatan Siber; Literasi Digital; Pengguna Malaysia.

1. Pengenalan

Keselamatan siber merupakan isu yang semakin kritikal dalam era digital moden, sejajar dengan kebergantungan masyarakat terhadap teknologi, internet, dan perkhidmatan dalam talian dalam pelbagai sektor seperti pendidikan, kewangan, komunikasi dan e-dagang. Ancaman dalam ruang siber bukan sahaja menggugat privasi individu, malah turut memberi impak besar terhadap kestabilan ekonomi, keselamatan data dan pembangunan sosial sesebuah negara. Di Malaysia, insiden jenayah siber seperti pancingan data, serangan perisian hasad, dan pencurian identiti menunjukkan trend peningkatan yang membimbangkan. Menurut laporan CyberSecurity Malaysia (2023), lebih daripada 13,000 insiden keselamatan siber telah direkodkan melibatkan

pelbagai bentuk serangan digital. Sementara itu, laporan Suruhanjaya Komunikasi dan Multimedia Malaysia (MCMC, 2022) mendedahkan bahawa hampir 45% pengguna masih belum mengamalkan langkah perlindungan asas semasa menggunakan internet, dengan golongan seperti warga emas dan peniaga mikro dilihat sebagai kumpulan paling terdedah.
Walaupun pelbagai inisiatif kesedaran telah digerakkan oleh pihak kerajaan dan swasta, jurang yang ketara masih wujud antara tahap pengetahuan dan amalan keselamatan siber dalam kalangan pengguna. Ramai pengguna sedar akan wujudnya risiko di alam digital, namun masih gagal melaksanakan amalan perlindungan yang berkesan seperti penggunaan kata laluan yang kukuh, pengesahan dua faktor, dan kemas kini perisian secara berkala. Dapatan ini turut disokong oleh kajian-kajian terdahulu termasuk oleh Zwilling et al. (2020) dan Fikry et al. (2023), yang menekankan bahawa tingkah laku keselamatan siber sangat dipengaruhi oleh faktor psikososial, sikap dan latar belakang individu. Dalam konteks ini, pemahaman yang lebih mendalam terhadap dimensi sosial dan psikologi pengguna digital di Malaysia amat penting bagi membolehkan pelaksanaan dasar dan intervensi keselamatan siber yang lebih efektif dan kontekstual.

Kajian ini bukan sahaja menyumbang kepada pemahaman yang lebih luas terhadap tahap kesedaran dan amalan keselamatan siber pengguna digital di Malaysia, malah turut menyokong Matlamat Pembangunan Mampan (SDG) yang digariskan oleh Pertubuhan Bangsa-Bangsa Bersatu. Kajian ini menyokong SDG 4 (Pendidikan Berkualiti) melalui peningkatan literasi digital dan keselamatan siber dalam kalangan masyarakat, serta SDG 16 (Keamanan, Keadilan dan Institusi Kukuh) melalui penekanan terhadap pembinaan budaya tanggungjawab digital, akses selamat kepada maklumat, dan penggubalan dasar perlindungan data yang inklusif. Selain itu, kajian ini juga secara tidak langsung menyumbang kepada SDG 9 (Industri, Inovasi dan Infrastruktur) dengan menyediakan data empirikal yang boleh digunakan untuk memperkukuh infrastruktur digital yang selamat dan menyokong inovasi dalam reka bentuk sistem perlindungan pengguna serta kandungan latihan keselamatan siber yang lebih responsif.

Sehubungan itu, objektif utama kajian ini adalah untuk menilai tahap kesedaran dan amalan keselamatan siber dalam kalangan pengguna digital di Malaysia, serta mengenal pasti hubungan antara kedua-dua pemboleh ubah tersebut. Kajian ini turut meneliti pengaruh faktor demografi seperti jantina, umur dan tahap pendidikan terhadap tingkah laku keselamatan digital. Walau bagaimanapun, kajian ini terhad kepada data yang diperoleh melalui laporan kendiri (self-reported) oleh responden dan tidak melibatkan pemerhatian terhadap tingkah laku digital sebenar. Meskipun responden terdiri daripada latar belakang yang pelbagai, mereka tidak mewakili keseluruhan populasi pengguna digital di Malaysia. Maka, generalisasi dapatan adalah terbatas kepada konteks data yang dikumpul semasa tempoh kajian. Kajian ini juga tidak menilai aspek teknikal keselamatan seperti konfigurasi sistem atau pemantauan log digital. Oleh itu, penyelidikan lanjutan disarankan menggunakan pendekatan kaedah campuran yang bukan sahaja melibatkan soal selidik, tetapi juga pemerhatian terhadap tingkah laku digital sebenar serta eksplorasi terhadap faktor psikososial seperti kepercayaan terhadap teknologi dan tahap motivasi dalam mengamalkan keselamatan siber.

2. Kajian Literatur

Keberkesanan program keselamatan siber masa kini tidak lagi bergantung kepada pengetahuan teknikal semata-mata, tetapi turut dipengaruhi oleh dimensi sosial, sikap pengguna serta pengalaman peribadi mereka dalam dunia digital. Kajian oleh Zulkifli et al. (2020; 2024) menggunakan pendekatan Rangka Kerja Keselamatan Siber NIST untuk menilai tahap kesedaran keselamatan siber dalam kalangan pelajar sekolah dan institusi pengajian tinggi (IPT). Dapatan mereka menunjukkan bahawa kerangka ini berkesan dalam membentuk pemahaman

dan tingkah laku keselamatan siber secara menyeluruh. Sementara itu, kajian Noor et al. (2022) membuktikan bahawa pendekatan gamifikasi melalui aplikasi "Our Cyberhero" mampu meningkatkan kesedaran dalam kalangan pengguna muda secara signifikan.
Faktor demografi dan nilai kemanusiaan juga didapati memainkan peranan penting. Kajian oleh Ting et al. (2024) dan Hasbullah et al. (2023) menunjukkan bahawa jantina, usia, dan sikap empati memberi kesan terhadap tahap amalan keselamatan digital. Raju et al. (2022) pula menegaskan bahawa latihan keselamatan siber secara formal dapat meningkatkan kemahiran pengguna, terutama dalam kalangan pelajar institusi pendidikan. Hal ini menunjukkan bahawa intervensi pendidikan dan latihan berstruktur perlu menjadi sebahagian daripada strategi literasi digital negara.

Dari sudut perundangan dan dasar, Widodo et al. (2024) menekankan kepentingan undang-undang antarabangsa dalam menangani jenayah siber, terutama bagi negara membangun yang masih lemah dari segi pelaksanaan dasar dan kerjasama rentas sempadan. Laporan ENISA (2023) turut menggariskan bahawa teknik serangan manipulasi psikologi seperti *social engineering* kini menjadi tumpuan utama penjenayah siber. Maka, pembentukan kesedaran keselamatan digital yang menyeluruh perlu merangkumi pendekatan psikososial selain aspek teknikal semata-mata.

Dalam konteks antarabangsa, Kovacevic et al. (2020) menekankan bahawa personaliti, motivasi intrinsik dan persekitaran sosial merupakan faktor utama yang mempengaruhi tingkah laku keselamatan siber di Eropah. Lee dan Chua (2023) pula mendapati bahawa faktor pendidikan, tahap pendapatan dan jantina memberi kesan signifikan terhadap tahap pengetahuan dan amalan pengguna digital di Amerika Syarikat. Ini membuktikan bahawa intervensi keselamatan siber perlu direka bentuk secara kontekstual, bersesuaian dengan profil pengguna di setiap lokasi.

Dalam landskap Malaysia, kajian oleh Ahlan et al. (2021) menunjukkan bahawa peningkatan penggunaan teknologi digital dalam sektor pendidikan, kewangan dan e-dagang secara tidak langsung meningkatkan risiko keselamatan siber. Namun, tahap kesedaran dan amalan keselamatan pengguna masih tidak konsisten. Sebagai contoh, kajian oleh Zulkifli et al. (2020) dan Raju et al. (2022) menunjukkan bahawa pelajar IPT dan pelajar sekolah mempunyai tahap kesedaran yang sederhana dan cenderung mengabaikan amalan keselamatan secara berkala. Yeo et al. (2021) dan Krishnan et al. (2023a; 2023b) pula menunjukkan bahawa pengguna media sosial dan pekerja sektor perbankan turut dipengaruhi oleh budaya organisasi dan latar sosiodemografi dalam membentuk perlakuan keselamatan mereka.

Dalam konteks pembangunan mampan, keselamatan siber tidak hanya bertindak sebagai mekanisme perlindungan individu, tetapi turut memainkan peranan penting dalam memperkukuh infrastruktur digital yang selamat dan tahan gangguan, selari dengan matlamat SDG 9: Industri, Inovasi dan Infrastruktur**.** Kajian oleh Ahlan et al. (2021) dan Widodo et al. (2024) membuktikan bahawa kelemahan dalam sistem keselamatan digital boleh mengganggu operasi organisasi dan menyekat pertumbuhan inovasi digital negara. Oleh itu, pendidikan dan literasi keselamatan siber yang berasaskan bukti tempatan perlu diberi perhatian dalam memperkasa masyarakat digital Malaysia.

Satu penemuan konsisten dalam banyak kajian terdahulu ialah kewujudan jurang yang ketara antara pengetahuan dan perlakuan keselamatan sebenar. Kajian oleh Zwilling et al. (2020) dan Ting et al. (2024) mengesahkan bahawa pengguna cenderung tidak mengamalkan perlindungan seperti pengesahan dua faktor walaupun menyedari kepentingannya. Fikry et al. (2023a; 2023b)

pula mengaitkan kelemahan ini dengan sikap acuh tak acuh serta kekurangan latihan keselamatan yang konsisten.

Bagi mengatasi cabaran ini, pelbagai cadangan telah diketengahkan. Diana et al. (2024) mencadangkan integrasi keselamatan digital dalam kurikulum pendidikan, manakala Zulkifli et al. (2024) mencadangkan penggunaan Rangka Kerja NIST sebagai asas pembangunan modul pendidikan keselamatan. Hasbullah et al. (2023) menekankan pentingnya nilai empati dalam membentuk budaya keselamatan digital yang lestari. Namun, kebanyakan kajian ini tertumpu kepada pelajar IPT dan pekerja sektor formal, dengan memberi kurang perhatian kepada golongan lain seperti suri rumah, peniaga mikro dan warga emas. Tambahan pula, program kesedaran keselamatan siber di Malaysia sering bersifat umum dan jarang dinilai secara menyeluruh melalui pendekatan longitudinal (Rahman, 2024; Chua, 2020).

Berdasarkan jurang yang dikenal pasti, kajian ini dijalankan untuk menilai tahap kesedaran dan amalan keselamatan siber dalam kalangan pengguna digital di Malaysia dengan mengambil kira pelbagai latar sosiodemografi dan faktor psikososial. Usaha ini diharapkan dapat menyumbang kepada pembangunan strategi keselamatan digital yang lebih bersasar, inklusif, dan selari dengan keperluan sebenar pengguna digital semasa. Kajian ini bukan sahaja menyokong SDG 4 (Pendidikan Berkualiti) dan SDG 16 (Institusi Kukuh dan Akses Selamat kepada Maklumat)**,** malah turut memberi sumbangan penting kepada SDG 9 (Industri, Inovasi dan Infrastruktur) melalui penyediaan data empirik yang menyokong pembinaan infrastruktur digital yang lebih selamat dan berdaya tahan di Malaysia.

3. Metodologi Kajian

Kajian ini menggunakan pendekatan kuantitatif berasaskan reka bentuk tinjauan deskriptif dan inferensi, bagi menilai tahap kesedaran serta amalan keselamatan siber dalam kalangan pengguna digital di Malaysia. Pemilihan reka bentuk ini adalah sesuai kerana ia membolehkan pengumpulan data secara sistematik dan berskala besar melalui soal selidik atas talian, sekaligus menjimatkan masa dan kos pelaksanaan. Selain itu, pendekatan ini membolehkan analisis hubungan antara pemboleh ubah diuji dengan lebih tepat menggunakan kaedah statistik. Populasi kajian terdiri daripada pengguna digital yang mempunyai akses kepada internet dan menggunakan perkhidmatan digital seperti media sosial, e-mel dan platform e-dagang. Sampel kajian dipilih secara persampelan mudah melalui edaran soal selidik dalam talian menggunakan Google Forms, dan seramai 392 responden telah terlibat, mewakili pelbagai latar belakang dari segi umur, jantina dan tahap pendidikan. Walaupun kaedah ini memudahkan capaian yang luas, ia juga membawa keterbatasan dari segi kemampuan untuk mewakili keseluruhan populasi, justeru kajian masa hadapan disarankan untuk menggunakan kaedah persampelan rawak berstrata.

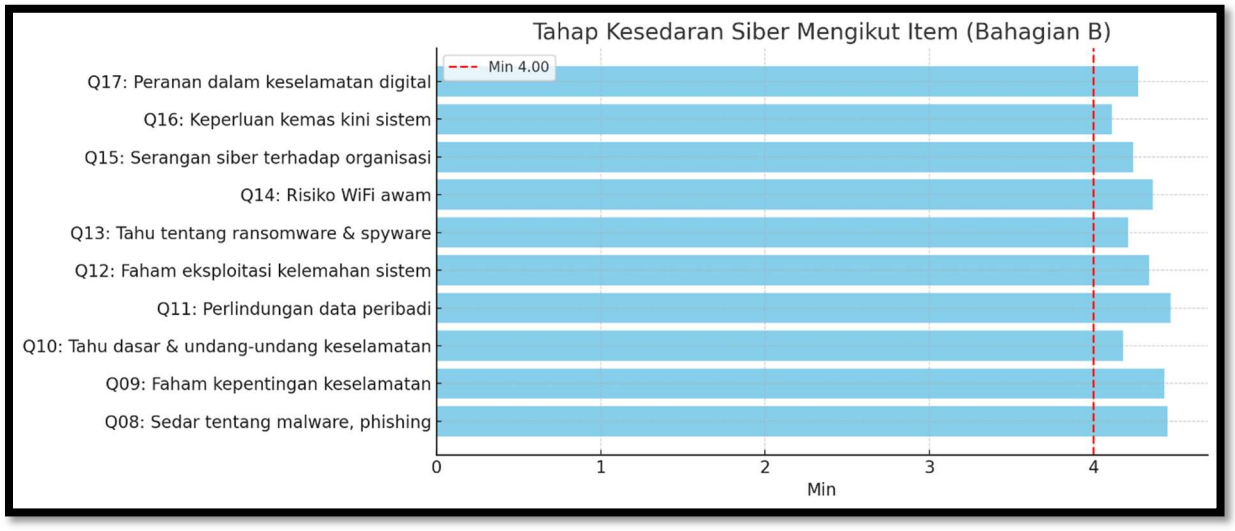
Instrumen utama kajian ialah soal selidik berstruktur yang dibangunkan berdasarkan kajian literatur terdahulu serta disesuaikan mengikut konteks pengguna digital di Malaysia. Soal selidik ini terdiri daripada tiga bahagian iaitu maklumat demografi, tahap kesedaran keselamatan siber, dan amalan keselamatan siber, masing-masing dinilai menggunakan skala Likert lima mata. Pembinaan item dalam soal selidik berpandukan kepada kerangka keselamatan siber oleh *National Institute of Standards and Technology (NIST)* yang meliputi lima fungsi utama: mengenal pasti, melindungi, mengesan, bertindak balas dan memulihkan (Riley et al., 2008), serta disokong oleh dapatan kajian seperti Fikry et al. (2023) dan Zwilling et al. (2020) yang menekankan kepentingan dimensi psikososial dan jurang antara pengetahuan serta amalan. Bagi memastikan kesahan kandungan, soal selidik telah disemak oleh pakar dalam bidang keselamatan siber dan teknologi pendidikan. Ujian kebolehpercayaan dilakukan ke atas 30 responden awal

menggunakan pekali Cronbach's Alpha, menunjukkan nilai kebolehpercayaan yang tinggi dengan α = 0.87 untuk bahagian kesedaran dan α = 0.89 untuk bahagian amalan, melepasi piawaian minimum α = 0.70 seperti disarankan oleh Chua (2020).

Pengumpulan data dilaksanakan dalam tempoh empat minggu dengan edaran pautan soal selidik melalui media sosial, e-mel serta aplikasi pesanan seperti WhatsApp dan Telegram. Semua responden diberikan maklumat mengenai tujuan kajian dan jaminan kerahsiaan data, dan penyertaan adalah secara sukarela. Data yang diperoleh dianalisis menggunakan perisian SPSS versi 26. Statistik deskriptif digunakan untuk mendapatkan nilai min, sisihan piawai dan taburan frekuensi bagi tahap kesedaran dan amalan keselamatan. Ujian Korelasi Pearson digunakan bagi menilai hubungan antara kedua-dua pemboleh ubah tersebut. Bagi mengenal pasti perbezaan berdasarkan demografi, ujian-t bebas digunakan bagi jantina manakala Ujian ANOVA Sehala digunakan bagi kumpulan umur dan tahap pendidikan. Aras kesignifikanan ditetapkan pada $p < 0.05$ bagi semua analisis. Walau bagaimanapun, skop kajian ini terhad kepada laporan kendiri yang mungkin tidak menggambarkan tingkah laku sebenar pengguna digital. Kajian ini juga tidak menilai secara langsung keberkesanan intervensi keselamatan siber. Oleh itu, disarankan agar penyelidikan lanjutan dilaksanakan menggunakan pendekatan campuran yang merangkumi kaedah kuantitatif dan kualitatif seperti temu bual mendalam atau pemerhatian tingkah laku digital sebenar bagi memperoleh pemahaman yang lebih menyeluruh terhadap faktor yang mempengaruhi amalan keselamatan siber dalam kalangan pengguna digital di Malaysia.

4. Dapatan dan Perbincangan

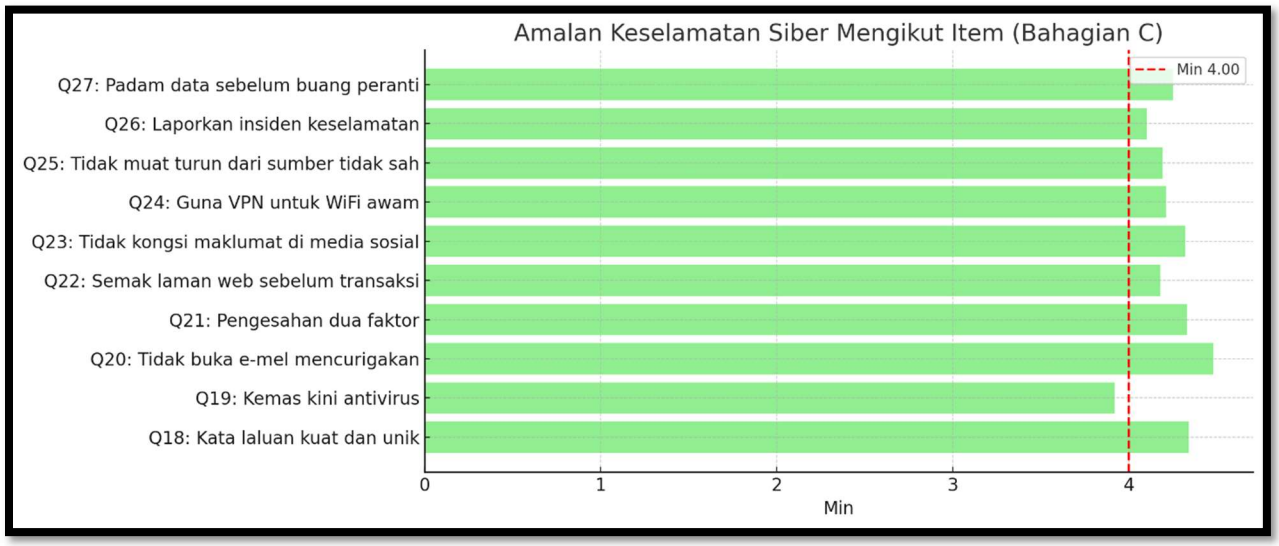
Kajian ini telah melibatkan seramai 392 responden daripada pelbagai latar belakang demografi di Malaysia. Majoriti responden merupakan wanita iaitu sebanyak 62.2%, manakala lelaki pula merangkumi 37.8% daripada keseluruhan sampel. Dari aspek umur, kebanyakan responden berumur antara 18 hingga 25 tahun iaitu sebanyak 55.4%, diikuti oleh kumpulan umur 26 hingga 35 tahun sebanyak 31.1%, manakala selebihnya berumur melebihi 36 tahun. Dari sudut tahap pendidikan pula, 54% daripada responden memiliki kelayakan diploma, 29% berkelulusan ijazah sarjana muda, manakala bakinya terdiri daripada pemegang sijil atau pascasiswazah.



Rajah 1. Perbandingan skor min bagi setiap item kesedaran

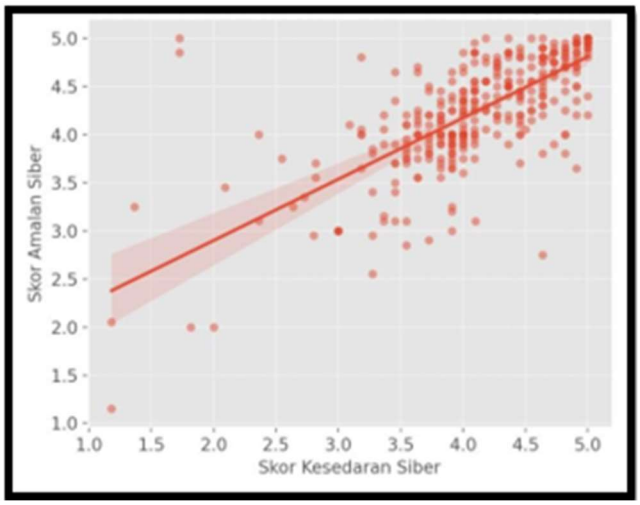
Hasil analisis deskriptif dari rajah 1 yang menilai tahap kesedaran keselamatan siber menunjukkan nilai min keseluruhan adalah 4.15 dengan sisihan piawai sebanyak 0.66. Dapatan

ini menandakan bahawa tahap kesedaran dalam kalangan responden adalah tinggi, dengan sebanyak 89.3% daripada mereka menunjukkan tahap kesedaran yang tinggi dan hanya 2.0% berada pada tahap yang rendah. Item dengan min tertinggi ialah “Saya sedar mengenai kepentingan perlindungan data peribadi.” (min = 4.61), manakala min terendah ialah “Saya menyedari keperluan untuk mengemas kini perisian dan sistem keselamatan.” (min = 4.26). Ini menunjukkan bahawa pengguna lebih sedar tentang langkah perlindungan asas, tetapi masih lemah dalam memahami keperluan untuk mengemas kini perisian dan sistem keselamatan. Ini menunjukkan tindakan perlu diambil untuk memberi pemahaman mengenai pentingnya memastikan perisian dan sistem keselamatan yang sentiasa terkini.



Rajah 2. Perbandingan skor min bagi setiap item amalan

Dapatan daripada rajah 2 yang mengukur tahap amalan keselamatan siber pula menunjukkan nilai min keseluruhan adalah 4.27 dengan sisihan piawai sebanyak 0.58, sekali gus menandakan tahap amalan yang tinggi dalam kalangan responden. Ini menunjukkan bahawa bukan sahaja responden mempunyai tahap kesedaran yang tinggi, bahkan mereka turut mengamalkan perlindungan asas dalam penggunaan teknologi.Item amalan dengan skor tertinggi adalah tindakan tidak membuka lampiran e-mel daripada pengirim tidak dikenali, manakala item dengan skor terendah adalah amalan mengemas kini perisian dan antivirus secara berkala. Ini memperlihatkan satu jurang yang ketara dalam kesedaran teknikal, yang berpotensi menjadi titik kelemahan dalam sistem perlindungan digital peribadi. Analisis Korelasi Pearson telah dijalankan bagi menilai hubungan antara skor kesedaran dan skor amalan keselamatan siber.



Rajah 3. Korelasi antara Kesedaran dan Keselamatan Siber

Dalam rajah 3 di tunjukkan secara jelas hubungan linear yang jelas antara dua konstruk tersebut. Ujian Korelasi Pearson menunjukkan hubungan positif yang sangat kuat antara tahap kesedaran dan amalan keselamatan siber ($r = 0.73$, $p < 0.001$). Ini menunjukkan bahawa peningkatan kesedaran berkait rapat dengan peningkatan amalan keselamatan.
Perkara ini selari dengan dapatan oleh Fikry et al. (2023) dan Krishnan et al. (2023) yang menyatakan bahawa peningkatan tahap pengetahuan memberi impak positif kepada perubahan tingkah laku pengguna digital. Ia turut disokong oleh kajian antarabangsa oleh Lee dan Chua (2023) serta Kovacevic et al. (2020) yang menyatakan faktor pendidikan, jantina dan motivasi intrinsik sebagai penentu amalan keselamatan digital.

Analisis lanjut turut dijalankan menggunakan ujian ANOVA dan ujian-t bagi mengenal pasti perbezaan tahap kesedaran dan amalan berdasarkan faktor demografi seperti umur, tahap pendidikan dan jantina.

Jadual 1. ANOVA Berdasarkan Umur

Pemboleh Ubah	Nilai F	p-value	Keputusan
Skor Kesedaran	0.82	0.513	Tidak signifikan
Skor Amalan	1.32	0.260	Tidak signifikan

Ujian ANOVA bagi kumpulan umur menunjukkan bahawa tiada perbezaan signifikan dalam tahap kesedaran ($F = 0.82$, $p = 0.513$) dan amalan keselamatan siber ($F = 1.32$, $p = 0.260$). Hasil analisis ini menunjukkan bahawa tiada perbezaan yang signifikan dalam tahap kesedaran dan amalan keselamatan siber antara kumpulan umur yang berbeza.

Jadual 2. ANOVA Berdasarkan Tahap Pendidikan

Pemboleh Ubah	Nilai F	p-value	Keputusan
Skor Kesedaran	5.24	0.0004	Signifikan
Skor Amalan	1.88	0.114	Tidak signifikan

Namun begitu, keputusan ANOVA berdasarkan tahap pendidikan menunjukkan perbezaan signifikan dalam tahap kesedaran ($F = 5.24$, $p = 0.0004$), manakala perbezaan dalam tahap amalan tidak signifikan ($F = 1.88$, $p = 0.114$). Analisis menunjukkan terdapat perbezaan yang signifikan dalam tahap kesedaran keselamatan siber namun tiada perbezaan signifikan dalam tahap amalan.

Jadual 3. Ujian-t Berdasarkan Jantina

Pemboleh Ubah	Nilai t	p-value	Keputusan
Kesedaran	-0.93	0.351	Tidak signifikan
Amalan	-2.31	0.022	Signifikan

Ujian-t bagi pemboleh ubah jantina pula menunjukkan tiada perbezaan signifikan dalam tahap kesedaran ($t = -0.93$, $p = 0.351$) antara lelaki dan perempuan, tetapi terdapat perbezaan signifikan dalam tahap amalan ($t = -2.31$, $p = 0.022$), dengan wanita mencatatkan skor amalan yang lebih tinggi berbanding lelaki.

Secara keseluruhannya, dapatan kajian ini menunjukkan bahawa pengguna digital di Malaysia secara amnya mempunyai tahap kesedaran dan amalan keselamatan siber yang tinggi. Namun demikian, kelemahan masih wujud terutama dalam aspek pemahaman terhadap serangan siber yang lebih kompleks seperti social engineering serta keperluan untuk mengemas kini sistem dan perisian secara berkala. Ini memberi isyarat bahawa pendidikan keselamatan digital perlu diperluas dengan memberi penekanan kepada bentuk ancaman moden dan memperkenalkan kaedah penyampaian yang lebih berkesan seperti gamifikasi, chatbot, dan intervensi digital yang berasaskan profil pengguna. Secara tidak langsung, dapatan kajian ini menyokong aspirasi Matlamat Pembangunan Mampan (SDG) terutamanya SDG 4 berkaitan Pendidikan Berkualiti dan SDG 16 berkaitan Institusi Kukuh dan Akses kepada Maklumat Selamat. Kajian ini juga menggesa agar program pendidikan keselamatan digital yang lebih menyeluruh, bukti berasaskan dan sesuai dengan keperluan komuniti tempatan dilaksanakan secara sistematik dan menyeluruh.

5. Kesimpulan dan Cadangan

Kajian ini telah memberikan gambaran yang menyeluruh mengenai hubungan antara tahap kesedaran keselamatan siber dengan amalan keselamatan dalam kalangan pengguna digital di Malaysia. Berdasarkan analisis data kuantitatif yang diperoleh daripada 392 responden, dapatan menunjukkan bahawa terdapat hubungan positif yang sangat kuat antara kedua-dua pemboleh ubah, dengan nilai min kesedaran sebanyak 4.15 dan amalan sebanyak 4.27, manakala nilai korelasi Pearson (r) adalah 0.73. Ini membuktikan bahawa literasi digital tidak hanya merangkumi pengetahuan teknikal, tetapi turut melibatkan sikap, nilai, dan kebiasaan pengguna dalam melindungi maklumat peribadi serta peranti digital mereka daripada ancaman siber. Kajian ini turut mengesahkan dapatan terdahulu seperti oleh Lee dan Chua (2023) serta Kovacevic et al. (2020), yang menyatakan peningkatan pengetahuan berkait rapat dengan perlakuan perlindungan digital. Namun begitu, kelemahan tertentu dikenal pasti seperti kurang pengetahuan mengenai teknik serangan seperti social engineering dan amalan kemas kini perisian yang rendah. Faktor sosiodemografi seperti tahap pendidikan dan umur turut mempengaruhi tahap kesedaran dan amalan keselamatan, sekali gus menunjukkan keperluan kepada intervensi bersasar berdasarkan profil pengguna.

Walaupun kajian ini tertumpu kepada pengguna digital di Malaysia, dapatan yang diperoleh boleh digeneralisasikan dalam konteks negara membangun lain yang berdepan jurang literasi digital dan ancaman keselamatan siber yang semakin kompleks. Golongan rentan seperti warga emas, pelajar sekolah dan peniaga kecil berisiko tinggi menjadi mangsa jenayah siber sekiranya tiada intervensi bersesuaian. Oleh itu, strategi literasi digital kebangsaan yang inklusif dan holistik amat diperlukan. Kajian ini turut memberi impak signifikan kepada institusi pendidikan melalui penyediaan asas bagi pembangunan kurikulum dan latihan keselamatan digital yang lebih efektif, khususnya dalam konteks institusi TVET. Bagi agensi kerajaan pula, dapatan ini boleh

menyokong dasar keselamatan siber nasional serta membentuk program celik digital yang lebih mesra komuniti. Dalam sektor industri, hasil kajian ini menjadi rujukan penting bagi membina sistem perlindungan pengguna yang bersesuaian dengan tahap literasi siber rakyat.

Secara langsung, kajian ini menyumbang kepada tiga Matlamat Pembangunan Mampan (SDGs) yang penting, iaitu: SDG 4 (Pendidikan Berkualiti) melalui cadangan integrasi pendidikan keselamatan siber dalam kurikulum dan latihan kemahiran; SDG 9 (Industri, Inovasi dan Infrastruktur) melalui sokongan terhadap pembangunan infrastruktur digital yang selamat dan inovatif berasaskan data komuniti; serta SDG 16 (Keamanan, Keadilan dan Institusi Kukuh) melalui penekanan kepada pengukuhan budaya tanggungjawab digital, pembangunan dasar perlindungan data, dan peningkatan kepercayaan terhadap institusi digital. Kajian ini membina asas penting ke arah masyarakat digital yang lebih beretika, selamat dan berdaya tahan.

Berdasarkan dapatan, beberapa cadangan strategik dikemukakan untuk tindakan lanjut. Pertama, pembangunan modul latihan keselamatan digital yang inklusif untuk kumpulan sasar seperti pelajar, warga emas dan suri rumah perlu dilaksanakan secara menyeluruh. Kedua, pelaksanaan program komuniti celik siber melalui kolaborasi antara agensi kerajaan, NGO dan industri boleh memperluas jangkauan pendidikan keselamatan digital. Ketiga, institusi TVET wajar diperkasa sebagai pusat latihan keselamatan digital peringkat nasional dengan penekanan kepada latihan praktikal dan pembangunan kompetensi. Untuk memperkukuh hasil kajian, penyelidikan lanjutan disarankan menggunakan pendekatan mixed-methods, termasuk penggunaan log data, simulasi serangan, dan temubual mendalam bagi memahami motivasi, kepercayaan, dan persepsi risiko yang mempengaruhi perlakuan keselamatan digital. Dengan pendekatan yang lebih menyeluruh, kajian masa hadapan berpotensi menyumbang kepada ekosistem keselamatan digital yang lebih mapan dan lestari untuk Malaysia serta rantau serantau.

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APPLICATION OF THE MATURITY METHOD FOR CONCRETE STRENGTH ESTIMATION: ACTIVATION ENERGY MODEL ANALYSIS

Herdawati binti Bohari[1]*, Norwati binti Jamaluddin[2], Mohammad Soffi bin Md Noh[2]

[1]Civil Engineering Department, Port Dickson Polytechnic, 71050 Port Dickson, Negeri Sembilan, Malaysia

[2]Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia

*Corresponding author e-mail address: herdawati@polipd.edu.my

Abstract

In the construction industry, the concrete strength is a crucial parameter because it can affect the structure's durability and performance. This study examines the maturity method for estimating concrete strength by investigating the relationship between temperature, curing time, and strength. This study aims to develop the strength maturity curve for C25 grade concrete using the Arrhenius function to predict the concrete strength by following ASTM C1074 standards. The study involves 17 cylindrical specimens: 15 for compression tests and 2 embedded with thermocouples for temperature monitoring over 28 days. The results demonstrate the successful application of the maturity method in predicting the strength of concrete. The activation energy model yields a satisfactory result, as the strength prediction for C25 aligns closely with the actual compressive strength obtained from tests, within an acceptable range of less than 10%.
Keywords: Concrete strength; Maturity method; Strength maturity curve.

1. Introduction

Concrete strength is an essential parameter in construction, and it refers to the durability and performance of a constructed structure. To ensure that the built structure meets the requirements of safety, quality, and life expectancy, concrete strength monitoring needs to be done continuously until the concrete reaches the final strength. In addition, concrete strength monitoring plays an essential role in producing quality construction, complying with established standards, and implementing effective project management. Without proper monitoring, the risk of structural failure, additional costs, safety issues, and project time management will increase significantly. One of the critical aspects in this context is determining the appropriate time at which the formwork can be removed safely without compromising the integrity of the concrete structure. To remove the supporting formwork under horizontal members, the compressive strength must be at least 70% of the concrete's final (28 days) strength for members up to 6 m and 85% for spans more than 6 m (Szymon, 2017). Removing formwork too soon can result in dangerous conditions and structural damage or distortion, whilst keeping it in place for too long might make removal difficult and damage the surface quality of the concrete, thereby increasing overall rental costs.

Usually, concrete strength at the construction site is monitored using a conventional method: compression test on a cube or cylinder. Samples must be prepared often when concrete casting works are carried out, where compression tests will be carried out on three samples, starting at 7, 14, and 28 days. Many samples used for break tests will increase the cost of concrete, and the time required to gather the compressive strength data will delay the decision-making for striking formwork and waste time, at the same time making it less practical for real-time applications. A method has been developed to address this issue: the maturity method, which estimates concrete strength based on the relationship between temperature, curing time, and concrete strength

(Carino N.J & Lew H.S, 2001). The advantage of this method is that real-time strength monitoring can be implemented on the construction site compared to the conventional method.

The main objective of this study is to produce a maturity-strength chart using the Arrhenius function by implementing the maturity method according to ASTM C1074 to predict concrete strength. The concrete used in this study focuses on C25 grade concrete. The results of this study aim to contribute to researchers and all parties and institutions involved in understanding the maturity method in predicting the strength of concrete and promoting efficiency and quality in construction practice.

2. Development of the Maturity Method

The maturity method is one of the non-destructive approaches used to estimate the early-age strength of concrete. In the early 1950s, researchers in England conducted a study of methods to accelerate the curing process of concrete, and the findings show that the combination of temperature and time affects the development of concrete. This combination of temperature and time refers to the maturity of the concrete. Understanding this concept allows for predicting concrete strength at any time, based on temperature conditions and curing time. The first step in this method is to create a relationship between concrete strength and maturity index, also called equivalent age, which will be determined using temperature data. The maturity index measured in situ (at the actual location where the concrete is, such as a construction site) is used to estimate the strength of the concrete at that location. This method has also been used in various studies for different activities and types of concrete.

Referring to Tekle et al. (2022) the maturity method provides a more accurate estimation of in-situ concrete strength under cold weather conditions compared to standard cylinder specimens. Meanwhile, the findings in the research to evaluate self-compacting concrete strength (SCC) suggest that the maturity method provides a reliable estimation of SCC strength development. (Nepomuceno & Bernardo, 2019). The research conducted by Hrischev et al. (2022), confirms that the maturity method provides an accurate and reliable estimation of early-age compressive strength, especially when compared to the rebound hammer test, making it a viable alternative for on-site strength monitoring. Other research to predict the strength development of concrete made by Portland Cement Composite (PCC) in high-temperature countries shows that the maturity method effectively estimates the early-age compressive strength. These results confirm that the maturity method is applicable for PCC concrete under high temperatures, with prediction errors consistently below 4%, indicating its reliability for in-situ strength estimation in warm climates (Turuallo et al., 2022).

2.1 Arrhenius Maturity Function

The concept of maturity for estimating the strength generated by concrete is described in ASTM C1074 (Standard Practice for Estimating Concrete Strength by the Maturity Method). Two functions have been allowed in ASTM C1074 to determine the maturity index: the Nurse-Saul function and the Arrhenius function. These two functions use different constants to measure the maturity index, where the Nurse-Saul maturity function uses the Datum Temperature constant, and the Arrhenius maturity function uses the Activation Energy constant. This constant varies according to the type of cement used.

The function developed by Freiesleben, Hansen, and Pedersen (1977) using the equivalent age expression is one of the most often used functions based on the Arrhenius equation. The use of

equivalent age has been standardized in most standards, such as ASTM C1074 and the European code (Dane Miller et al., 2023) The Arrhenius function is given by Equation (1).

$$t_e = \sum_{t=0}^{t^*} e^{-Q\left(\frac{1}{T_a}-\frac{1}{T_s}\right)}.\Delta t \qquad \text{Equation (1)}$$

where:

t_e = Maturity given as Equivalent Age (hrs)
Δt = Time interval (hrs)
t^* = Concrete age at time of strength estimation (hrs)
T_a = Average concrete temperature during Δt (K)
T_s = Specified temperature (K)
Q = Activation energy (E) divided by the universal gas constant (R)

The Arrhenius maturity function is used to convert degrees Celsius to degrees Kelvin (Celsius + 273). According to ASTM C1074 (2011), the equivalent age calculation also requires a specific temperature. Traditionally, 20 ^{0}C has been used, while other references have used 23 ^{0}C. Meanwhile, the universal gas constant, R value, has been specified as 8.3144 J/mol-K. Several researchers hypothesized activation energies for various cementitious systems, which were then empirically determined. ASTM C1074 also mentioned that the activation energy values of Type I cement without admixtures range from 40,000 to 45,000 J/mol.

2.2 Logarithmic Functions in Modelling Concrete Strength-Maturity Relationships

A calibration process is essential to ensure that the estimation of the strength of concrete is accurate. This calibration, which establishes the strength-maturity relationship, must be performed specifically for each concrete mix design. By developing this relationship in the lab for a particular mix, it becomes possible to predict the concrete's compressive strength on-site in real time. The strength of concrete can be considered to have a direct linear relationship with the logarithm of its maturity index, regardless of whether the Temperature-Time Factor or Equivalent Age method is used to calculate maturity. Wade et al. (2006) note that only three functions were typically employed, which are hyperbolic, exponential, and polynomial. Meanwhile, Akuamoah (2021) have suggested that hyperbolic and logarithmic functions are the most used to model strength-maturity correlations, despite other proposed functions. Quan Ma et al. (2023) have mentioned that the logarithmic function generally provides a better correlation for predicting concrete strength than the exponential function. It was proven when the predicted results for compressive strength were relatively accurate for the first 1-14 days, with most errors within 10%. The logarithmic function is shown below:

Logarithmic Function:

$$Strength = a + b\ log(M) \qquad (2)$$

Where:

a = strength for maturity index M =1,
b = slope of the line, and
M = maturity index

3. Experimental Methodology

3.1 Materials Preparation and Testing

The primary materials used in this study were Ordinary Portland Cement (OPC), fine aggregate, coarse aggregate, and water. OPC (Type I) was certified by SIRIM compliance to MS 197-1:2007. Sieve analysis for aggregate on both fine and coarse aggregates was conducted to determine the particle size distribution, referring to BS 882, 1992 standards.

3.2 Design Mix

Concrete grade C25 was utilized for calibration and validation testing. The Department of the Environment Method was used to design the concrete mixture. This concrete mix will be designed to achieve a compressive strength of 25 N/mm^2 in 28 days. The mix proportions for the concrete mixture were illustrated in Table 1, with a total target collapse slump test between 60mm and 180mm.

Table 1. C25 mix proportions.

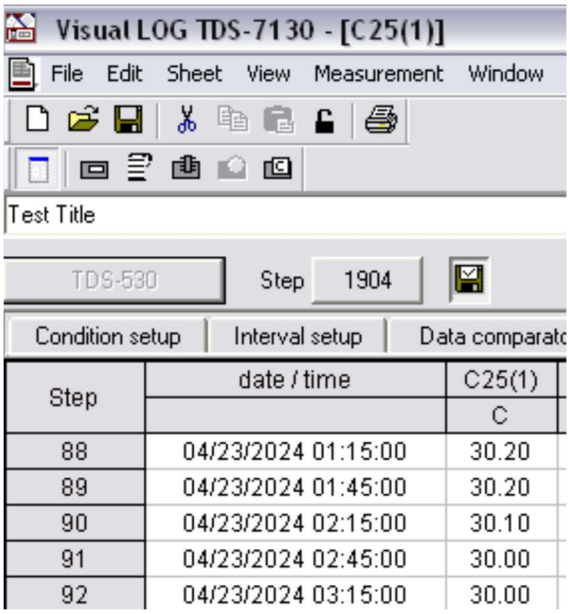
Cement (kg/m^3)	Water Cement Ratio (w/c)	Fine Aggregate (kg/m^3)	Coarse Aggregate (kg/m^3)
410	0.5	808	983

3.3 Calibration Test

The calibration test was performed using strength and temperature tests on the same sample size. The ASTM C1074 standard states that a minimum of five points must be obtained, and the suggested testing duration can be set to 1, 3, 7, 14, or 28 days. Therefore, 17 units of cylinder samples (100 mm in diameter and 200 mm in length) were prepared, where 2 units of cylinder samples were used for temperature monitoring, and another 15 units of cylinder samples were used for strength monitoring. All the samples were cured using the water bath method. For temperature monitoring, a thermocouple of 100 mm type 'K' was placed at the centre of the sample with an average depth of 130mm from the bottom surface of the cylinder, as shown in Figure 1 below. This thermocouple was connected directly to a data logger, TDS-530, and the temperature was recorded using 30-minute intervals as recommended by ASTM C1074 for 28 days. The data from the data logger was forwarded to the TDS-7130 software as shown in Figure 2.



Fig. 1. Placement of thermocouple type 'K' during sample casting.



Step	date / time	C25(1)
		C
88	04/23/2024 01:15:00	30.20
89	04/23/2024 01:45:00	30.20
90	04/23/2024 02:15:00	30.10
91	04/23/2024 02:45:00	30.00
92	04/23/2024 03:15:00	30.00

Fig. 2. Temperature data recorded by TDS-7130 software.

Three-cylinder samples were tested to determine the average strength for every age, as stated before, using a compressive strength test. ASTM C1074 states that another cylinder should be tested and the three results averaged if the compressive strength ranges of the two specimens are greater than 10% of their average strength. Any low-test results brought on by a defective specimen should be discarded.

The equivalent age (20 ^{0}C), t_e is calculated based on the temperature data recorded using Equation 2.1 above. Then, the strength age vs. maturity index graph is plotted to obtain the calibration curve using 5-point data (1, 3, 7, 14, and 28 days). The overview of the maturity calibration test is shown in Figure 3 below.

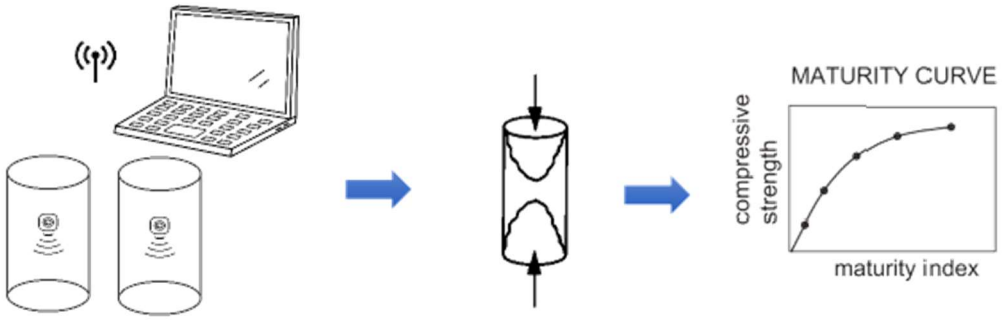


Fig. 3. Overview of the maturity calibration test

3.4 Validation Test

The validation test is crucial to confirming the successful application of the maturity method. The 11-cylinder test sample must be identical to the concrete that is utilized during testing. Two of these cylinders were equipped with thermocouples for temperature monitoring. The remaining 9

cylinders were used for compression tests at 7, 14, and 28 days, and all samples were cured in a water bath. Concrete strength was determined by testing the cylinders at the specified ages. Maturity is calculated using the temperature data from the monitoring cylinders, and then the estimated strength is obtained from the maturity curve using the calculated maturity. According to ASTM C1074, the maturity curve is considered valid if the estimated and measured compressive strengths are within 10% of each other. If the strength difference exceeds 10%, a new curve needs to be developed to better represent the specific concrete mix.

4. Results and Discussion

4.1 Development of Calibration Maturity Curve

Figure 4 shows the average temperature monitoring of both thermocouples during the 28 days of curing. According to the findings, the concrete emits more heat during the first 24 hours (Day 1) of hardening, reaching an average maximum temperature of 36.08 ^{0}C, before beginning to decrease over the next 28 days. This situation is brought on by cement hydration, which thickens and hardens the mixture. Figure 5 shows the average temperature against equivalent age (1, 3, 7, 14, and 28 days), which is converted to degrees Kelvin (^{0}K).

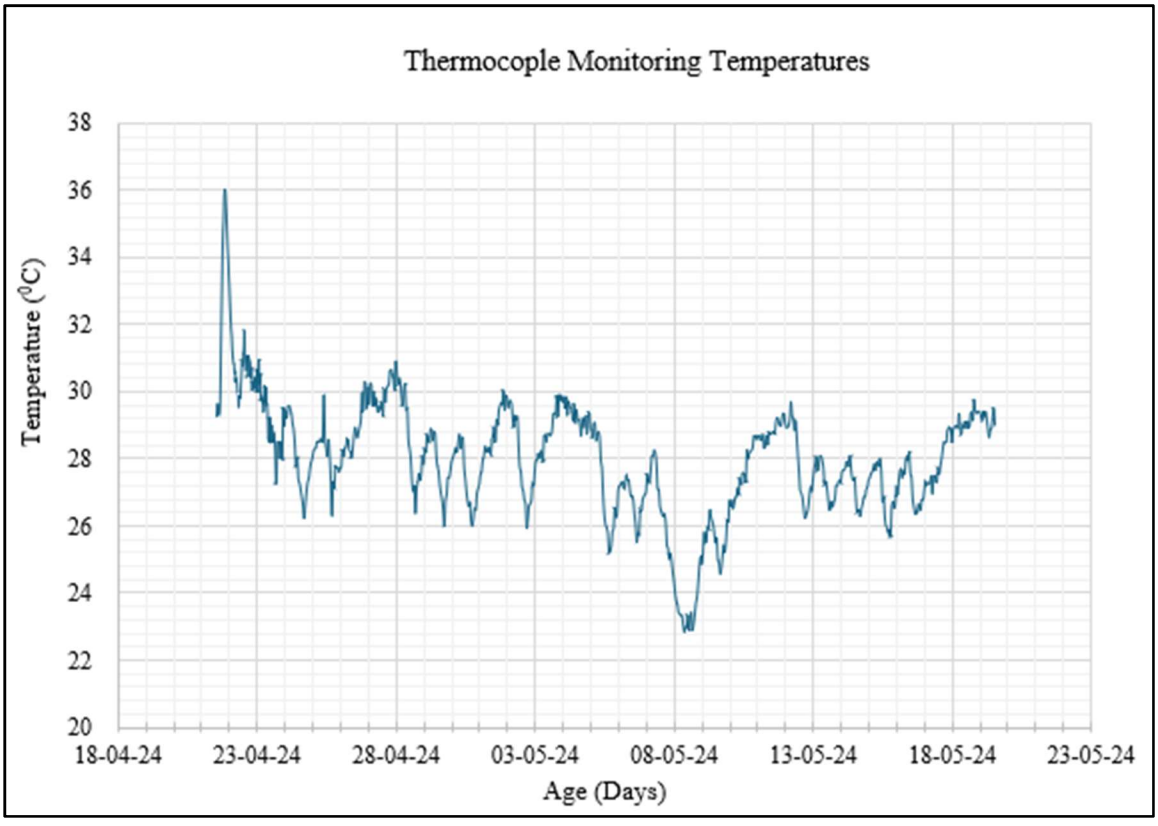


Fig. 4. Temperature monitoring of a concrete cylinder using a thermocouple.

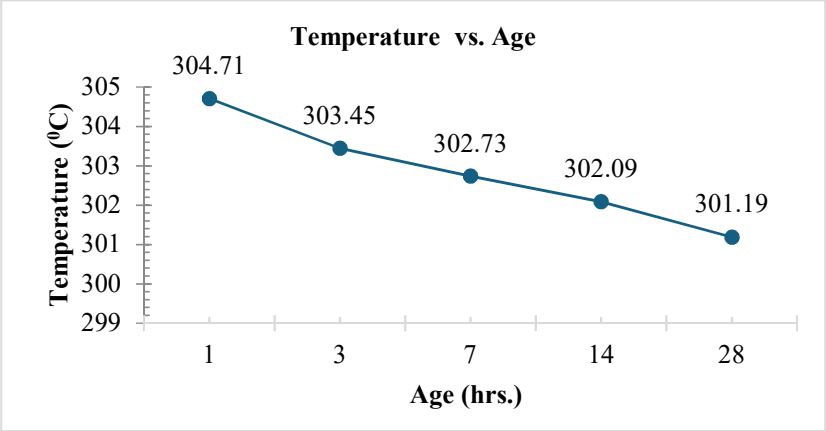


Fig. 5. Temperature average at equivalent age.

Figure 6 below illustrates the average strength of the calibration cylinder test for 1, 3, 7, 14, and 28 days. The 28-day compressive strength of the calibration mix exceeded 100% of the 25 N/mm^2 design compressive strength.

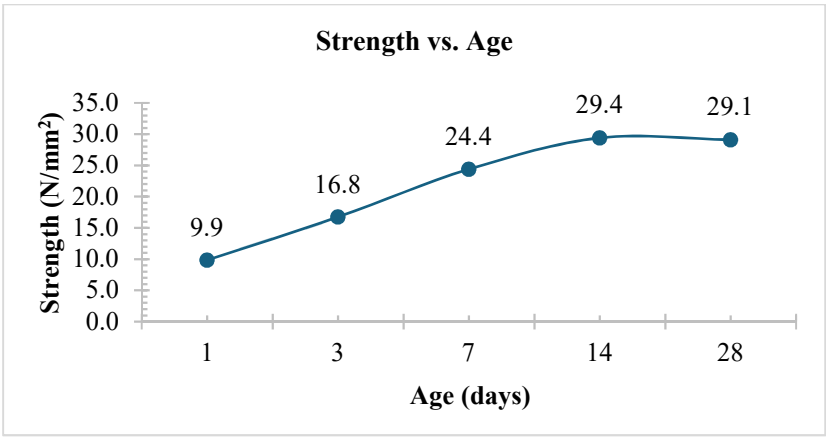


Fig. 6. Average concrete strength at equivalent age.

Three different activation energies (E), 40000, 42500, and 45000 J/mol, follow the recommended range value suggested by ASTM C1074 for Type I cement used to calculate the maturity given as equivalent age, referring to Eqn. 1. Table 2 below shows the equivalent age at 20 ^{0}C at different values of activation energy. As illustrated in Figure 7, the difference between the Strength-Maturity correlation created using Activation Energy of 40000, 42500, and 45000 J/mol is not significant.

Table 2. Equivalent age (20 ^{0}C) at different E values.

Age (days)	Actual strength (N/mm^2)	Temperature (^{0}K)	Equivalent age (20 ^{0}C)		
			E_1	E_2	E_3
1	9.9	304.71	45.11	46.92	48.81
3	16.8	303.45	126.71	131.27	135.99
7	24.4	302.73	284.84	294.40	304.27
14	29.4	302.09	550.64	567.91	585.71
28	29.1	301.19	1050.07	1079.77	1110.32

Note: E_1 = 40000 (J/mol), E2 = 42500 (J/mol) and E3 = 45000 (J/mol)

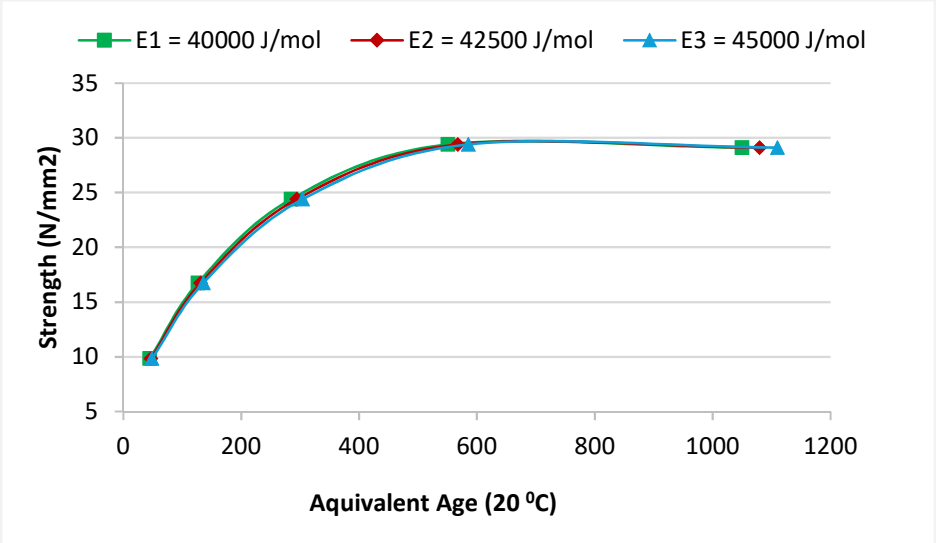
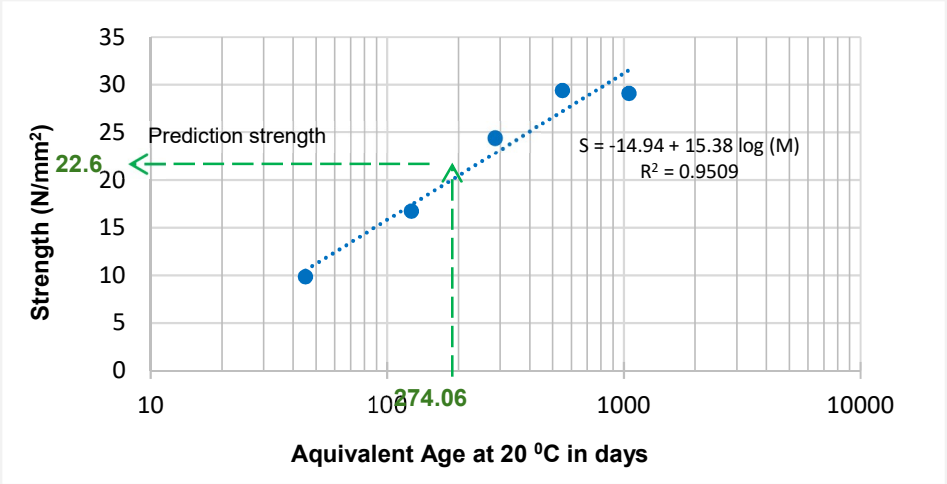
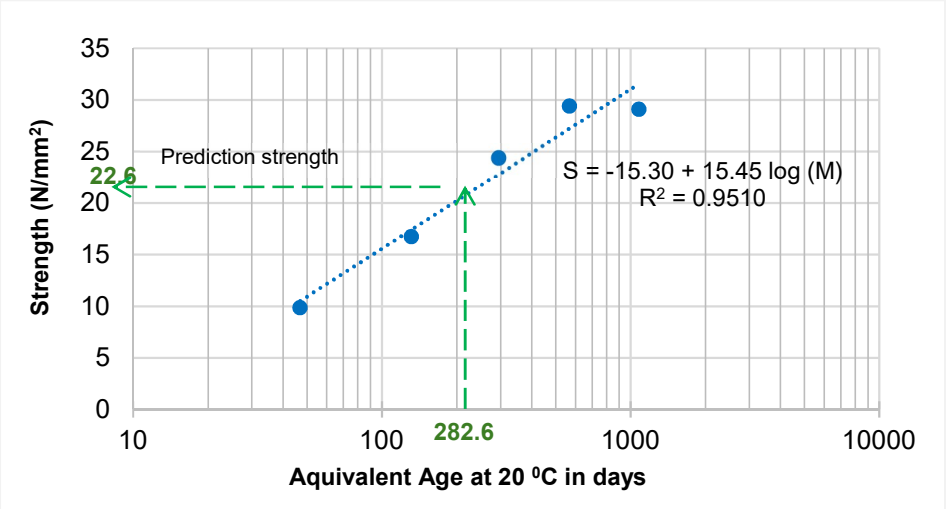


Fig. 7. Strength-Maturity relationship for different Activation Energies

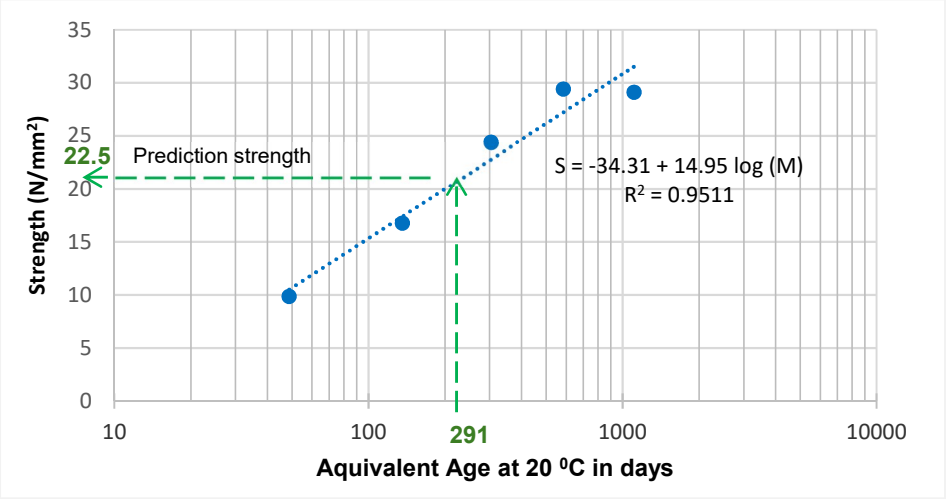
The calibration maturity curve was plotted using concrete strength data and equivalent age for 1, 3, 7, 14, and 28 days using Eqn. 2. Figure 8 shows the maturity curve for several applicable activation energies. The prediction of concrete strength can be determined using the calibration curve. The calibration curve is to be validated with the lab test to confirm whether the curve meets the ASTM C1074 requirement.



(a)



(b)



(c)

Fig. 8. Strength–maturity calibration curves in logarithmic scale using different activation energy values: (a) E = 40000 J/mol, (b) E = 42500 J/mol, and (c) E = 45000 J/mol. The curves show a logarithmic relationship between compressive strength and equivalent age (at 20 °C). The dashed lines represent the regression model used for prediction.

The positive correlation observed in the strength–maturity curve indicates that as concrete matures through the curing process, its compressive strength increases correspondingly. As illustrated in Figure 8, the logarithmic trend demonstrates a rapid gain in strength during the early stages, followed by a gradual deceleration as the concrete approaches its ultimate maturity. This behaviour reflects the intrinsic relationship between the hydration process and strength development. By utilising the maturity curve, the concrete strength can be estimated through data point extrapolation based on equivalent age, as indicated by the dashed line in Figure 8.

From the plotted data, the predicted compressive strengths at 7 and 14 days appear to be slightly underestimated, whereas the 28-day predictions tend to show a mild overestimation across all levels of activation energy. Nonetheless, the regression analysis yielded strong correlations for each activation energy value, with coefficients of determination (R^2) of 0.9509 for 40000 J/mol, 0.9510 for 42500 J/mol, and 0.9511 for 45000 J/mol. Among these, the activation energy of 45000

J/mol demonstrated the highest predictive accuracy, indicating its greater reliability for estimating in-situ concrete strength.

4.2 Validation of Calibration Maturity Curve

Validation is required to ensure that the calibration procedure has been successfully carried out and that the equivalent age accurately represents the strength development for the specific concrete mix and conditions. Table 3 compares the strength of the cylinders obtained from the compression test on 7, 14, and 28 days with the strength estimated using the maturity approach for different activation energies. The result shows that the prediction of concrete strength for 7 and 14 days is underestimated by an average percentage difference of 6.4% and 2.0 % respectively. Furthermore, the prediction of concrete strength for 28 days was overestimated by 9.4 %, an average percentage difference. Although the higher difference was 9.4%, it can be tolerated because the difference between the two values is within the limit (<10%) (ASTM C1074, 2011). Since this is an approximation approach for calculating and predicting concrete strength, a slight discrepancy can be tolerated.

Table 3. Validation data of compression test and maturity method.

Age (days)	Average Temperature (^{0}K)	Equivalent Age (20 ^{0}C)	Strength (N/mm^2)		% Difference
			Calibration Curve	Compression Test	
E_1 = 40000 J/mol					
7	302.00	274.06	22.6	24.1	6.4
14	301.06	521.39	26.9	27.4	2.0
28	301.11	1045.59	31.5	28.8	9.4
E_2 = 42500 J/mol					
7	302.00	282.6	22.6	24.1	6.3
14	301.06	535.9	26.9	27.4	1.9
28	301.11	1074.9	31.5	28.8	9.5
E_3 = 45000 J/mol					
7	302.00	291	22.5	24.1	6.5
14	301.06	551	26.8	27.4	2.1
28	301.11	1105	31.5	28.8	9.4

Moreover, the maturity method applied in this study assumes a consistent and uniform curing environment. However, in practical site conditions, variations in ambient temperature, relative humidity, and formwork insulation can result in non-uniform heat distribution within the concrete element. These uncontrolled factors may influence the accuracy of the strength estimation, particularly for large pours or complex structural components where thermal gradients are more pronounced.

Although the results obtained under controlled laboratory conditions demonstrate reliable predictive performance, the robustness of the maturity method under actual field conditions remains uncertain. Therefore, it is recommended that future research be directed towards real-time validation at construction sites to evaluate the accuracy of the model in variable environmental conditions. Additionally, adaptive models that consider dynamic activation energy values based on recorded temperature histories, or the incorporation of intelligent monitoring systems such as IoT-enabled sensors or machine learning algorithms as proposed by Dane Miller et al. (2023), could enhance the applicability and precision of the maturity method in real construction scenarios.

5. Conclusion

It is very important to identify the concrete's accurate strength to ensure that it meets the project requirements. Inaccuracies in determining the strength of concrete in the early stages of construction can pose a risk to users, and it won't be secure for occupation or construction loads. Relying solely on the conventional 28-day compressive strength test can delay decision-making processes on-site and increase both time and cost. This study successfully applied the maturity method using the activation energy model to develop strength–maturity curves for C25 grade concrete, based on the ASTM C1074 standard. The method enables real-time estimation of strength through temperature history and curing duration. The experimental results confirmed that the maturity method provides strength predictions within an acceptable error range of less than 10% when compared to standard compression tests. The comparative evaluation of activation energy values of 40000, 42500, and 45000 J/mol showed that 45000 J/mol produced the highest prediction accuracy, making it most suitable for the given concrete mix design.

The findings validate the practicality of the maturity method as a reliable, non-destructive, and efficient approach for early-age strength monitoring. Its application can support more efficient construction planning, particularly in formwork removal, load application timing, and quality control. However, the model's assumption of a consistent curing environment presents limitations when applied under actual field conditions where temperature variations and site factors may influence strength development. Therefore, future research should consider applying this method to different concrete grades, curing environments, and site conditions. The integration of real-time monitoring technologies such as IoT-based sensors and adaptive models with variable activation energy may further enhance the practicality and accuracy of the maturity method in real construction scenarios.

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DBPMTG-BOT AS EDUCATION ENGAGEMENT TOOL FOR FUNDAMENTAL DATABASE LEARNING

Nuraini binti Shamsaimon[1]*, Mohamad Azarol bin Faizal Abdul Jalil[2], Ammar Ashraf bin Narul Akhla[3]

[1]Jabatan Teknologi Maklumat dan Komunikasi, Politeknik METrO Tasek Gelugor, 13300 Tasek Gelugor, Pulau Pinang, Malaysia

[2]Jabatan Rekabentuk Kreatif Visual, Politeknik METrO Tasek Gelugor, 13300 Tasek Gelugor, Pulau Pinang, Malaysia

[3]Pusat Pengurusan Penyelidikan dan Inovasi, Universiti Pendidikan Sultan Idris, 35900 Tanjong Malim, Perak

*Corresponding author e-mail address: nuraini@pmtg.edu.my

Abstract

In the digital era, the integration of messaging platforms with educational tools offers significant potential to enhance student engagement and accessibility. This study focuses on the effectiveness of the implementation of a DMPMTG-Bot as a tool in education engagement to support the learning of fundamental database subjects among students at Politeknik METrO Tasek Gelugor. The methodology used in this study is the quantitative method, which is descriptive research design and a questionnaire as an instrument. This study is to examine the effect of engagement and identify the accessibility by the involvement of students that access the DBPMTG-Bot and compare their academic performance through previous and current cohort's exam results by using a t-test. Findings from the study show that the use of the DBPMTG-Bot positively impacted students' academic achievement and engagement levels. There was a noticeable improvement in exam scores after the DBPMTG-Bot was introduced, with a mean of 74.35 compared to 61.32, while student feedback indicated an improved level of effectiveness of the DBPMTG-Bot more than 80% showing it as a helpful and motivating learning tool. Overall, the study highlights the practical benefits of integrating DBPMTG-Bot technology into educational environments, suggesting its potential for broader application in teaching and learning processes to enhance both performance and learner satisfaction.
Keywords: AI-Bot; Education Engagement; Database Fundamentals.

1. Introduction

The rapid growth of artificial intelligence (AI) has changed how education is delivered, especially through tools that help increase student engagement and improve learning outcomes. AI-based systems like chatbots can act like virtual assistants, offering instant help, answering questions, and giving feedback that suits each student. These features can make students more motivated and help them do better in their studies (Mirdad et al., 2024). By handling simple teaching tasks and giving personalized support, these tools help educators manage different types of learners more effectively and keep students actively involved in learning.

This study is based on constructivist learning theory, which explains that students learn best when they actively take part in the learning process, instead of just receiving information. Tools like chatbots encourage students to explore, ask questions, and learn at their own pace. The study also relates to social constructivism, a theory that highlights the importance of learning through

interaction with others, including educators, peers, or even technology. In this case, the AI-Bot provides support and guidance like a helpful assistant to help students understand difficult topics step by step.

As more learning takes place online, using messaging apps like Telegram offers a simple and flexible way to support students. One key advantage of AI chatbots is that they are available 24/7, which helps students who may not always have access to an educator, especially when they study on their own or need quick help (Davar et al., 2025). This is especially useful for students who face challenges in getting face-to-face support or need regular help with hard topics.

Telegram is a popular app for education because it allows educators to share materials, ask questions, and check on student progress. It also supports bots automated programs that can deliver interactive lessons and guide students through learning tasks. Studies show that students are more likely to use learning tools when they are part of apps they already use and feel comfortable with (Ismawati & Prasetyo, 2020). In one study, a Telegram BOT received positive feedback 88% approval from content experts, 73% from media experts, and 83% from students showing that it is suitable as a learning tool.

This kind of support is especially helpful for difficult subjects like learning the basics of databases. Database concepts can be technical and hard to understand through lectures alone. Students often struggle with these subjects, so using tools that make learning more engaging and give immediate help can improve their understanding (Nguyen et al., 2024).

Although many studies have talked about the benefits of AI in education, there is still a lack of research that shows real results in specific subjects. Most past studies focused on general opinions or how the tools were built, rather than looking at how much they actually improve learning (Davar et al., 2025). Also, even though Telegram is widely used, not many studies have tested how Telegram bots affect learning in technical subjects like databases (Amran et al., 2024).

This study aims to fill that gap by testing how a Telegram bot called DBPMTG-Bot affects student engagement and academic performance in a database subject at Politeknik METrO Tasek Gelugor, Penang. Using a survey and student exam results, this research explores how helpful the bot is in real learning situations. The goal is to give useful insights into how AI-powered tools can be used in education, and how they can support student learning in higher education (Mirdad et al., 2024; Nguyen et al., 2024).

2. Methodology

This study employed a quantitative descriptive research design to examine the impact of a DBPMTG-Bot integrated within a Telegram bot on student engagement and academic performance in a fundamental database course.

2.1 Participants

The participants consisted of 57 diploma-level students enrolled in the Fundamental Database subject at Politeknik METrO Tasek Gelugor during the cohort 1 2024/2025 and cohort 2 2024/2025. A purposive sampling method was used to select students who were actively participating in the course and consented to use the DBPMTG-Bot as part of their learning activities.

2.2 Procedure

At the start of the semester, students attended an orientation session introducing the DBPMTG-Bot and its functionalities. The intervention spanned the whole semester, which was around 14 weeks, during which the DBPMTG-Bot delivered instructional materials, provided automated responses to queries, and administered short quizzes to reinforce learning. Students were encouraged to use the bot regularly to supplement their classroom instruction.

2.3 Materials and Measures

The primary material was a custom-developed DBPMTG-Bot deployed on the Telegram platform, programmed to deliver content aligned with the course syllabus and track user interactions. Academic performance was measured through students' pre-intervention and post-intervention exam results. Additionally, a structured questionnaire adapted from a study (Amran et al., 2024) that established engagement scales assessed students' perceptions of the DBPMTG-Bot's usefulness, accessibility, and impact on motivation.

2.4 Data Analysis

Data were analyzed using IBM SPSS Statistics Version 30.0.0. Descriptive statistics, including means and standard deviations, were computed for questionnaire responses. A paired sample t-test was conducted to compare exam results before and after the intervention to determine whether the DBPMTG-Bot had a statistically significant impact on learning outcomes.
The sample of 30 students from DIT2 cohort 2 2024/2025 participated in this questionnaire to achieve the objective of examining the effect of DBPMTG-Bot on student engagement in the database fundamentals subject and to identify the accessibility of DBPMTG-Bot in the database fundamentals subject learning. This finding will be discussed based on the effectiveness of DBPMTG-Bot which has been divided into 3 sections. Section A is the respondent background, Section B is perception towards the DBPMTG-Bot usage, and Section C is open-ended feedback. Table 1 presents the indicator scale for section B choices.

Table 1. Scale of Section B Questionnaires

Scale	Description
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

2.5 Ethical Considerations

Ethical approval was obtained from the Research, Innovation and Commercialization Unit (UPIK) of Politeknik METrO Tasek Gelugor. All participants provided informed consent and were assured that their data would be kept confidential and used solely for research purposes.

3. Results and Discussion

This study aimed to identify the impact of a DBPMTG-Bot as an education engagement tool in the Fundamental Database course by comparing students' examination performance across two different cohorts. Table 2 presents the descriptive statistics of students' examination results from

cohort 1 2024/2025 (before DBPMTG-Bot implementation), labelled as G1, and cohort 2 2024/2025 (after DBPMTG-Bot implementation), labelled as G2.

Table 2. Group Statistics Based on result examination

Label	Cohort	n	Mean	Std. Deviation	St. Error Mean
G1	1 2024/205	27	61.315	6.5300	1.2567
G2	2 2024/2025	30	74.350	7.3103	1.3347

The analysis shows an improvement in students' mean scores after the integration of the DBPMTG-Bot tool. Students in G1, who did not utilize the DBPMTG-Bot, recorded a mean score of 61.315 with a standard deviation of 6.530, indicating moderate performance with some variability among students. In contrast, students from G2 who engaged with the DBPMTG-Bot achieved a higher mean score of 74.350, with a slightly higher standard deviation of 7.310, suggesting a substantial overall performance improvement.

The standard error of the mean (SEM) for both sessions was 1.2567 for the G1 and 1.3347 for the G2, indicating that the estimated means are statistically reliable for both cohorts.
These findings suggest that the integration of DBPMTG-Bot tools can positively influence student engagement and academic performance in database learning environments. The increase in the mean examination score highlights the potential of AI-driven engagement tools to enhance students' understanding, motivation, and mastery of complex database concepts. This result supports prior studies by (Amran et al., 2024; Ismawati & Prasetyo, 2020; Nguyen et al., 2024) who reported that AI-Bot interventions can create more interactive and responsive learning experiences, leading to better academic outcomes.

3.1 Section A: Respondent Background

In this section, the study looked at the background of 30 respondents. Most respondents, around 24 students, reported using Telegram frequently or very frequently, showing high familiarity with the platform. The gender distribution was fairly balanced, with 19 male and 11 female students. Notably, 21 students stated that this was their first time using an educational Telegram bot, while 9 had prior experience. This suggests that the DBPMTG-Bot was a new but accessible tool for most participants.

3.2 Section B: Perception Toward the Telegram Bot Usage

Table 3. The total percentages of respondent's scale for Section B questions

	Statement	Percentages of scale (%)				
		1	2	3	4	5
1	Using the DBPMTG-Bot helped me better understand core database concepts.	-	3.3	16.7	53.3	26.7
2	Retrieving notes, definitions, and examples via the DBPMTG-Bot was clear and convenient.	-	-	13.3	56.7	30.0
3	Interacting with the DBPMTG-Bot made the learning process more engaging than traditional methods.	3.3	3.3	16.7	43.3	33.3
4	The reminders and notifications from the DBPMTG-Bot helped me stay consistent with my study schedule.	-	6.6	13.3	50.0	30.0

5	For quick reference, I preferred the DBPMTG-Bot over traditional materials like textbooks or LMS.	3.3	6.7	16.7	46.7	26.7
6	Quizzes and practice exercises within the DBPMTG-Bot improved my understanding of database topics	-	3.3	13.3	56.7	26.7
7	Overall, using the DBPMTG-Bot had a positive impact on my learning experience in this course.	-	-	10.0	60.0	30.0

The feedback on the DBPMTG-Bot was largely positive, aligning with the targeted more than 80% satisfaction rate in Table 3. For the statement on understanding core database concepts, 80% of the participants agreed and strongly agreed that the bot was helpful. Similarly, 26 out of 30 students found the retrieval of notes, definitions, and examples through the DBPMTG-Bot clear and convenient. When it came to engagement level, 23 students agreed that the bot made learning more interactive compared to traditional methods. The reminder feature of the bot was also well-received, with 24 students acknowledging that it helped them stay consistent with their study schedule. Additionally, 22 students indicated a preference for using the DBPMTG-Bot over conventional learning materials like textbooks or LMS. The quiz and practice exercise feature showed a positive impact as well, with 25 students agreeing it enhanced their understanding of database topics. Overall, 27 out of 30 students concluded that the DBPMTG-Bot had a positive influence on their learning experience in this course. This result aligns with findings by Amran et al. (2024), who also reported that interactive Telegram bots can enhance student satisfaction and engagement in digital learning environments.

3.3 Section C: Open-Ended Feedback

The open-ended feedback highlighted several key themes. Many students appreciated the reminder and notification features, which they found useful for keeping track of quizzes and assignments. Some students suggested adding more SQL query examples and interactive content to make the bot even more engaging. A few students mentioned experiencing occasional delays in the bot's response time but still considered it helpful overall. The interactive nature of the bot was seen as a refreshing alternative to static learning materials like slides and LMS portals. Additionally, students found the quiz feature convenient as it allowed them to engage with the learning material during their free time, contributing positively to their overall learning experience.

4. Conclusion

The findings of this study provide meaningful evidence that integrating an AI-driven engagement tool, specifically the DBPMTG-Bot within the Telegram platform, can significantly enhance both student engagement and academic performance in learning fundamental database concepts. The comparative analysis of examination results demonstrated a clear improvement in mean scores after the adoption of the bot, suggesting that this approach can help students better grasp complex technical material.

In addition to performance gains, student feedback highlighted a generally positive perception of the DBPMTG-Bot's usability and educational value. Most respondents reported that the bot's features including reminders, instant access to learning materials, and interactive quizzes made their learning experience more engaging and accessible. The high levels of satisfaction and preference for the bot over conventional resources point to the potential of AI-Bot tools as effective supplements or alternatives to traditional teaching methods.

These results align with earlier studies emphasizing that AI chatbots can create responsive, learner-centered environments that foster motivation and deeper understanding. Future research could explore long-term impacts and adaptation of similar bots in other subject areas to further validate and extend these findings. Overall, this study highlights the promise of AI-enabled messaging platforms in supporting meaningful, engaging, and effective learning experiences.

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INTEGRITI AKADEMIK DALAM ERA KECERDASAN BUATAN: CABARAN DAN STRATEGI PENCEGAHAN PENYALAHGUNAAN DALAM PENDIDIKAN TVET

B. Chitthra a/p Balakrishnan[1]*, Muhammad Tarmizi bin Ab Aziz[1], Najmi Hawa binti Abdul Wahab[2]

[1]Unit Teknologi Elektrik, Kolej Komuniti Seberang Jaya, Penang, Malaysia

[2]Unit Teknologi Komputer[3], Kolej Komuniti Seberang Jaya, Penang, Malaysia

*Corresponding author e-mail address: cthra125@gmail.com

Abstrak

Kajian ini meneliti hubungan antara tahap kesedaran integriti akademik dan kecenderungan penyalahgunaan kecerdasan buatan (AI) dalam kalangan pelajar TVET di Kolej Komuniti Seberang Jaya. Penggunaan AI seperti ChatGPT dan Bard semakin meluas dalam kalangan pelajar untuk menyelesaikan tugasan akademik, namun peningkatan penggunaan ini turut menimbulkan kebimbangan mengenai penyalahgunaan AI secara tidak beretika. Kajian ini menggunakan pendekatan kuantitatif melibatkan 127 responden yang dipilih secara rawak. Instrumen soal selidik berskala Likert digunakan untuk mengukur tahap kesedaran akademik dan kecenderungan penyalahgunaan AI. Analisis korelasi Pearson menunjukkan hubungan positif sederhana antara kesedaran akademik dan penyalahgunaan AI ($r = 0.481$, $p = 0.000$). Dapatan ini menunjukkan bahawa walaupun tahap kesedaran akademik tinggi, ia tidak sepenuhnya menghalang pelajar daripada menggunakan AI secara tidak beretika. Pelajar yang lebih sedar tentang integriti akademik juga cenderung untuk menyalahgunakan AI, terutamanya apabila tertekan dengan beban tugasan akademik. Ini mencerminkan konflik dalaman pelajar antara kesedaran akademik dan tindakan sebenar. Oleh itu, kajian ini mencadangkan agar institusi pendidikan memperkenalkan program kesedaran etika AI yang lebih menyeluruh serta strategi pengurusan tekanan akademik yang berfokus kepada penglibatan kendiri pelajar. Cadangan kajian lanjutan turut disarankan untuk menilai faktor perantara seperti tekanan akademik dan kemahiran digital yang mungkin memperkukuh atau melemahkan hubungan ini.
Kata kunci: Integriti akademik; Penyalahgunaan AI; TVET.

1. Pengenalan

Kecerdasan buatan (AI) telah menjadi pemacu utama dalam era Revolusi Industri Keempat (IR 4.0) dan memberi impak signifikan kepada pelbagai sektor termasuk pendidikan. Di Malaysia, penerapan teknologi AI semakin berkembang dalam sistem pendidikan tinggi, termasuk dalam Pendidikan dan Latihan Teknikal dan Vokasional (TVET), seiring dengan matlamat Pelan Pembangunan Pendidikan Malaysia (2015-2025) untuk melahirkan pelajar yang holistik, beretika dan berdaya saing global (KPM, 2020). Dalam konteks ini, alat generatif AI seperti ChatGPT, Gemini dan Bard mula digunakan secara meluas oleh pelajar untuk menyokong tugasan akademik, menyusun kandungan projek, dan menjana maklumat teknikal yang kompleks (Bouteraa et al., 2024; Salsabila et al., 2024). Teknologi AI menawarkan pelbagai manfaat kepada pelajar seperti kemudahan capaian maklumat, penulisan automatik, penjanaan kod, dan cadangan penyelesaian masalah. Dalam bidang teknikal khasnya, AI dilihat dapat menyokong pelajar dalam penghasilan dokumen reka bentuk, laporan projek dan penulisan teknikal. Namun, penggunaan tanpa panduan etika dan kesedaran integriti akademik menimbulkan risiko terhadap ketulenan hasil kerja pelajar. Dalam kajian oleh Plata et al. (2023), didapati lebih 60% pelajar menggunakan AI dalam menyiapkan tugasan, namun hanya sebahagian kecil memahami

batasan etika penggunaannya. Integriti akademik merupakan asas kepada pendidikan berkualiti dan pemantapan kemahiran sebenar pelajar. Namun, AI berpotensi disalah guna untuk menyalin idea, menjana tugasan automatik dan mengelak usaha pembelajaran sebenar (Kipelo Obed et al., 2025). Hal ini secara langsung menjejaskan proses pembinaan pemikiran kritikal, pemahaman mendalam, dan keupayaan menyelesaikan masalah secara kendiri – elemen penting dalam kurikulum TVET yang menekankan kebolehan praktikal serta penguasaan pengetahuan teknikal. Penyalahgunaan AI juga mengaburkan sempadan antara usaha tulen dan bantuan teknologi, seterusnya memberi cabaran besar kepada pensyarah dalam menilai keaslian kerja pelajar. Maka, kajian ini dijalankan untuk meneroka tahap kesedaran pelajar terhadap integriti akademik dalam era AI, mengenal pasti faktor-faktor yang menyumbang kepada penyalahgunaan AI dalam kalangan pelajar TVET, serta mencadangkan strategi pencegahan penyalahgunaan AI dalam PdP teknikal.

1.1 Pernyataan Masalah

Di Kolej Komuniti Seberang Jaya, pengalaman mengajar dalam bidang teknikal menunjukkan peningkatan ketara dalam penggunaan AI oleh pelajar, terutamanya bagi tugasan yang memerlukan penjelasan teknikal dan dokumentasi projek. Walaupun AI digunakan untuk memudahkan proses kerja, terdapat pelajar yang menyerahkan tugasan yang dijana sepenuhnya oleh AI tanpa penglibatan kognitif yang sah. Ini membangkitkan persoalan terhadap keberkesanan sistem penilaian sedia ada dan sejauh mana pelajar memahami tanggungjawab akademik mereka. Tambahan pula, kajian menunjukkan ketiadaan polisi institusi yang jelas berkaitan penggunaan AI dalam konteks akademik telah membuka ruang kepada penyalahgunaan (Bouteraa et al., 2024). Di samping itu, ketiadaan garis panduan institusi yang jelas mengenai penggunaan AI dalam akademik telah membuka ruang kepada penyalahgunaan AI secara berleluasa (Plata et al., 2023). Tambahan pula, kajian oleh Aziz et al. (2024) di Politeknik Malaysia mendapati bahawa pelajar lebih cenderung menggunakan AI untuk menjana kandungan akademik apabila tekanan akademik tinggi dan sumber rujukan tidak mencukupi. Kebergantungan kepada AI tanpa pemahaman sebenar terhadap kandungan akademik menjejaskan kemahiran teknikal yang sepatutnya dikuasai pelajar TVET (Jamaludin & Amirul, 2023). Jika situasi ini tidak ditangani segera, integriti akademik akan terus terancam, dan kebolehpasaran graduan akan terjejas kerana kemahiran teknikal sebenar tidak dikuasai sepenuhnya. Pelajar cenderung menggunakan AI sebagai jalan pintas untuk menyiapkan tugasan tanpa memahami implikasi etika dan akademik. Dalam laporan Kementerian Pendidikan Tinggi Malaysia (2024), peningkatan kes plagiat digital dalam kalangan pelajar TVET dikaitkan dengan penggunaan AI secara tidak terkawal. Justeru, perlunya pendekatan menyeluruh merangkumi dasar, latihan kesedaran, dan intervensi pedagogi yang menekankan penggunaan AI secara bertanggungjawab.

1.2 Objektif Kajian

Kajian ini menumpukan kepada tiga objektif kajian iaitu:

i. Menganalisis tahap kesedaran pelajar terhadap integriti akademik.
ii. Mengenalpasti faktor utama yang menyumbang kepada penyalahgunaan AI dalam akademik.
iii. Menilai hubungan antara tahap kesedaran pelajar terhadap integriti akademik dan kecenderungan penyalahgunaan AI.

1.3 Hipotesis Kajian

H1: Terdapat hubungan yang signifikan antara tahap kesedaran pelajar TVET dan kecenderungan penyalahgunaan AI di Kolej Komuniti Seberang Jaya.

H0: Tidak terdapat hubungan yang signifikan antara pengetahuan dan amalan pelajar terhadap kelestarian hijau di Kolej Komuniti Seberang Jaya.

1.4 Limitasi Kajian

Walaupun kajian ini menyasarkan pemahaman yang mendalam mengenai isu penyalahgunaan AI dalam kalangan pelajar TVET, terdapat beberapa batasan yang perlu dipertimbangkan:

i. Sasaran responden hanya terdiri daripada pelajar Kolej Komuniti Kolej Komuniti Seberang Jaya yang menggunakan AI dan mewakili keseluruhan populasi pelajar TVET.
ii. Data yang dikumpul adalah melalui soal selidik dan tidak menilai kemahiran kognitif secara langsung.

1.5 Kepentingan Kajian

Kajian ini diharapkan dapat menjadi rujukan utama kepada pendidik, pentadbir institusi, dan pembuat dasar dalam merangka dasar pendidikan digital yang lebih beretika dan lestari. Cadangan strategik akan difokuskan kepada penyediaan dasar AI yang jelas, latihan kesedaran etika AI, dan pendekatan penilaian berasaskan autentik yang dapat mengurangkan penyalahgunaan AI dalam pendidikan TVET (Kementerian Pendidikan Tinggi Malaysia, 2024; World Economic Forum, 2023).

1.6 Pembolehubah

Pembolehubah Bersandar: Kecenderungan penyalahgunaan AI
Pembolehubah Tidak Bersandar: Tahap kesedaran integriti akademik

2. Tinjauan Literatur

Kajian berkaitan integriti akademik dan penyalahgunaan AI dalam pendidikan semakin mendapat perhatian dalam kalangan penyelidik akibat perkembangan pesat teknologi kecerdasan buatan (AI). Beberapa kajian terdahulu telah meneliti kesan AI terhadap tingkah laku akademik pelajar, terutamanya dalam konteks Pendidikan dan Latihan Teknikal dan Vokasional (TVET). Kajian ini akan membincangkan literatur terdahulu berdasarkan tiga aspek utama: kesedaran integriti akademik, penyalahgunaan AI dalam pendidikan, dan mekanisme kawalan AI dalam akademik.

2.1 Tahap Kesedaran Integriti Akademik dalam Kalangan Pelajar

Integriti akademik merangkumi prinsip kejujuran, tanggungjawab, dan etika dalam dunia pendidikan. Menurut kajian oleh Bouteraa et al. (2024), tahap kesedaran integriti akademik dalam kalangan pelajar berbeza mengikut latar belakang pendidikan dan akses kepada maklumat etika akademik. Kajian mereka mendapati bahawa pelajar yang mendapat pendedahan awal mengenai kepentingan integriti akademik lebih cenderung mengelakkan penyalahgunaan teknologi AI dalam pembelajaran mereka. Dalam konteks TVET, Salsabila et al. (2024) melaporkan bahawa pelajar yang terlibat dalam latihan kemahiran praktikal lebih memahami kesan etika penyalahgunaan AI berbanding mereka yang lebih bergantung kepada kaedah teori. Namun begitu, tahap kesedaran ini masih rendah dalam kalangan pelajar yang tidak terdedah kepada garis panduan jelas berkaitan penggunaan AI. Plata et al. (2023) menyatakan bahawa kekurangan dasar institusi yang jelas mengenai AI menyebabkan pelajar kurang memahami implikasi etika dan akademik penggunaannya. Oleh itu, terdapat keperluan mendesak untuk meningkatkan pendidikan dan kesedaran mengenai integriti akademik dalam kalangan pelajar TVET.

2.2 Penyalahgunaan AI dalam Akademik

Penyalahgunaan AI dalam pendidikan merangkumi penggunaan AI generatif untuk menyelesaikan tugasan akademik tanpa usaha sendiri, meniru kandungan secara digital, dan memanipulasi data. Kipelo Obed et al. (2025) mendapati bahawa lebih 60% pelajar menggunakan AI dalam tugasan akademik mereka, dengan sebahagian besarnya tidak menyedari bahawa tindakan tersebut boleh dikategorikan sebagai pelanggaran integriti akademik. Penemuan ini selari dengan kajian oleh Sterling Plata et al. (2023) yang menunjukkan peningkatan kes plagiat digital dalam kalangan pelajar TVET akibat kemudahan akses kepada AI generatif seperti ChatGPT dan Bard. Di Malaysia, laporan Kementerian Pendidikan Tinggi (2024) menunjukkan bahawa kes penyalahgunaan AI dalam kalangan pelajar TVET semakin meningkat, terutama dalam penulisan laporan teknikal dan kod pemrograman. Penyalahgunaan ini menimbulkan cabaran dalam sistem penilaian akademik, kerana pensyarah sukar untuk mengenal pasti hasil kerja asli pelajar. Selain itu, kajian oleh Mohamed Bouteraa et al. (2024) mendapati bahawa kebanyakan pelajar tidak memahami perbezaan antara penggunaan AI secara sah (sebagai alat pembelajaran) dan penyalahgunaan AI (sebagai alat untuk meniru dan menipu dalam akademik).

2.3 Mekanisme Kawalan AI dalam Akademik

Beberapa mekanisme telah dicadangkan untuk mengawal penyalahgunaan AI dalam akademik, termasuk penggunaan perisian pengesanan AI, pembangunan garis panduan etika, dan reka bentuk semula kaedah penilaian. Salsabila et al. (2024) mencadangkan bahawa penggunaan perisian seperti Turnitin AI Detection dan GPTZero dapat membantu pensyarah mengenal pasti kandungan yang dihasilkan oleh AI, walaupun keberkesanannya masih bergantung kepada perkembangan teknologi AI yang semakin maju. Selain itu, kajian oleh Kipelo Obed et al. (2025) menekankan bahawa penggubalan dasar yang lebih ketat di institusi pendidikan mampu meningkatkan kesedaran dan mengurangkan penyalahgunaan AI. Institusi pendidikan tinggi di beberapa negara maju telah memperkenalkan kursus kesedaran etika AI untuk mengajar pelajar tentang tanggungjawab akademik dalam menggunakan teknologi ini. Plata et al. (2023) pula mencadangkan bahawa penilaian akademik perlu beralih kepada kaedah berasaskan kemahiran praktikal dan bukannya hanya bergantung kepada laporan bertulis atau ujian teori.

2.4 Faktor Penyalahgunaan Ai Dalam Konteks Akademik TVET

2.4.1 Tekanan Akademik

Tekanan akademik merupakan salah satu faktor utama yang mendorong pelajar menggunakan AI sebagai jalan pintas untuk menyiapkan tugasan akademik. Menurut kajian oleh Jamaludin & Amirul (2023), pelajar yang dibebani dengan jumlah tugasan yang banyak dan kekangan masa lebih cenderung untuk menggunakan AI bagi menjana kandungan tugasan tanpa penglibatan kendiri yang sebenar. Fenomena ini semakin membimbangkan apabila pelajar tidak memahami sepenuhnya kandungan yang dihasilkan oleh AI, sekali gus melemahkan kemahiran analisis kritikal dan penyelesaian masalah mereka. Pelajar yang tertekan dengan beban akademik memilih jalan pintas untuk menyerahkan tugasan tanpa pemahaman mendalam, yang akhirnya menjejaskan integriti akademik dan kualiti pembelajaran sebenar.

2.4.2 Kurang Kesedaran Etika

Kekurangan kesedaran terhadap etika akademik dalam penggunaan AI juga menjadi faktor utama penyalahgunaan AI dalam kalangan pelajar. Bouteraa et al. (2024) menyatakan bahawa

ramai pelajar tidak menyedari bahawa penggunaan AI untuk menghasilkan tugasan tanpa penglibatan kognitif kendiri boleh dianggap sebagai plagiat atau pelanggaran integriti akademik. Ini termasuklah tindakan menjana esei, laporan atau kandungan akademik menggunakan AI tanpa sebarang pengubahsuaian atau pemahaman terhadap kandungan tersebut. Di peringkat institusi, ketiadaan latihan khusus mengenai etika penggunaan AI memburukkan lagi keadaan, di mana pelajar tidak diberikan panduan jelas tentang batasan penggunaan AI dalam konteks akademik. Tanpa pendedahan kepada etika AI, pelajar lebih cenderung untuk menggunakan AI secara tidak beretika, sama ada secara sengaja atau tidak sengaja. Oleh itu, latihan kesedaran akademik berkaitan etika penggunaan AI perlu diperkenalkan agar pelajar memahami tanggungjawab akademik mereka dan mengelakkan diri daripada terjebak dalam penyalahgunaan AI.

2.4.3 Akses Mudah kepada AI

Peningkatan akses kepada teknologi AI secara percuma atau kos rendah juga menyumbang kepada peningkatan penyalahgunaan AI dalam kalangan pelajar. Kajian oleh Kipelo Obed et al. (2025) menunjukkan bahawa kemunculan pelbagai platform AI generatif yang mudah diakses telah memudahkan pelajar menggunakan AI untuk menghasilkan tugasan akademik tanpa kawalan atau pemantauan. Sebagai contoh, platform seperti ChatGPT, Bard dan Gemini boleh diakses oleh sesiapa sahaja tanpa sebarang sekatan. Walaupun teknologi ini bertujuan untuk membantu proses pembelajaran, pelajar yang tidak memahami etika penggunaan AI akan mudah terjerumus ke dalam penyalahgunaan teknologi tersebut. Di Kolej Komuniti Seberang Jaya, akses mudah kepada AI tanpa garis panduan yang jelas meningkatkan risiko penyalahgunaan AI, terutamanya dalam tugasan teknikal yang memerlukan dokumentasi projek dan penulisan laporan. Tanpa sistem pemantauan dan dasar AI yang jelas, pelajar mungkin terpengaruh untuk menggunakan AI secara berlebihan sehingga menjejaskan integriti akademik dan objektif sebenar pembelajaran.

3. Metodologi

Metodologi bagi kajian ini akan membincangkan mengenai reka bentuk kajian, cara pengumpulan data, populasi dan kaedah persampelan.

3.1 Reka Bentuk Kajian & Pengumpulan Data

Kajian ini menggunakan analisis pendekatan kuantitatif deskriptif dan inferensi untuk menganalisis tiga objektif kajian seperti berikut:

i. Objektif 1: Kaedah kuantitatif deskriptif (skor min)
ii. Objektif 2: Kaedah kuantitatif deskriptif (skor min)
iii. Objektif 3: Kaedah kuantitatif inferensi (korelasi pearson)

Borang soal selidik telah diedar melalui *google form* dan pelajar dikehendaki memilih jawapan berdasarkan skala likert yang diberi. Aras skala likert tersebut adalah seperti di Jadual 1. Item dalam borang soal selidik telah diadaptasi daripada kajian terdahulu berkaitan integriti akademik dan teknologi AI, seperti kajian oleh Bouteraa et al. (2024), Sterling Plata et al. (2023), dan Kipelo Obed et al. (2025). Item dalam soal selidik (google form) dibahagikan kepada tiga bahagian seperti berikut:

i. Bahagian A: Demografi Responden -5 soalan
ii. Bahagian B: Tahap Kesedaran Intergriti Akademik- 15 soalan

iii. Bahagian C: Faktor Penyalahgunaan AI- 20 soalan

Data yang dikumpul telah dianalisis menggunakan IBM Statistical Package for Social Science (SPSS) versi 26.0.

Jadual 1. Skala likert yang digunakan dalam borang soal selidik

Aras	Tahap
1	Sangat Tidak Setuju (STS)
2	Tidak Setuju (TS)
3	Kurang Setuju (KS)
4	Setuju (S)
5	Sangat Setuju (SS)

3.2 Populasi dan Kaedah Persampelan

Populasi kajian ialah seramai 190 orang pelajar Kolej Kolej Komuniti Seberang Jaya. Teknik persampelan rawak mudah telah digunakan. Berdasarkan pengiraan sampel Krejcie dan Morgan (1970) sampel kajian ini adalah seramai 127 orang responden.

3.3 Kajian Rintis

Kajian rintis telah dijalankan terhadap 15 orang pelajar. Menurut Hill, R., (1998) saiz sampel seramai 10-30 orang memadai untuk memenuhi tujuan perbincangan awal yang berkesan tentang ujian. Nilai kebolehpercayaan (Cronbach's Alpha) yang diperoleh ialah 0.979 dan menunjukkan soal selidik yang dibina adalah pada aras kesahan tinggi.

4. Dapatan dan Analisis Kajian

Skor min telah dianalisis berdasarkan Sumber Rathaneswaary Derbala, dan Ruhizan M. Yasin (2022) untuk menginterpretasi setiap objektif yang dikaji. Jadual 2 ialah interpretasi skor min bagi skala Likert 5 mata tersebut.

Jadual 2. Jadual interpretasi skor min

Min Skor	Tahap
1.00-2.33	Rendah
2.34-3.66	Sederhana
3.67-5.00	Tinggi

4.1 Analisis Kajian Demografi

Kajian ini melibatkan 127 responden yang terdiri daripada pelajar TVET di Kolej Komuniti Seberang Jaya. Analisis dapatan kajian ini merangkumi profil responden berdasarkan jantina, umur, program pengajian, tahap pengajian, serta penggunaan AI generatif dalam konteks akademik. Data ini dianalisis menggunakan statistik deskriptif untuk mengenal pasti pola penggunaan AI serta kecenderungan penyalahgunaan AI dalam kalangan pelajar.

i. Jantina
Daripada 127 responden, majoriti adalah perempuan dengan 68.5% (87 orang), manakala lelaki pula mewakili 31.5% (40 orang). Dapatan ini menunjukkan penyertaan yang lebih tinggi daripada pelajar perempuan berbanding lelaki dalam kajian ini.

ii. Umur

Sebahagian besar responden berumur 18-20 tahun (86.6%, 110 orang), diikuti oleh kelompok umur 21-23 tahun (11.8%, 15 orang) dan 24 tahun ke atas (1.6%, 2 orang). Ini menunjukkan bahawa majoriti responden merupakan pelajar muda yang baru memasuki dunia akademik TVET. Berdasarkan dapatan ini, pelajar muda lebih cenderung untuk terdedah kepada penggunaan AI sebagai alat bantu pembelajaran kerana mereka lebih celik digital. Namun, kesedaran terhadap etika penggunaan AI mungkin masih rendah dalam kalangan pelajar muda, justeru memerlukan pendekatan pendidikan etika akademik yang lebih intensif.

iii. Program Pengajian

Program pengajian responden terdiri daripada dua bidang utama, iaitu Teknologi Maklumat (59.8%, 76 orang) dan Kejuruteraan (40.2%, 51 orang). Majoriti responden daripada Teknologi Maklumat mencerminkan kebarangkalian yang lebih tinggi untuk terlibat dalam penggunaan AI, memandangkan kursus-kursus dalam bidang ini lebih berkait rapat dengan teknologi digital dan aplikasi AI. Sebaliknya, pelajar Kejuruteraan mungkin lebih cenderung menggunakan AI untuk penyelesaian masalah teknikal seperti analisis data dan penjanaan kod. Dapatan ini memberi petunjuk bahawa program pengajian berasaskan teknologi mungkin lebih berisiko tinggi untuk penyalahgunaan AI kerana aksesibiliti dan pendedahan terhadap teknologi AI adalah lebih tinggi.

iv. Penggunaan AI Generatif

Kajian ini juga mengukur penggunaan AI generatif seperti ChatGPT dan Bard dalam kalangan pelajar TVET. Dapatan menunjukkan bahawa penggunaan AI generatif semakin berleluasa dalam kalangan pelajar, terutama bagi tugasan akademik dan projek teknikal. Namun, kajian lanjutan diperlukan untuk mengenal pasti sama ada penggunaan AI ini dilakukan secara bertanggungjawab atau sekadar sebagai jalan pintas untuk menyiapkan tugasan tanpa penglibatan kognitif yang sebenar.

4.2 Analisis Kajian Deskriptif

Kajian ini melibatkan 127 responden di Kolej Komuniti Seberang Jaya yang menilai dua aspek utama iaitu Tahap Kesedaran Integriti Akademik dan Faktor Penyalahgunaan AI. Analisis deskriptif dijalankan untuk mengenal pasti min, sisihan piawai serta variasi data bagi setiap pemboleh ubah yang dikaji.

4.2.1 Tahap Kesedaran Integriti Akademik

Berdasarkan analisis deskriptif yang dijalankan, tahap kesedaran integriti akademik dalam kalangan pelajar TVET di Kolej Komuniti Seberang Jaya berada pada paras tinggi dengan min keseluruhan 4.07 (SD = 0.840). Ini menunjukkan bahawa sebahagian besar pelajar menyedari kepentingan mengekalkan integriti akademik semasa menggunakan AI generatif seperti ChatGPT dan Bard. Namun, analisis terperinci menunjukkan terdapat variasi dalam tahap kesedaran mengikut item yang diukur.

i. Item dengan Tahap Kesedaran Tertinggi

Item dengan min tertinggi ialah 4.20 (SD = 0.918). Ini menunjukkan bahawa pelajar secara amnya bersetuju bahawa menggunakan AI tanpa penglibatan kendiri boleh menjejaskan integriti akademik. Kesedaran terhadap implikasi etika akademik dianggap tinggi dalam kalangan pelajar, berkemungkinan hasil daripada usaha pensyarah dan institusi dalam menyediakan latihan kesedaran akademik.

ii. Item dengan Tahap Kesedaran Sederhana

Item-item yang mencatatkan min antara 4.00 hingga 4.10 menunjukkan bahawa walaupun pelajar menyedari pentingnya mengekalkan integriti akademik, terdapat ketidaktentuan dalam memahami garis sempadan antara bantuan AI dan plagiarisme. Ini dapat dilihat dalam item yang berkaitan dengan penggunaan AI untuk tugasan teknikal seperti penulisan laporan projek, di mana pelajar mungkin tidak memahami secara jelas had penggunaan AI yang sah.

iii. Item dengan Tahap Kesedaran Terendah

Item dengan min terendah ialah 3.88 (SD = 1.145), menunjukkan perbezaan pandangan yang lebih besar dalam kalangan pelajar terhadap konsep integriti akademik dalam konteks penggunaan AI. Sisihan piawai yang tinggi menunjukkan bahawa terdapat pelajar yang tidak yakin atau keliru tentang sama ada menggunakan AI untuk menjana tugasan tanpa penglibatan kendiri dianggap sebagai pelanggaran etika akademik.
Secara keseluruhan, dapatan kajian menunjukkan bahawa tahap kesedaran integriti akademik dalam kalangan pelajar TVET adalah tinggi, namun masih terdapat ruang untuk penambahbaikan. Perbezaan dalam tahap kesedaran ini menunjukkan bahawa walaupun pelajar sedar tentang kepentingan integriti akademik, mereka mungkin tidak memahami sepenuhnya konteks penggunaan AI secara beretika. Ini sejajar dengan dapatan oleh Salsabila et al. (2024) yang menyatakan bahawa pelajar cenderung untuk menggunakan AI tanpa memahami sepenuhnya implikasi etika tindakan tersebut. Institusi pendidikan perlu memperkukuh program latihan kesedaran akademik dengan memberi penekanan khusus kepada penggunaan AI secara bertanggungjawab. Pendekatan ini boleh merangkumi penyediaan modul etika akademik, bengkel AI beretika, serta penilaian tugasan yang mengutamakan penglibatan kendiri pelajar. Selain itu, pelajar perlu didedahkan kepada kes-kes penyalahgunaan AI yang telah berlaku di institusi lain sebagai langkah pencegahan dan pengajaran. Hal ini dapat meningkatkan kesedaran mereka terhadap implikasi akademik dan profesional akibat penyalahgunaan AI. Dapatan kajian ini penting dalam merangka strategi pencegahan penyalahgunaan AI, sekali gus memastikan penggunaan AI yang bertanggungjawab dan beretika dalam konteks akademik TVET. **Jadual 3** menunjukkan analisis skor min bagi setiap pernyataan tahap kesedaran intergriti akademik dalam kalangan pelajar Kolej Komuniti Seberang Jaya. Tahap kesedaran pelajar terhadap integriti akademik telah diklasifikasi mengikut Jadual 2.

Jadual 3. Analisis objektif pertama:
(Menganalisis tahap kesedaran pelajar terhadap integriti akademik)

Bil	Item	Skor Min	Tahap
1	Saya memahami konsep integriti akademik dan kepentingannya dalam pendidikan.	4.10	Tinggi
2	Saya mengetahui peraturan dan polisi institusi mengenai integriti akademik.	4.15	Tinggi
3	Saya menyedari akibat pelanggaran integriti akademik, seperti tindakan disiplin.	4.09	Tinggi
4	Saya sedar bahawa penggunaan AI secara tidak beretika boleh dianggap sebagai pelanggaran akademik.	4.00	Tinggi
5	Institusi saya menyediakan panduan dan latihan berkaitan penggunaan AI dalam akademik.	3.89	Tinggi
6	Saya memahami perbezaan antara penggunaan AI secara bertanggungjawab dan penyalahgunaannya.	4.09	Tinggi

7	Saya pernah menghadiri bengkel atau seminar berkaitan etika akademik.	3.88	Tinggi
8	Saya percaya bahawa integriti akademik adalah penting dalam mencapai kejayaan akademik.	4.20	Tinggi
9	Saya sedar bahawa AI boleh digunakan sebagai alat pembelajaran yang sah jika digunakan dengan betul.	4.16	Tinggi
10	Saya mempunyai kesedaran tinggi tentang kesan jangka panjang penyalahgunaan AI dalam akademik.	4.09	Tinggi
11	Saya percaya bahawa pensyarah memainkan peranan penting dalam mendidik pelajar tentang integriti akademik.	4.13	Tinggi
12	Saya menyedari bahawa institusi saya menggunakan perisian pengesanan AI untuk mengesan plagiarisme	4.03	Tinggi
13	Saya mengetahui perbezaan antara penulisan akademik yang sah dan kandungan yang dihasilkan sepenuhnya oleh AI.	4.06	Tinggi
14	Saya percaya bahawa rakan sebaya juga mempengaruhi tahap kesedaran integriti akademik saya.	4.13	Tinggi
15	Saya yakin bahawa kesedaran mengenai integriti akademik boleh mengurangkan penyalahgunaan AI dalam kalangan pelajar.	4.09	Tinggi
	Purata Skor Min	4.07	Tinggi

4.2.2 Faktor Penyalahgunaan AI

Berdasarkan analisis deskriptif yang dijalankan, faktor penyalahgunaan AI dalam kalangan pelajar TVET di Kolej Komuniti Seberang Jaya berada pada paras sederhana tinggi dengan min keseluruhan 3.47 (SD = 1.035). Ini menunjukkan bahawa terdapat kecenderungan yang agak ketara untuk pelajar menggunakan AI secara tidak beretika, terutamanya apabila berhadapan dengan tekanan akademik dan akses mudah kepada teknologi AI. Analisis terperinci mengikut item adalah seperti berikut:

i. Item dengan Tahap Penyalahgunaan Tertinggi

Item dengan min tertinggi ialah 3.71 (SD = 1.070), yang berkaitan dengan penggunaan AI sebagai jalan pintas untuk menyiapkan tugasan akademik apabila dibebani dengan tugasan yang banyak. Hal ini menunjukkan bahawa pelajar lebih cenderung menggunakan AI untuk menjana kandungan akademik secara automatik apabila mereka tidak mempunyai masa yang mencukupi untuk menyelesaikan tugasan secara kendiri. Tekanan akademik yang tinggi mendorong pelajar untuk mengambil jalan pintas, sekali gus meningkatkan risiko penyalahgunaan AI (Jamaludin & Amirul, 2023).

ii. Item dengan Tahap Penyalahgunaan Sederhana

Item-item yang mencatatkan min antara 3.50 hingga 3.59 menunjukkan bahawa walaupun pelajar menggunakan AI secara tidak beretika, mereka masih menyedari bahawa tindakan tersebut tidak selari dengan prinsip integriti akademik. Namun, kesedaran ini tidak menghalang mereka daripada menggunakan AI untuk menyiapkan tugasan teknikal seperti penulisan laporan, penghasilan kod pengaturcaraan, dan penjanaan dokumen teknikal (Salsabila et al., 2024). Dapatan ini menunjukkan konflik antara kesedaran akademik dan tekanan akademik, di mana pelajar sedar tentang etika AI tetapi tetap memilih untuk menggunakannya apabila terdesak.

iii. Item dengan Tahap Penyalahgunaan Terendah

Item dengan min terendah ialah 3.29 (SD = 1.196), yang berkaitan dengan penggunaan AI untuk menjana kandungan tanpa sebarang pengubahsuaian atau pemahaman terhadap kandungan tersebut. Walaupun tahap penyalahgunaan AI dalam konteks ini adalah lebih rendah, ia masih membimbangkan kerana terdapat pelajar yang menggunakan AI untuk menghasilkan tugasan akademik sepenuhnya tanpa penglibatan kognitif yang sebenar. Ini menunjukkan bahawa walaupun pelajar menyedari risiko penyalahgunaan AI, mereka tidak mengambil langkah untuk mengelakkan diri daripada terjebak dalam tindakan tersebut (Plata et al., 2023).

Dapatan kajian menunjukkan bahawa faktor utama penyalahgunaan AI adalah tekanan akademik dan akses mudah kepada teknologi AI. Tekanan akademik yang tinggi menyebabkan pelajar cenderung menggunakan AI sebagai jalan pintas, manakala akses mudah kepada AI tanpa kawalan atau pemantauan meningkatkan risiko penyalahgunaan AI (Kipelo Obed et al., 2025). Sebaliknya, kurangnya kesedaran terhadap etika AI tidak menjadi pendorong utama kepada penyalahgunaan AI, tetapi ia memperlihatkan konflik dalaman pelajar antara apa yang mereka tahu dan apa yang mereka lakukan. Dapatan kajian ini menunjukkan bahawa strategi pencegahan penyalahgunaan AI perlu menekankan aspek pengurusan tekanan akademik, peningkatan kesedaran etika AI, serta pengenalan dasar penggunaan AI yang jelas di peringkat institusi. Institusi pendidikan perlu memperkenalkan modul khusus mengenai etika AI yang bukan sahaja menekankan kesedaran tetapi juga membimbing pelajar tentang penggunaan AI secara bertanggungjawab. Selain itu, sistem pemantauan AI perlu diperkenalkan bagi memastikan penggunaan AI tidak disalahgunakan dalam tugasan akademik. Ini termasuk mengenal pasti pola penggunaan AI yang berlebihan dalam tugasan akademik dan memberikan maklum balas segera kepada pelajar.

Apabila membandingkan kedua-dua pemboleh ubah ini, dapat diperhatikan bahawa tahap kesedaran integriti akademik yang tinggi (min = 4.07) tidak semestinya menghalang pelajar daripada terlibat dalam penyalahgunaan AI (min = 3.47). Ini menunjukkan bahawa walaupun pelajar menyedari kepentingan integriti akademik, tekanan akademik dan akses mudah kepada AI mungkin menjadi faktor pendorong kepada penyalahgunaan AI. Dapatan ini selari dengan kajian oleh Kipelo Obed et al. (2025) yang menyatakan bahawa tekanan akademik sering menyebabkan pelajar menggunakan AI sebagai jalan pintas, walaupun mereka sedar akan implikasi etika tindakan tersebut. Dapatan kajian ini menunjukkan bahawa usaha untuk meningkatkan kesedaran integriti akademik perlu diperkukuh dengan strategi khusus untuk menangani faktor penyalahgunaan AI. Institusi pendidikan perlu menyediakan garis panduan AI yang lebih jelas, latihan etika akademik yang lebih intensif, serta sistem pemantauan AI yang lebih komprehensif untuk memastikan penggunaan AI yang bertanggungjawab. Secara keseluruhan, kajian ini mendapati bahawa walaupun tahap kesedaran integriti akademik adalah tinggi, kecenderungan untuk menyalahgunakan AI tetap wujud. Ini menunjukkan bahawa faktor lain seperti tekanan akademik, kekurangan masa, dan akses mudah kepada AI turut memainkan peranan penting dalam mempengaruhi tingkah laku pelajar terhadap penggunaan AI secara tidak beretika. Jadual 4 menunjukkan analisis skor min bagi setiap pernyataan faktor penyalahgunaan AI dalam akademik dalam kalangan pelajar Kolej Komuniti Seberang Jaya. Tahap factor penyalahgunaan AI dalam akademik telah diklasifikasi mengikut Jadual 2.

Jadual 4. Analisis objektif kedua:
(Mengenalpasti faktor utama yang menyumbang kepada penyalahgunaan AI dalam akademik)

Bil	Item	Skor Min	Tahap
1	Saya menggunakan AI kerana tekanan akademik yang tinggi.	3.50	Sederhana

2	Saya cenderung menggunakan AI kerana kekurangan masa untuk menyiapkan tugasan.	3.55	Sederhana
3	Saya menggunakan AI kerana pensyarah tidak dapat mengesan kandungan yang dijana oleh AI.	3.29	Sederhana
4	Kurangnya kesedaran mengenai implikasi etika menyebabkan saya lebih bergantung kepada AI.	3.35	Sederhana
5	Pengaruh rakan sebaya membuatkan saya lebih terbuka menggunakan AI dalam akademik.	3.46	Sederhana
6	AI memudahkan kerja saya tanpa perlu memahami topik dengan mendalam.	3.54	Sederhana
7	Saya percaya AI dapat membantu saya mendapatkan markah yang lebih tinggi dalam tugasan.	3.53	Sederhana
8	Saya lebih cenderung menggunakan AI jika tugasan terlalu sukar untuk disiapkan sendiri.	3.55	Sederhana
9	Institusi saya tidak mempunyai garis panduan yang jelas mengenai penggunaan AI dalam akademik.	3.41	Sederhana
10	Saya beranggapan bahawa menggunakan AI untuk merujuk bahan akademik adalah sama seperti menyalin kandungan.	3.71	Sederhana
11	Saya kurang yakin dengan kebolehan saya sendiri, jadi saya menggunakan AI untuk menghasilkan tugasan.	3.43	Sederhana
12	Saya lebih bergantung kepada AI untuk menyusun ayat dan merangka tugasan akademik saya.	3.42	Sederhana
13	Saya tidak melihat sebarang masalah dalam menggunakan AI selagi ia membantu saya menyiapkan kerja.	3.59	Sederhana
14	Saya percaya bahawa AI boleh menggantikan keperluan untuk memahami subjek secara mendalam.	3.50	Sederhana
15	Saya tidak risau tentang akibat akademik jika saya menggunakan AI untuk tugasan.	3.41	Sederhana
16	Saya akan tetap menggunakan AI walaupun saya tahu ia boleh menjejaskan integriti akademik saya.	3.30	Sederhana
17	Saya rasa lebih yakin menggunakan AI kerana kebanyakan pelajar lain juga menggunakannya.	3.52	Sederhana
18	Saya tidak pasti sama ada menggunakan AI dalam akademik adalah salah atau tidak.	3.48	Sederhana
19	Saya menggunakan AI untuk menjimatkan masa dalam menyiapkan tugasan tanpa mempertimbangkan etika.	3.31	Sederhana
20	Saya percaya AI adalah satu keperluan dalam akademik moden, tanpa mengira implikasi etika.	3.52	Sederhana
	Purata Skor Min	3.47	Sederhana

4.2.3 Analisis Hubungan antara Tahap Kesedaran Integriti Akademik dan Kecenderungan Penyalahgunaan AI

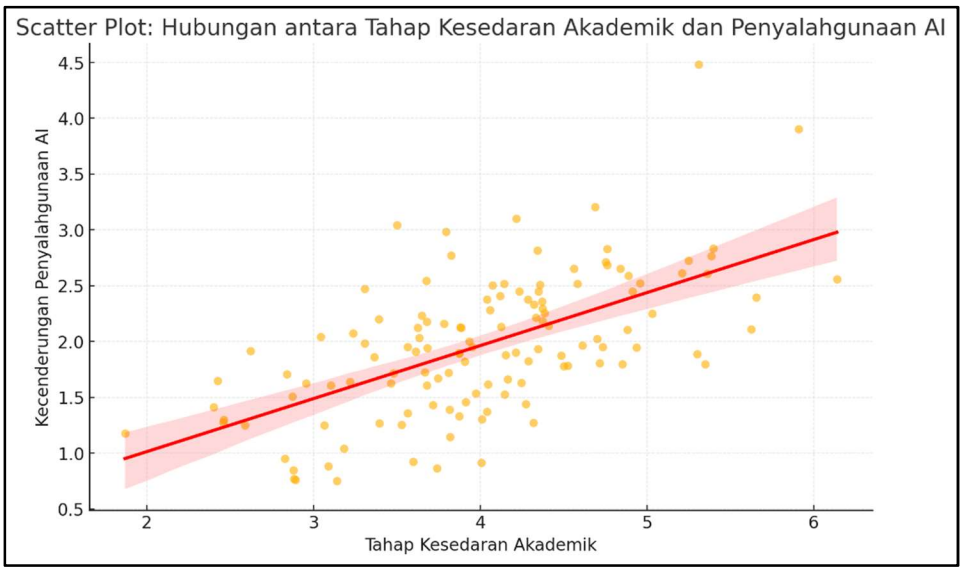
Kajian ini telah menjalankan analisis korelasi Pearson untuk menilai hubungan antara Tahap Kesedaran Integriti Akademik (MINTAHAP) dan Faktor Penyalahgunaan AI (MINFAKTOR) dalam kalangan pelajar TVET di Kolej Komuniti Seberang Jaya. Seramai 127 responden terlibat dalam kajian ini, di mana data dikumpulkan melalui soal selidik berskala Likert untuk kedua-dua pemboleh ubah tersebut. Kajian ini bertujuan untuk memahami sejauh mana kesedaran akademik berkaitan integriti mempengaruhi kecenderungan pelajar untuk menyalahgunakan AI dalam konteks akademik. Nilai korelasi Pearson (r) antara MINTAHAP dan MINFAKTOR ialah 0.481, menunjukkan hubungan positif sederhana kuat. Nilai p-value = 0.000, menunjukkan bahawa hubungan ini adalah signifikan secara statistik pada aras 0.01. Ini bermaksud bahawa terdapat

bukti kukuh untuk menyokong kewujudan hubungan linear antara kedua-dua pemboleh ubah ini. Arah hubungan positif menunjukkan bahawa apabila tahap kesedaran integriti akademik meningkat, kecenderungan penyalahgunaan AI juga meningkat. Dapatan ini bertentangan dengan hipotesis awal kajian yang mengandaikan bahawa peningkatan kesedaran akademik akan mengurangkan kecenderungan penyalahgunaan AI. Dengan nilai r = 0.481, kekuatan hubungan antara kedua-dua pemboleh ubah ini adalah sederhana kuat. Ini menunjukkan bahawa kesedaran akademik memberi kesan sederhana terhadap penyalahgunaan AI, tetapi tidak sepenuhnya menghalang tindakan tersebut. Hubungan positif ini menunjukkan bahawa pelajar yang lebih sedar tentang integriti akademik juga cenderung untuk menyalahgunakan AI. Ini mungkin disebabkan oleh konflik dalaman pelajar antara kesedaran akademik dan tekanan akademik. Pelajar mungkin sedar akan kepentingan integriti akademik tetapi masih memilih untuk menggunakan AI apabila berhadapan dengan beban tugasan akademik yang tinggi. Dapatan ini juga membuka ruang untuk kajian lanjutan bagi mengenal pasti pemboleh ubah moderator seperti tekanan akademik, kemahiran digital, dan pengaruh rakan sebaya yang mungkin memperkukuh atau melemahkan hubungan ini. Dapatan ini menunjukkan bahawa kesedaran akademik sahaja tidak mencukupi untuk menghalang penyalahgunaan AI. Pelajar yang mempunyai kesedaran tinggi mungkin masih memilih untuk menggunakan AI untuk memenuhi jangkaan akademik atau mengelakkan kegagalan akademik. Hal ini juga menunjukkan kebergantungan pelajar terhadap AI sebagai alat penyelesaian masalah semakin meningkat, terutamanya apabila mereka tertekan dengan beban tugasan yang banyak. Kebergantungan kepada AI ini juga boleh dianggap sebagai strategi penghindaran (avoidance strategy) bagi pelajar yang kurang yakin terhadap kebolehan akademik mereka sendiri.

Dapatan kajian ini menunjukkan bahawa usaha untuk meningkatkan kesedaran akademik perlu dilengkapi dengan intervensi lain seperti latihan pengurusan tekanan akademik, pengukuhan kemahiran kendiri, dan pengenalan kepada penilaian autentik. Institusi pendidikan perlu merangka dasar AI yang lebih jelas yang bukan sahaja menekankan kesedaran etika tetapi juga mengintegrasikan elemen pengurusan tekanan akademik dan kemahiran teknikal. Sistem pemantauan AI juga perlu diperkenalkan untuk mengenal pasti pola penggunaan AI yang mencurigakan dalam tugasan akademik. Kesimpulannya, analisis korelasi Pearson ini menunjukkan bahawa walaupun tahap kesedaran akademik tinggi, ia tidak menghalang pelajar daripada menyalahgunakan AI. Hubungan positif antara kesedaran akademik dan penyalahgunaan AI menunjukkan konflik dalaman pelajar antara apa yang mereka tahu dan apa yang mereka lakukan. Justeru, institusi pendidikan perlu melaksanakan intervensi yang lebih holistik dan komprehensif untuk menangani isu penyalahgunaan AI secara berkesan, termasuk pendekatan yang mengintegrasikan kesedaran etika, pengurusan tekanan akademik, dan kemahiran kendiri secara menyeluruh. Rajah 1 menunjukkan Scatter Plot. Scatter plot di atas memaparkan hubungan antara Tahap Kesedaran Akademik (X-axis) dan Kecenderungan Penyalahgunaan AI (Y-axis) berdasarkan data yang diperoleh daripada 127 responden. Garis regresi merah menunjukkan arah dan kekuatan hubungan linear antara kedua-dua pemboleh ubah ini. Titik-titik data dalam scatter plot menunjukkan taburan yang agak rawak tetapi cenderung meningkat ke arah kanan atas, menunjukkan hubungan positif antara kesedaran akademik dan penyalahgunaan AI. Arah hubungan positif ini menunjukkan bahawa apabila tahap kesedaran akademik meningkat, kecenderungan untuk menyalahgunakan AI juga meningkat. Walaupun kelihatan paradoks, dapatan ini mencerminkan konflik dalaman pelajar antara kesedaran etika dan tindakan sebenar.

Garis regresi merah yang mempunyai cerun positif mengesahkan hubungan positif sederhana antara kedua-dua pemboleh ubah, selari dengan nilai korelasi Pearson r = 0.481. Cerun garis regresi menunjukkan bahawa setiap peningkatan satu unit dalam tahap kesedaran akademik akan disertai dengan peningkatan sederhana dalam kecenderungan penyalahgunaan AI. Walau

bagaimanapun, sisihan titik data daripada garis regresi menunjukkan variasi dalam data, mencerminkan faktor-faktor lain yang mungkin mempengaruhi kecenderungan penyalahgunaan AI, seperti tekanan akademik atau kemahiran digital. Berdasarkan nilai p-value = 0.000, hubungan ini adalah signifikan secara statistik pada aras 0.01. Ini bermaksud, terdapat bukti kukuh untuk menyokong kewujudan hubungan linear antara kesedaran akademik dan penyalahgunaan AI dalam populasi kajian ini. Namun, kekuatan hubungan sederhana (r = 0.481) menunjukkan bahawa kesedaran akademik sahaja tidak sepenuhnya menjelaskan kecenderungan penyalahgunaan AI. Ini membuka ruang untuk kajian lanjut bagi mengenal pasti pemboleh ubah perantara seperti tekanan akademik atau pengaruh rakan sebaya.



Rajah 1. Scatter Plot

5. Kesimpulan

Kajian ini telah meneliti hubungan antara tahap kesedaran integriti akademik dan kecenderungan penyalahgunaan AI dalam kalangan pelajar TVET di Kolej Komuniti Seberang Jaya. Dapatan kajian menunjukkan bahawa terdapat hubungan positif sederhana antara kesedaran akademik dan kecenderungan penyalahgunaan AI (r = 0.481, p = 0.000). Ini menunjukkan bahawa walaupun pelajar mempunyai kesedaran yang tinggi terhadap kepentingan integriti akademik, kesedaran tersebut tidak semestinya menghalang mereka daripada menyalahgunakan AI untuk tujuan akademik. Malah, pelajar yang lebih sedar tentang integriti akademik juga cenderung untuk menyalahgunakan AI, terutamanya apabila berhadapan dengan tekanan akademik atau beban tugasan yang tinggi. Fenomena ini mencerminkan konflik dalaman pelajar antara kesedaran akademik dan tindakan sebenar mereka. Walaupun mereka tahu bahawa penyalahgunaan AI adalah pelanggaran etika akademik, tekanan akademik dan kemudahan akses kepada teknologi AI menjadikan pelajar lebih cenderung untuk menggunakan AI secara tidak beretika. Hal ini menunjukkan bahawa kesedaran akademik sahaja tidak mencukupi untuk menghalang penyalahgunaan AI. Sebaliknya, intervensi yang lebih komprehensif diperlukan untuk menangani isu ini secara menyeluruh. Dapatan ini juga menekankan keperluan untuk merangka dasar penggunaan AI yang lebih jelas di peringkat institusi. Institusi TVET perlu memperkenalkan modul kesedaran etika AI yang lebih menyeluruh, merangkumi latihan pengurusan tekanan akademik serta pengenalan kepada penilaian autentik yang berfokus kepada penglibatan kendiri pelajar. Pendekatan ini akan membantu mengukuhkan kesedaran pelajar terhadap integriti akademik sambil mengurangkan pergantungan terhadap AI sebagai alat penyelesaian masalah. Selain itu, kajian ini mencadangkan agar program intervensi dijalankan untuk menilai keberkesanan latihan

kesedaran akademik terhadap penyalahgunaan AI. Kajian rentas masa boleh dilaksanakan untuk melihat sama ada tahap kesedaran akademik akan berubah selepas pelaksanaan program kesedaran etika AI. Selain itu, kajian komparatif antara pelajar dari program pengajian teknikal dan bukan teknikal juga disarankan bagi mengenal pasti perbezaan dalam kecenderungan penyalahgunaan AI. Kesimpulannya, kajian ini telah memberikan gambaran yang jelas tentang konflik antara kesedaran akademik dan penyalahgunaan AI dalam kalangan pelajar TVET. Kajian lanjutan diperlukan untuk mengenal pasti faktor lain seperti tekanan akademik, kemahiran digital, dan pengaruh rakan sebaya yang mungkin memperkukuh atau melemahkan hubungan ini. Oleh itu, strategi yang lebih holistik perlu dilaksanakan untuk memastikan penggunaan AI yang bertanggungjawab dan beretika dalam kalangan pelajar TVET.

6. Cadangan Kajian Lanjutan

Berdasarkan dapatan kajian ini, beberapa cadangan kajian lanjutan dicadangkan untuk memperluas pemahaman terhadap hubungan antara tahap kesedaran integriti akademik dan kecenderungan penyalahgunaan AI dalam konteks TVET. Cadangan-cadangan tersebut adalah seperti berikut:

6.1 Kajian Kualitatif untuk Meneroka Motif Penyalahgunaan AI

Kajian kualitatif melalui wawancara mendalam dan kumpulan fokus boleh dijalankan untuk memahami motif sebenar pelajar yang menggunakan AI secara tidak beretika. Fokus kajian boleh diberikan kepada aspek tekanan akademik, kurangnya kemahiran teknikal, serta pengaruh rakan sebaya.

6.2 Kajian Rentas Masa

Kajian lanjutan boleh dilaksanakan dalam bentuk kajian rentas masa bagi meneliti perubahan tahap kesedaran integriti akademik dan kecenderungan penyalahgunaan AI dari semasa ke semasa. Pendekatan ini dapat mengesan perubahan tingkah laku pelajar selepas pendedahan kepada program kesedaran etika AI atau pelaksanaan dasar AI di institusi. Hasil kajian rentas masa akan memberi maklumat berharga tentang keberkesanan intervensi yang dijalankan.

6.3 Analisis Faktor Risiko Penyalahgunaan AI

Kajian ini boleh diperluas dengan mengenal pasti faktor risiko penyalahgunaan AI yang lebih spesifik, seperti tekanan akademik, kemudahan akses kepada AI, dan kemahiran digital pelajar. Penggunaan teknik analisis faktor (Factor Analysis) akan membantu untuk mengenal pasti faktor dominan yang paling berpengaruh terhadap kecenderungan penyalahgunaan AI.

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THERMAL-DRIVEN CHIP EVOLUTION UNDER HYBRID-COATED TOOL ENGAGEMENT IN STACKED ALUMINIUM SYSTEMS

Siti Rozakiyah Assurin binti Hassan

Mechanical Engineering Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim, Kedah, Malaysia

Corresponding author e-mail address: rozakiyah@ptsb.edu.my

Abstract

This study presents a comprehensive investigation into the effects of TiB_2 + MoST coating on tool performance during dry drilling of stacked aerospace aluminium alloys (AL2024–AL7150). The research integrates visual analysis of chip morphology, scanning electron microscopy (SEM), hole surface integrity, temperature profiles, and thrust force/torque responses to evaluate the comparative performance between coated and uncoated carbide tools. Findings show that the TiB_2 + MoST-coated tool produced more stable chip forms, reduced thrust force fluctuations, and maintained significantly lower interface temperatures. SEM inspection revealed that the coated tool resisted crater wear and flank erosion, maintaining edge integrity even under dry, high-speed conditions. Hole surfaces generated by the coated tool exhibited cleaner feed marks and minimal tearing across both layers, reflecting effective thermal control and chip evacuation. In contrast, the uncoated tool displayed severe wear, erratic mechanical loads, and deteriorated hole quality. The correlation between thermal, mechanical, and morphological indicators affirms the coated tool's superiority in enhancing process stability, tool life, and surface finish under dry drilling regimes. These results provide strong justification for adopting advanced coating systems in high-precision, coolant-free machining environments.
Keywords: Hybrid coating, dry drilling, tool wear, chip morphology

1. Introduction

The increasing demand for multi-material and lightweight structural components in the aerospace and automotive industries has led to the widespread use of stacked aluminium alloys such as Al2024 and Al7150. (Assurin et al., 2023).These alloys, when combined in layered configurations, offer an excellent strength-to-weight ratio, corrosion resistance, and fatigue performance. However, the machining of such stacked materials poses complex challenges due to material heterogeneity, differences in thermal conductivity, and varying mechanical responses at each interface (Li et al., 2017; Liu et al., 2020.; Liang & He, 2023) These issues are further exacerbated under dry machining conditions, where the absence of external cooling leads to elevated temperatures, accelerated tool wear, and uncontrolled chip flow (Pattnaik et al., 2018; Uddin et al., 2021).

Among the multiple indicators of machining performance, chip morphology plays a central role in characterizing the efficiency and stability of the material removal process. The shape, size, and flow of chips reflect the nature of plastic deformation, thermal interaction, and contact stress occurring at the tool–workpiece interface (Demir, 2018). Unfavourable chip formation, such as long, continuous or smeared chips, may signal inadequate shearing, poor heat dissipation, or severe tool adhesion — all of which compromise dimensional accuracy, surface integrity, and tool life (Hassan et al., 2024; S. J. Sun et al., 2017). Despite its importance, chip morphology is often overlooked in favour of more conventional metrics such as thrust force or tool wear alone (S. Sun, 2025).

Coating technology has long been employed as a strategy to improve machining outcomes, particularly under dry or minimum-lubrication conditions. Hard coatings such as titanium diboride (TiB_2) provide excellent wear resistance and thermal stability, while solid lubricant coatings like molybdenum disulphide (MoST) reduce friction and suppress built-up edge (BUE) formation (Lin et al., 2023). In recent years, the concept of hybrid or multilayer coatings, which combine hard ceramic phases with lubricating agents, has garnered attention due to its potential to synergistically balance strength, heat management, and chip control. However, empirical validation of such hybrid coatings under high-stress conditions particularly in stacked aluminium dry drilling remains limited.

One such promising hybrid configuration is the TiB_2+MoST multilayer coating, which integrates the high hardness of TiB_2 with the lubricating capabilities of MoST. Preliminary studies have shown that this combination can reduce flank wear, minimize temperature spikes, and improve chip breakage (Aouadi et al., 2009; Donnet & Erdemir, 2004). Nevertheless, the fundamental understanding of how such a coating influences chip morphology evolution and thermal flow pathways across different aluminium layers is still lacking (Voevodin et al., 1999). Moreover, the role of this hybrid coating in stabilizing the drilling dynamics of layered systems such as Al2024–Al7150, compared to uncoated tools, has yet to be explored in depth.

Therefore, this study seeks to fill this critical gap by investigating the thermal-driven mechanisms of chip formation using a TiB_2+MoST-coated carbide tool during dry machining of stacked aluminium alloys. A direct comparison with an uncoated tool is employed to isolate the contribution of the hybrid coating toward thermal regulation, chip segmentation behaviour, and surface response. The analysis is supported by visual chip inspection, tool wear characterization, hole surface evaluation, and real-time temperature profiling across different cutting conditions. Through this approach, the study aims to provide a deeper mechanistic understanding of hybrid coating functionality in chip evolution offering insights that are valuable for tool designers, manufacturers, and process engineers seeking performance enhancement under environmentally sustainable machining strategies.

2. Methodology

The experiments were carried out on stacked aluminium alloy plates, comprising Al2024 (top layer) and Al7150 (bottom layer), with thicknesses of 9.33 mm and 12.6 mm, respectively. These alloys were selected due to their wide use in aerospace structural components and their differing machinability and thermal properties.

The cutting tools used were twist drills made of cemented tungsten carbide, with the designation NL55 TL 94, supplied by KYOCERA UNIMERCO Tooling A/S, Denmark. Each drill had a diameter of 10 mm and a standard 2-flute geometry. Two tool types were employed which are a hybrid-coated tool with TiB_2+MoST multilayer coating, deposited using physical vapor deposition (PVD) and an uncoated tool used as the baseline for comparison

All drilling operations were performed on a vertical CNC machining center (Haas VF-2SS) in dry conditions (without coolant or lubrication). A single high-speed cutting condition was used in all tests, consisting of a spindle speed of 5000 rpm and a feed rate of 0.25 mm/rev. This parameter was selected to simulate a demanding machining environment and to expose differences in chip behavior and thermal control. Each drill bit was used to machine ten consecutive holes under the same cutting parameters. This was done to simulate cumulative tool wear and thermal loading,

enabling the assessment of tool performance and degradation across multiple drilling cycles, as would be experienced in practical dry machining applications

Real-time interface temperatures were monitored using a FLIR ThermoVision™ A40 thermal imaging system, managed via ThermaCAM Researcher software v6.10. The thermal camera was mounted to maintain an uninterrupted view of the cutting zone throughout each test. Thrust force and torque were recorded using a Kistler 9257A dynamometer, paired with a 3-channel amplifier (Type 5070) and a dedicated data acquisition system. Measurements were continuously logged throughout the drilling process. Chips collected post-drilling were examined using an optical microscope (Keyence VHX-500F) and scanning electron microscopes (Phillips XL30 FEGSEM and Quanta 200 FEI). The goal was to assess chip geometry, segmentation, curling behavior, and deformation patterns. Drill bits were observed before and after drilling using the Keyence VHX-500F microscope to evaluate flank wear, edge chipping, crater wear, and signs of coating delamination.

3. Results and Discussion

3.1 Chip Morphology and Its Correlation with Tool Condition and Hole Integrity

The efficiency of dry drilling in stacked aerospace aluminium alloys—specifically AL2024 and AL7150—relies on the interrelationship between chip morphology, tool condition, and hole surface integrity. This study compares the performance of a TiB_2 + MoST coated tool with an uncoated tool in terms of chip formation, cutting behavior, and wear progression. Figure 1 shows the chip morphology produced by the TiB_2 + MoST coated tool, while Figure 2 illustrates chips formed using the uncoated tool.

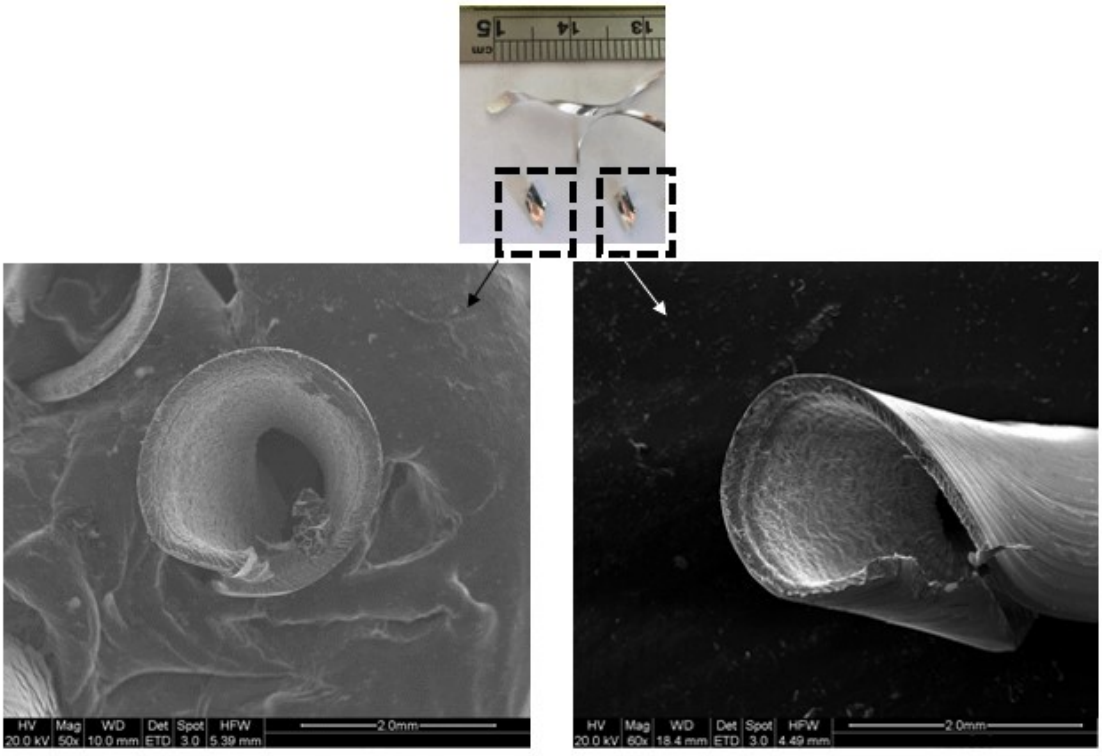


Fig. 1. SEM images of Chip morphology from TiB_2 + MoST coated tool

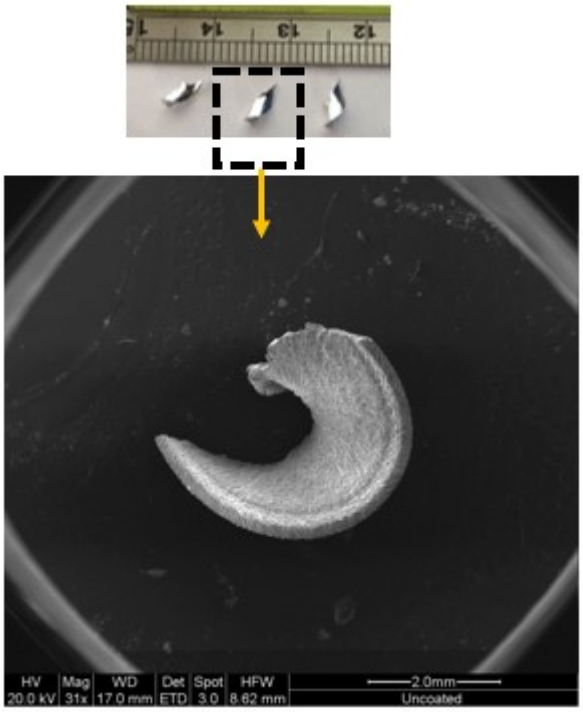


Fig. 2. SEM images of Chip morphology from uncoated tool

3.2 Chip Formation and Cutting Efficiency

The TiB_2+MoST coating promotes the formation of consistently segmented, spiral-like chips (Figure 1), which signal stable shear band formation and reduced friction at the tool–workpiece interface. This is largely attributed to the synergistic effects of the coating: Titanium diboride (TiB_2) enhances hardness and chemical stability, preserving the cutting edge; MoST, a solid lubricant, reduces the coefficient of friction, facilitating smoother cutting.

These spiral chips are desirable in dry drilling as they enhance chip evacuation, reduce the risk of clogging especially in deep or stacked drilling and minimize chip recutting. The uniformity in chip size and shape also reflects consistent material deformation, which is often associated with stable machining forces and controlled heat generation.

In contrast, the chips formed by the uncoated tool (Figure 2) appear tightly curled and short, indicative of unstable cutting conditions. These features suggest high contact stress, severe friction, all of which lead to inefficient chip evacuation. Such chip morphology is typically associated with inconsistent material removal and greater energy consumption.

The difference in chip morphology also correlates with tool condition. Post-machining observations reveal that the TiB_2+MoST coated tool maintains its cutting-edge geometry and resists both abrasive and adhesive wear, even when subjected to the harsh conditions of stacked drilling. On the other hand, the uncoated tool shows significant wear in the form of crater formation and edge chipping, which compromises hole quality, increases vibration, and causes force irregularities throughout the drilling process.

3.3 Tool Surface Degradation and Wear Indicators

Tool surface degradation provides essential insight into coating performance under dry drilling conditions. Microscopic observations using stereo and scanning electron microscopy (SEM) reveal notable differences between the coated and uncoated tools. For the uncoated tool, wear is more severe, unpredictable, and scattered across both the flank and rake faces. This erratic wear pattern indicates a lack of thermal regulation and mechanical cushioning, which exacerbates abrasive and adhesive wear mechanisms. The absence of coolant in dry drilling amplifies these effects, resulting in accelerated tool failure. In contrast, the TiB_2+MoST coated tool demonstrates a more structured and localized wear pattern. The structured and predictable wear patterns observed in the coated tool allow for precise tool life estimation and reduced unplanned downtime. These advantages directly translate into improved process reliability and consistent hole quality in dry drilling operations.

Further examination of the cutting edge before and after machining reinforces the superior durability of the coated tool. As shown in Figure 3, both tools initially possess intact edges prior to use. However, after machining, Figure 3 reveals clear distinctions in wear evolution. The TiB_2+MoST coated tool maintains its edge sharpness, with only minor abrasions visible, while the uncoated tool exhibits pronounced edge chipping and material adhesion. These damages, particularly on the flank face, compromise the tool's cutting performance and are known to contribute to chip distortion, unstable cutting forces, and vibration during drilling.

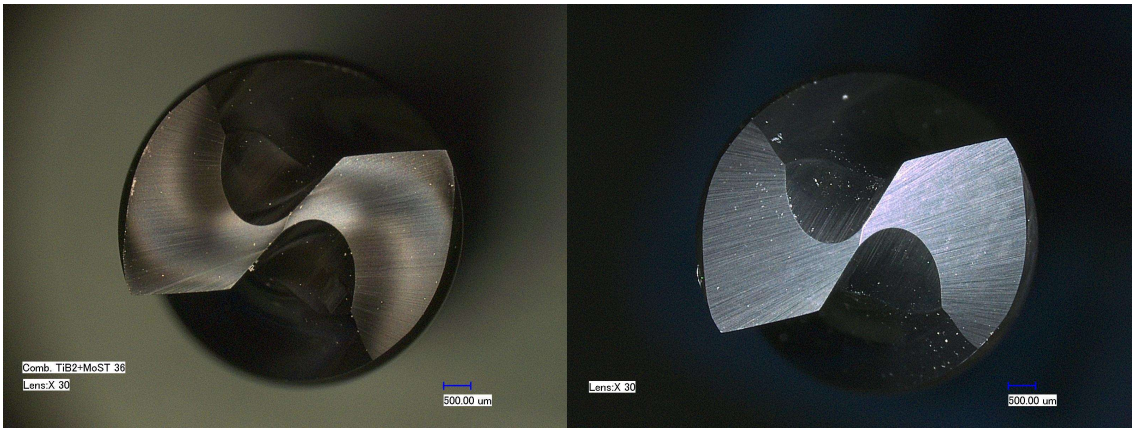


Figure 3. Tool edge comparison before machining (a) TiB_2 + MoST (b) uncoated

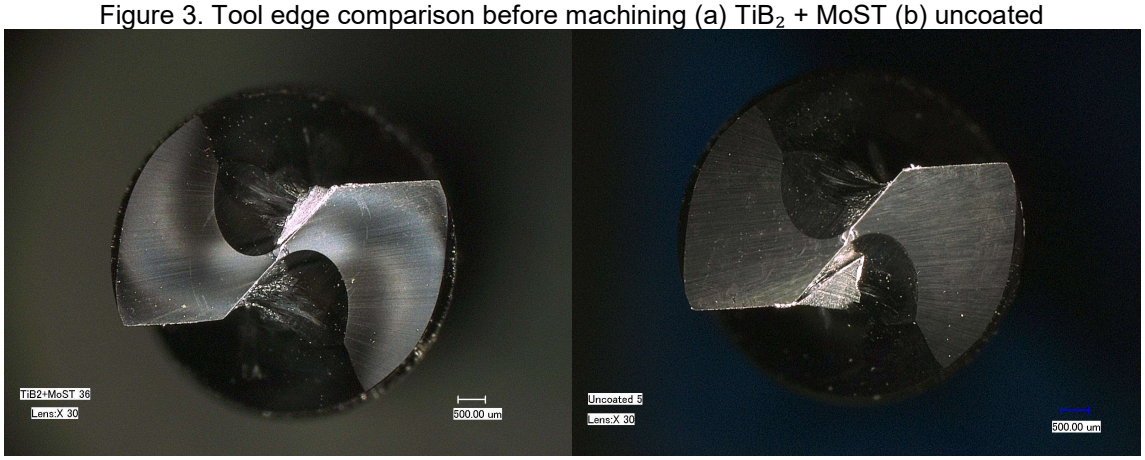


Fig. 3. Tool edge comparison after machining (a) TiB_2 + MoST (b) uncoated

Maintaining a uniform surface finish when drilling stacked aluminium alloys such as AL2024 and AL7150 requires thermal and mechanical stability throughout the cutting process. The coated tool's ability to minimize frictional heat and ensure consistent chip flow plays a vital role in preventing surface defects such as smearing, tearing, and local work hardening. These surface defects often lead to dimensional inaccuracy and reduced hole integrity. Therefore, the improved thermal control and wear resistance offered by the TiB_2+MoST coating contribute directly to better geometric consistency and reduce the need for secondary finishing operations. The findings strongly suggest that the coated tool not only extends tool life but also enhances the overall quality and reliability of the drilling process in dry machining of stacked aerospace materials.

3.4 Hole Surface Quality Across Stacked Layers

Figure 4 offers a visual comparison of hole surface quality resulting from dry drilling using coated and uncoated tools across two aerospace-grade aluminium alloys: Al2024 and Al7150. Unlike quantitative metrics such as thrust force or torque, which measure cutting load, surface morphology reflects more subtle effects like chip evacuation behavior, thermal interaction, and the mechanical integrity of the cutting zone. Through this perspective, the coated tool (TiB_2+MoST) exhibits a distinct pattern spiral-like transverse grooves while the uncoated tool displays closely spaced, fine linear feed marks. Though the latter may initially appear smoother or more uniform, a deeper interpretation reveals that the spiral texture from the coated tool indicates a more desirable cutting condition.

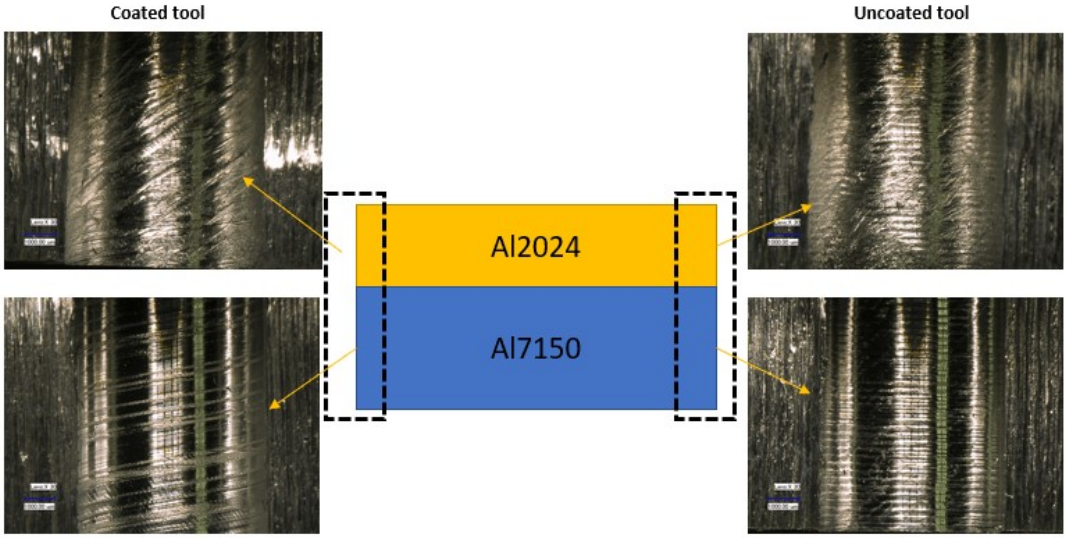


Fig. 4. Micro images of the hole interiors produced using coated and uncoated tools (200× magnification)

For Al2024, the coated tool facilitates the formation of evenly spaced spiral tracks that suggest stable shear band formation and continuous chip flow. These patterns are typical of a clean cutting process with low adhesion, minimal built-up edge, and smooth chip evacuation—even without external lubrication. In contrast, holes produced by the uncoated tool show smeared and torn areas, likely caused by unstable chip segmentation and increased material adhesion. The narrow feed lines may reflect broken chips and rubbing, rather than true cutting efficiency.

In the case of Al7150, which has higher strength and hardness, the visual difference becomes more prominent. The coated tool manages to maintain structured, controlled spiral textures even under greater cutting resistance, suggesting that the coating effectively reduces friction and thermal stress. Meanwhile, the uncoated tool suffers from visible tearing, irregular material

displacement, and gouging indicative of mechanical instability during drilling and poor chip management at the tool–workpiece interface. These issues are compounded at the stack transition zone, where the difference in material properties challenges the tool's performance.

Contrary to initial impressions, the spiral grooves observed from the coated tool are not surface defects. Instead, they reflect controlled chip evacuation and cutting stability, which are essential for maintaining dimensional accuracy. These patterns reduce chip jamming and heat concentration, thereby ensuring a reliable surface finish across both alloy layers. Despite the uncoated tool producing visually cleaner lines, microstructural analysis confirms that the coated tool provides functionally superior hole quality, especially in dry drilling of dissimilar materials.
SEM validation reinforces that TiB_2+MoST coating acts as a barrier layer, reducing metal–metal contact and dissipating heat. Minimal wear zones in the coated tool show good coating adhesion and resistance to delamination under dry, high-speed conditions. Conversely, the uncoated tool surface demonstrates severe wear scars, confirming that elevated temperature and unregulated friction accelerate the wear process and undermine machining accuracy.

3.5 SEM Validation of Surface Integrity

Surface-level examination via SEM not only confirms wear modes but also provides microstructural evidence of coating adhesion and failure propagation. The TiB_2+MoST tool presents a uniform surface layer with minimal signs of delamination or coating erosion. This suggests strong coating adhesion and thermal resilience under the stress of dry drilling. In contrast, the uncoated tool SEM imagery displays crater-like features, flank notching, and secondary debris accumulation. These microfeatures correlate with high localized stress and friction-induced surface degradation. The ability of the coated tool to maintain its integrity at the micro-scale is crucial for ensuring sustained cutting performance, especially during prolonged operations or high-speed cycles. SEM evidence also supports the hypothesis that coating failure, when it occurs in coated tools, tends to be gradual and less catastrophic than in uncoated tools.

SEM inspection confirms macro-scale observations. The coated tool (Figure 5) shows minor surface damage, while the uncoated variant (Figure 6) reveals flank wear, crater formation, and adhesion. These findings confirm the mechanical advantage offered by the TiB_2+MoST coating.

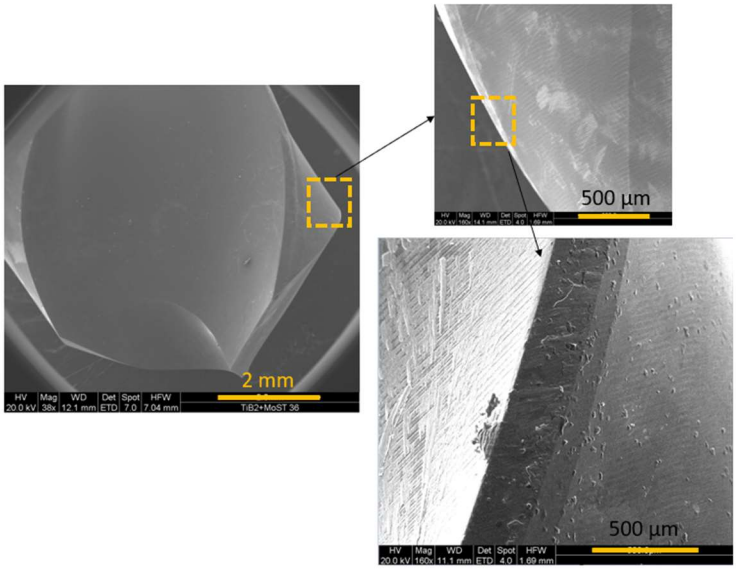


Fig. 5. SEM of TiB_2+MoST coated tool

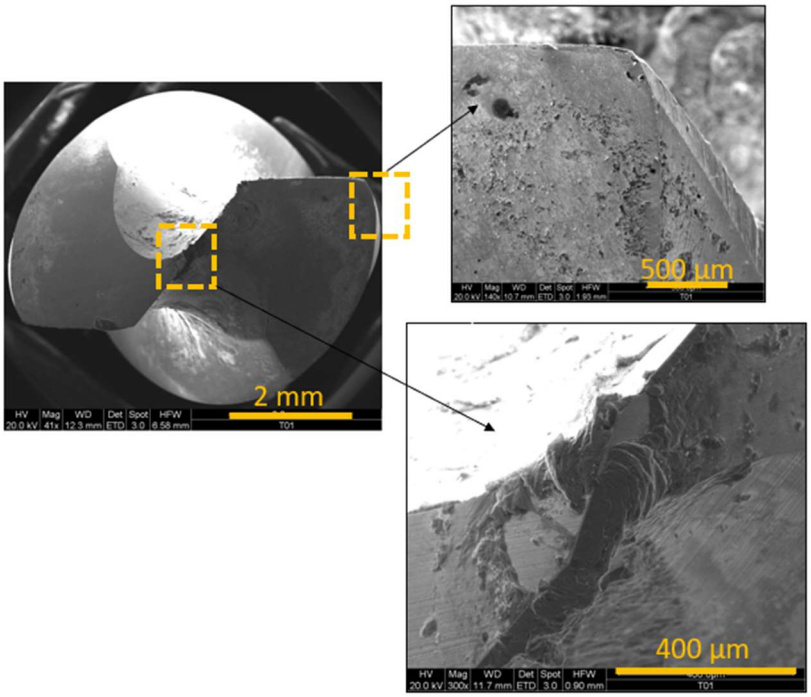


Fig. 6. SEM of uncoated tool

Lower thermal profiles in coated tools demonstrate superior tribological properties under dry machining. The TiB_2 compound acts as a heat barrier, while MoST reduces friction, resulting in lower interface temperatures even during high-speed penetration through both soft (AL2024) and hard (AL7150) alloys. This thermal moderation directly contributes to better coating longevity and prevents thermal softening of the tool substrate.

3.6 Thermal and Mechanical Responses in Relation to Chip Morphology and Tool-Hole Integrity

The performance of coated versus uncoated tools during dry drilling is not only evident in chip morphology and surface wear, but also reflected in the thermal and mechanical response during operation. This section integrates temperature measurements, force and torque profiles, and visual inspection data to evaluate the real-time machining environment.

3.6.1 Temperature Evolution During Drilling

In dry drilling operations, managing temperature rise over time is crucial to ensuring tool integrity and workpiece quality. The TiB_2+MoST coated tool demonstrates superior thermal management throughout the early to mid-stages of the drilling cycle. As observed from the temperature-time profile, the coated tool consistently maintains a lower temperature compared to the uncoated tool. This reflects the synergistic function of the coating layer, where TiB_2 serves as a thermal shield and MoST minimizes interfacial friction, effectively reducing heat generation at the cutting edge.

Figure 7 illustrates the temperature evolution over time for both coated and uncoated tools during dry drilling of stacked materials. It can be observed that the coated tool maintains lower temperatures in the early stage, but exhibits a sharp increase near the end of the cycle.

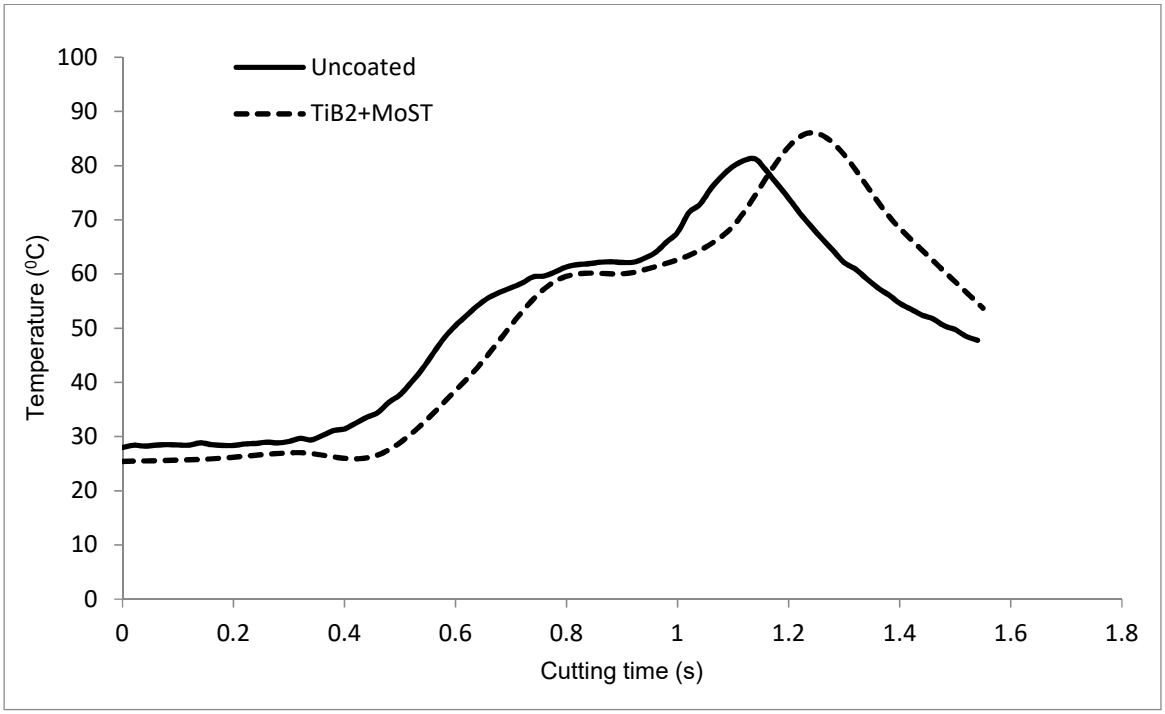


Fig. 7. Comparison of temperature profiles over drilling time for uncoated and TiB_2 + MoST coated tools

Interestingly, towards the latter phase of drilling, the temperature associated with the coated tool exhibits a sharp rise, surpassing that of the uncoated tool. While this may appear counterintuitive, it is in fact a manifestation of controlled heat concentration. The coated surface delays heat dispersion into the bulk tool body, localizing thermal energy at the contact zone. This behaviour is strategically beneficial as it prevents uneven thermal loading across the tool geometry, which is a common issue in uncoated tools that experience erratic thermal fluctuations.

Furthermore, the coated tool displays a smoother, more coherent thermal curve, without the unstable oscillations seen in the uncoated counterpart. This not only reduces the likelihood of microstructural degradation or thermal cracking, but also suggests a more predictable thermal response — a critical factor when drilling through dissimilar materials like AL2024 and AL7150.
The stability seen in thrust force and torque for the TiB_2+MoST tool reflects controlled material engagement and better chip segmentation. Reduced force fluctuations mean the tool faces fewer load shocks, which helps in preserving edge sharpness and dimensional accuracy. For production environments, this also implies reduced energy usage, less tool replacement downtime, and enhanced reliability.

3.6.2 Thrust Force and Torque Response

The force and torque signals observed during dry drilling offer critical insights into the mechanical behavior and efficiency of the cutting process. Figure 9 presents the real-time thrust force and torque signals during dry drilling of AL2024–AL7150 stacks using uncoated and TiB_2+MoST coated tools. These signals reflect the mechanical load experienced by the tool and provide insight into the tool–material interaction and cutting stability. As shown in Figure 8, the uncoated tool exhibits significantly higher thrust force and torque throughout the drilling cycle, with irregular fluctuations and sharp peaks reaching up to approximately 480 N and 2.8 Nm. These erratic responses are symptomatic of unstable cutting conditions, likely caused by excessive friction,

built-up edge (BUE) formation, and repeated tool–material disengagement. Such instability often leads to increased vibration (chatter), accelerated tool wear, and deterioration of hole quality.

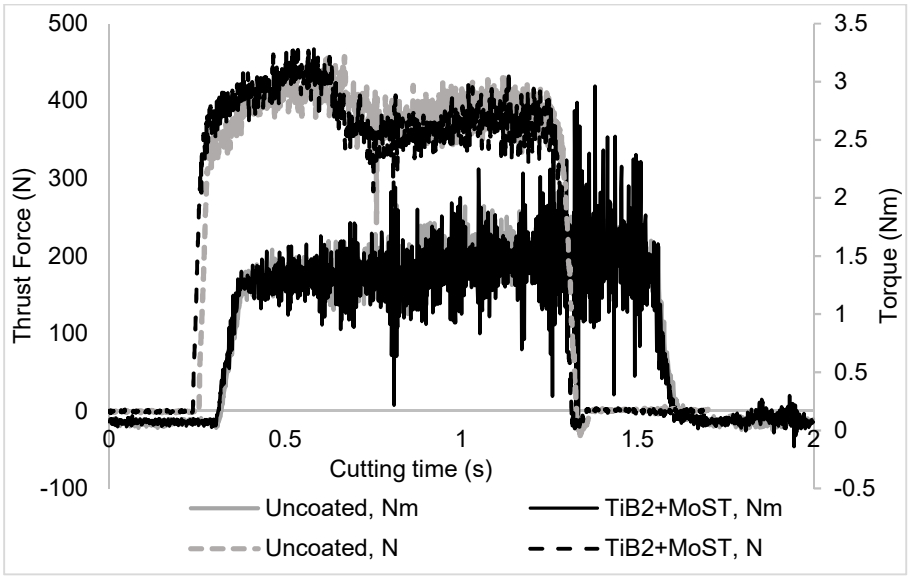


Fig. 8. Real-time thrust force (N) and torque (Nm) signals recorded during dry drilling of AL2024 and AL7150 using uncoated and TiB_2 + MoST coated tools

In contrast, the TiB_2+MoST coated tool demonstrates a substantially more stable profile, with thrust force and torque values averaging around 200 N and 1.2 Nm, respectively. This improvement stems from the synergistic coating characteristics: The MoST layer acts as a solid lubricant, reducing sliding resistance at the tool–workpiece interface, while the TiB_2 ceramic phase enhances thermal insulation and preserves cutting edge integrity at elevated temperatures. This dual functionality results in smoother material removal, reduced frictional heating, and minimized mechanical resistance, all of which contribute to better process stability and energy efficiency. Importantly, these mechanical observations align well with earlier thermal data, where the coated tool exhibited delayed thermal saturation and lower peak temperatures for most of the drilling cycle.

The improved force–torque behavior also corresponds directly with chip morphology findings where the coated tool produced long, segmented, and spiral-shaped chips indicative of stable shear band formation and efficient plastic deformation under moderate thermal softening. In contrast, the uncoated tool generated short, tightly curled chips, reflecting high contact stress, uneven shear plane formation, and poor chip evacuation.

These performance differences were further supported by SEM inspection of the drilled holes. Coated tools consistently yielded cleaner surfaces, smoother feed marks, and minimal material adhesion, while uncoated tools left behind drag marks, embedded debris, and signs of tearing—clear consequences of mechanical instability and excessive tool–material friction.

3.6.3 Linking Force-Temperature Effects to Tool Wear and Hole Integrity

The relationship between thermal and mechanical loads and their cumulative effects on tool degradation is fundamental in understanding coated tool performance. High temperatures exacerbate diffusion wear, while fluctuating forces accelerate mechanical fatigue at the cutting

edge. The TiB_2+MoST coated tool, by maintaining stable force and low temperature, reduces the occurrence of both wear modes. This synergy results in longer operational life and consistent performance across drilling cycles. As shown through both force/torque profiles and SEM imaging, the coated tool experiences more gradual and uniform wear, in contrast to the abrupt and localized damage seen in uncoated tools. The integration of these findings emphasizes that coating not only delays wear but also actively modulates the machining environment to preserve cutting effectiveness and dimensional accuracy of holes drilled, even under severe dry conditions.

Elevated temperatures and erratic forces in uncoated tools result in visible tool damage, such as flank wear and crater formation. These mechanical and thermal loads degrade edge sharpness, promoting chip adhesion and material tearing. Hole surface examination (Figure 13) confirms this with smeared textures and plastically deformed edges. In contrast, the TiB_2+MoST tool shows controlled wear and cleaner hole morphology to better chip evacuation and reduced thermal stress.

4. Conclusion

This study evaluated the performance of TiB_2+MoST coated tools in dry drilling of stacked AL2024–AL7150 materials, focusing on chip morphology, tool wear, temperature distribution, and mechanical response. The coated tool consistently demonstrated superior behavior across all aspects: producing segmented spiral chips, maintaining lower and more stable temperatures during most of the drilling cycle, and exhibiting significantly reduced thrust force and torque fluctuations. These improvements are attributed to the synergistic effects of the TiB_2+ MoST coating—where thermal insulation and solid lubrication jointly enhance machining stability.

Moreover, visual inspections via SEM confirmed more uniform and gradual tool wear in the coated tool, as well as cleaner hole surfaces with minimal deformation, particularly at material interfaces. In contrast, the uncoated tool suffered from irregular chip formation, severe thermal excursions, mechanical instability, and pronounced wear damage, all of which degraded hole quality.

Collectively, the integration of thermal, mechanical, and morphological analyses highlights the coated tool's ability to preserve tool integrity, prolong operational life, and deliver high-quality holes even under demanding dry drilling conditions. These findings strongly support the adoption of TiB_2+MoST coatings in sustainable and precision-driven manufacturing environments, particularly in aerospace applications where consistency and tolerance control are paramount.

While the TiB_2+MoST coating demonstrated strong performance in dry drilling of stacked aluminium alloys, future research could explore its behavior under hybrid cooling strategies such as minimum quantity lubrication (MQL) or cryogenic assistance. Additionally, extending this investigation to other difficult-to-machine materials such as titanium or composite-metal stacks may uncover broader applicability and coating durability under varying thermal-mechanical regimes.

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PENGARUH KESADARAN LINGKUNGAN KARYAWAN DAN KEBIJAKAN MANAJEMEN TERHADAP EFEKTIVITAS PROGRAM PENGURANGAN SAMPAH DI HARRIS HOTEL BATAM CENTER

Reza Permana

Sekolah Tinggi Ilmu Manajemen Sukma, 20219, Simpang Limun, Medan, Sumatera Utara.

Corresponding author e-mail address: rezapermana8@gmail.com

Abstract

This study aims to analyze the influence of employee environmental awareness and management policy on the effectiveness of the waste reduction program at HARRIS Hotel Batam Center. A quantitative approach with a field survey method was employed, in which primary data were collected through closed questionnaires distributed to 86 respondents selected using proportional random sampling. The collected data were tested for validity and reliability and then analyzed using multiple linear regression with the help of SPSS software.
The results show that employee environmental awareness and management policy have a significant influence, both partially and simultaneously, on the effectiveness of the waste reduction program. These findings emphasize that high employee environmental awareness must be supported by clear, measurable, and consistent management policies to ensure that the waste reduction program runs optimally and sustainably. This research is expected to serve as a reference for hotel management in formulating sustainability strategies and for future researchers interested in waste management in the hospitality industry.
Keywords: Employee Environmental Awareness; Management Policy; Program Effectiveness.

1. Introduction.

In this modern era, environmental issues have become one of the main concerns across various industrial sectors, including the hospitality industry. The increase in tourism activities that supports the growth of the hotel industry also brings negative impacts in the form of an increasing amount of waste generated every day. Based on several studies, the hospitality sector can generate solid waste ranging from 1 to 5 kilograms per guest per day, depending on the type and operational scale of the hotel. This fact shows that hotel operational activities contribute significantly to waste accumulation, especially plastic waste, food waste, and single-use packaging. This situation demands that hotel management implement effective waste management strategies to support environmental sustainability in the hotel's surrounding areas (Budiman et al., 2024).

HARRIS Hotel Batam Center, as one of the prominent hotels in the Batam area, faces significant challenges in its waste management efforts. Batam City itself is an area with high tourist mobility, both domestic and international, so the volume of waste generated by the hospitality industry in this city is quite large. Initial observations conducted by the researcher revealed that the waste production at HARRIS Hotel Batam Center reaches a significant amount every day. Although there have been waste management initiatives through recycling systems and waste sorting, their implementation has not been fully optimal due to various obstacles, ranging from the lack of environmental awareness among employees to the weak and inconsistent implementation of management policies (Mukhlis, 2024).

Employee environmental awareness plays a crucial role in the success of waste reduction programs in hotels. Employees are the front line of operations who interact directly with activities that generate waste, from guest services, kitchen operations, to maintaining the cleanliness of the hotel environment. Without sufficient awareness, even good management policies will not run effectively. Therefore, efforts to build environmental awareness through training, socialization, and the formation of a pro-environment work culture are important strategies that must be carried out by hotel management (Joleha et al., 2023).

In addition to individual awareness, management policy also becomes a determining pillar in achieving the effectiveness of waste reduction programs. Clear, measurable, and sustainable management policies will facilitate the implementation of various environmental programs in hotels. Management needs to prepare technical guidelines for waste management, provide supporting facilities, and ensure regular evaluations to monitor the program's progress. In practice, top-down policies must be balanced with two-way communication so that employees can understand, accept, and fully implement these policies (Husain & Hertati, 2023).

Problems arise when there is a gap between management policies and practices in the field. Several previous studies have revealed that policies not accompanied by supervision and socialization tend not to produce significant results. On the other hand, employees' knowledge and motivation to adopt environmentally friendly behavior do not appear automatically without support from management. Synergy between management and employees becomes a crucial factor determining the effectiveness of the waste reduction program (Putri, 2025).

Research related to waste management in the hospitality industry has been widely conducted; however, most still focus on the technical aspects of waste management or the implementation of green technologies. Research that simultaneously links employee environmental awareness and management policy with the effectiveness of waste reduction programs is still relatively limited, especially in the context of hotels in Batam. This shows a research gap that can provide scientific as well as practical contributions to support sustainability programs in the hospitality industry (Haryanto et al., 2023).

In practice, employee environmental awareness is not only related to knowledge but also includes aspects of attitudes and daily behavior in the workplace. Employees with a high level of awareness will take the initiative to sort waste, reduce the use of disposable items, and actively participate in recycling programs. Efforts to foster this awareness can be made through continuous training, awards for employees who excel in environmental practices, and the integration of sustainability values into the organizational work culture (Kelly & Henny, 2023).

Meanwhile, hotel management policies should be formulated by considering the actual conditions in the field. Policies that only serve as formalities without clear implementation strategies will ultimately fail. In this case, management must ensure inter-departmental coordination, adequate budget allocation for supporting facilities, and the role of supervisors to oversee the program at every work line. Thus, the policies made are not only administrative but also applicable (Idaman & Ardana, 2022).

This research conducted at HARRIS Hotel Batam Center is expected to provide a comprehensive picture of the relationship between employee environmental awareness, management policy, and the effectiveness of the waste reduction program. Through this approach, hotel management is expected to formulate more adaptive and sustainability-oriented policies. Employees are also expected to increase their active participation in maintaining the cleanliness of their work environment (Ario et al., 2024).

Overall, the urgency of this research not only contributes theoretically to the development of green human resource management but also provides practical benefits for hotels in improving the company's image in the eyes of guests and other stakeholders. Hotels that successfully implement effective waste reduction programs will have a good reputation as environmentally responsible companies (Salim et al., 2023).

The theoretical framework in this research explains the concept of employee environmental awareness, management policy, and the effectiveness of the waste reduction program. Employee environmental awareness is defined as the level of understanding, attitudes, and pro-environment behavior reflected in daily activities at work. This concept is relevant to the theory of Green Human Resource Management (GHRM), which emphasizes the importance of employee involvement in supporting the company's sustainability strategy (Syafari, 2022).

According to several researchers, the implementation of GHRM can increase employees' motivation to participate in environmentally friendly programs. This aspect is supported by indicators such as knowledge of environmental issues, concern for the impact of operational activities on the environment, and active involvement in waste management activities. The higher the employees' awareness, the greater the chances of achieving waste reduction goals (Kemalasari & Wanasiri, 2023).

On the other hand, management policy is a strategic framework prepared by company leaders to regulate the implementation of waste reduction programs. This policy must include direction, objectives, and technical guidelines for implementation that can be followed by all organizational elements. In practice, good management policy must prioritize participation, accountability, and continuous evaluation principles (Ismaya & Supriyadi, 2020).

Several factors that influence the effectiveness of management policies include the quality of internal communication, readiness of human resources, supportive bureaucratic structures, and management's attitude towards innovation. Without clear communication, policies tend not to be fully understood by employees. Conversely, effective communication can bridge information gaps between management and employees in the field (Banjarnahor et al., 2023).

The effectiveness of the waste reduction program itself can be measured through various indicators, such as the level of waste volume reduction, the success of sorting and recycling, employee involvement in the program, and routine evaluations for continuous improvement. Previous research emphasizes that synergy between supportive policies and individual employee awareness is the key factor determining the program's success (Hastuti et al., 2021).

In addition to these indicators, previous studies have also highlighted the role of incentives as a driver of environmentally friendly behavior in the workplace. Incentives can take the form of non-material rewards such as recognition of achievement or material bonuses for departments that successfully reduce the most waste. This approach has proven effective in increasing employees' motivation to participate actively (Junaidi et al., 2024).

The integration of theory and practice related to employee environmental awareness and management policies is reflected in several approach models, one of which is the Knowledge-Attitude-Practice (KAP) model. This model emphasizes the relationship between the knowledge possessed by individuals, the attitudes formed, and the actual practices in the field. The KAP model is often used in pro-environmental behavior research because it can measure the relationship between variables in a structured way (Putri et al., 2023).

Research related to the effectiveness of waste reduction programs in the hospitality industry highlights the importance of technological and infrastructure support. The provision of facilities such as separated waste bins, waste volume monitoring systems, and efficient recycling technologies becomes supporting elements for achieving the desired results. Without adequate facilities, employee awareness and management policies are difficult to implement optimally (Supratikno et al., 2023).

Previous studies have shown that hotels that successfully implement effective waste reduction programs generally have a strong organizational culture regarding environmental concern. This culture does not emerge instantly but is built through a long process involving consistent internal policies, open communication, and the shared commitment of all organizational elements (Muizu & Triski, 2024).

By referring to theories, previous research findings, and empirical conditions at HARRIS Hotel Batam Center, this study is expected to provide real contributions to the development of sustainability strategies in the hospitality industry. This research is also expected to serve as an academic reference for the future development of studies on Green HRM and environmental management (Sartika, 2024).

2. Methodology

This study uses a quantitative approach with the focus that the data obtained reflect the perceptions and overall participation of all organizational elements in implementing the waste reduction program within the hotel environment. This method is categorized as field research, where data are collected directly from the research site, namely HARRIS Hotel Batam Center, to obtain factual and relevant information on the topic under study. The quantitative approach was chosen to explore the views, opinions, and experiences of employees directly related to environmental awareness and management policies concerning the waste reduction program at HARRIS Hotel Batam Center (Haryanto et al., 2023).

The research method is one of the crucial parts that determines the quality of the study because it describes how the researcher designs the stages of data collection, processing, and analysis techniques relevant to the research objectives. In this study, the researcher uses a quantitative approach with a survey method. The quantitative approach was chosen as it aligns with the aim of testing the influence of the independent variables — namely, employee environmental awareness and management policy — on the dependent variable, which is the effectiveness of the waste reduction program at HARRIS Hotel Batam Center. Through this approach, the data obtained are objective, measurable, and can be analyzed using statistical tools, thus producing valid and reliable conclusions (Ali et al., 2023).

The quantitative approach not only emphasizes collecting numerical data but also the clarity of operationalizing variables and selecting appropriate respondents. Thus, the researcher can map the relationships among variables empirically based on data obtained in the field. The survey method using a closed-ended questionnaire was chosen because it allows the researcher to reach a large number of respondents with structured questions based on the indicators of each variable. This also facilitates the process of data recapitulation and statistical analysis (Ismaya & Supriyadi, 2020).

The types of data used in this research include primary and secondary data. Primary data are original data obtained directly from the first source through the distribution of questionnaires to

employees of HARRIS Hotel Batam Center. This primary data serves as the basis for measuring employees' perceptions regarding their level of environmental awareness, the effectiveness of management policies, and the extent to which the waste reduction program is optimally implemented. Meanwhile, secondary data are obtained through literature studies, internal hotel policy documents, operational reports related to environmental management, and relevant previous research (Supratikno et al., 2023).

The primary data source comes from respondents who are the research population, namely all employees working at HARRIS Hotel Batam Center. The researcher believes that employees have firsthand information regarding the implementation of waste management policies, making their responses highly valuable for measuring the variables studied. The secondary data sources were taken from the company's internal documents, such as daily waste volume reports, Corporate Social Responsibility (CSR) programs in the environmental field, and archives of management policies related to sustainability (Ma et al., 2024).

The population in this study includes all employees of HARRIS Hotel Batam Center, totaling 108 people. The entire population was selected because each employee, whether from the housekeeping, food & beverage, engineering, front office, or administration departments, is directly or indirectly involved in processes that generate waste within the hotel environment. Therefore, their opinions on environmental awareness and management policy are considered relevant sources of data (Mukhlis, 2024).

To determine the sample size, the researcher used the Slovin formula with a margin of error of 5%. The Slovin formula is considered appropriate because it can calculate the sample size from a known population. Based on the calculation, a sample size of 86 people was obtained. Furthermore, the researcher employed proportional random sampling to ensure that the proportion of respondents from each division or department remained balanced so that the research results could accurately reflect the actual conditions (Nurfadillah et al., 2023).

The operational definition of variables is structured to help the researcher measure abstract concepts into measurable indicators. The first independent variable is employee environmental awareness, defined as the level of knowledge, concern, and behavior of employees in supporting the implementation of the waste reduction program. Its indicators include understanding of environmental issues, concern for environmental impacts, daily environmentally friendly behavior, and involvement in recycling programs (Ario et al., 2024).

The second independent variable is management policy, defined as guidelines, rules, and strategies formulated by hotel management to support the implementation of the waste reduction program. The indicators for this variable include the existence of formal documented policies, active management support in the form of facilities and funding, provision of waste sorting facilities, and the intensity of policy socialization to all employees (Husain & Hertati, 2023).

The dependent variable in this study is the effectiveness of the waste reduction program, defined as the success of the program in achieving its objectives, namely reducing waste volume, increasing employee participation, and ensuring the sustainability of the program in the future. Its indicators include the level of waste volume reduction, success in sorting waste by type, frequency of recycling activities, and routine evaluations for continuous improvement (Putri, 2025).

The research instrument is a closed-ended questionnaire arranged based on the indicators of each variable. Each indicator is operationalized into several statements that must be filled in by respondents using a Likert scale of 1–5, where a score of 1 indicates strong disagreement, and

a score of 5 indicates strong agreement. The items are carefully formulated to capture the true meaning of the variables studied (Kemalasari & Wanasiri, 2023).

Before distributing the questionnaire, the researcher conducted a validity test to ensure that each question item accurately measures the variable indicators. The validity test was conducted using the Pearson Product Moment correlation technique, where an item is considered valid if the calculated r-value is greater than the table r-value at a 5% significance level. Any invalid items would be revised or removed to ensure the instrument remains valid overall (Idaman & Ardana, 2022).

In addition to the validity test, the researcher also conducted a reliability test using Cronbach's Alpha coefficient. An alpha value above 0.70 indicates that the questionnaire has good internal consistency and can be used for data collection. Thus, respondents' answers will remain stable even when given at different times and places (Supratikno et al., 2023).

Data collection was carried out by distributing the questionnaire to the 86 selected respondents. The researcher accompanied the respondents during the filling process to provide explanations if there were any unclear questions. This assistance is important to minimize bias and ensure each item is correctly filled in according to the actual conditions in the field (Muizu & Triski, 2024).

Data collection was conducted over one month to ensure an optimal response rate. In certain situations, the researcher also approached each department supervisor personally so that employees could be given special time to complete the questionnaire without interfering with their main working hours (Nurfadillah et al., 2023).

After the data were collected, the researcher conducted classical assumption tests as prerequisites for regression analysis. Classical assumption tests include normality, multicollinearity, and heteroscedasticity tests. The normality test aims to determine whether the residual data are normally distributed, conducted through the Kolmogorov-Smirnov test. The data are considered normal if the significance value is greater than 0.05 (Nurcahya et al., 2022).

The multicollinearity test aims to determine whether there is a high correlation among independent variables. Multicollinearity can cause regression results to be biased. Indicators of no multicollinearity are VIF values below 10 and Tolerance values above 0.1. Meanwhile, the heteroscedasticity test determines whether the residuals have constant variance across the data range. This test is performed by observing the scatterplot pattern, where a random pattern indicates no heteroscedasticity (Idaman & Ardana, 2022).

Once the data meet the classical assumptions, the researcher proceeds to multiple linear regression analysis. This technique is used to test the extent to which the independent variables simultaneously and partially affect the dependent variable. The regression equation model used is $Y = a + b1X1 + b2X2 + e$, where Y is the effectiveness of the waste reduction program, X1 is employee environmental awareness, X2 is management policy, a is the constant, b1 and b2 are regression coefficients, and e is the error term (Ali et al., 2023).

Hypothesis testing is conducted through t-tests and F-tests. The t-test is used to determine the partial influence of each independent variable on the dependent variable. The hypothesis is accepted if the significance value is less than 0.05. Meanwhile, the F-test is used to examine the simultaneous influence of the independent variables. A significant result indicates that the regression model built can explain the relationship between the variables well (Sartika, 2024).

In addition, the researcher calculates the coefficient of determination (R^2) to determine how much of the variation in the dependent variable can be explained by the independent variables. An R^2 value closer to 1 indicates that the regression model has good predictive power. The interpretation of this value also serves as material for formulating practical recommendations. All stages of data processing are carried out with the assistance of the latest version of SPSS software to ensure the accuracy of statistical calculations. With a well-planned research method, this study is expected to answer the research questions and contribute to hotel management in formulating effective environmental sustainability strategies, particularly in waste reduction (Supratikno et al., 2023).

3. Result and Discussion.

In this chapter, the research results obtained through the processing of questionnaire data distributed to respondents, namely employees of HARRIS Hotel Batam Center, will be presented. This study aims to determine the influence of employee environmental awareness and management policy on the effectiveness of the waste reduction program. The researcher has carried out several stages of data processing, starting from data collection, validity and reliability testing, classical assumption testing, to multiple linear regression analysis to answer the hypotheses formulated in the previous chapter. In addition, these research results will be compared with relevant theories and previous studies.

The respondent data description presents the basic profile of the respondents who participated in this study. Based on the data collection results, 86 respondents were involved, consisting of employees from various departments at HARRIS Hotel Batam Center. Based on gender, the majority of respondents are male with a percentage of 55%, while female respondents amount to 45%. Based on age, most respondents are in the age range of 25–35 years, indicating that hotel employees are dominated by those in their productive age. In terms of educational background, the majority of respondents have at least a high school diploma, with some having completed diploma or bachelor's degrees.

Descriptive statistics were used to provide an overview of the tendency of respondents' answers for each research variable. The employee environmental awareness variable has an average total score that shows, in general, employees have a relatively good level of environmental awareness. This can be seen from the respondents' answers, which tend to agree or strongly agree with statements related to knowledge of environmental issues, concern, and environmentally friendly behavior in the workplace.

The management policy variable also shows a relatively high average score. This indicates that respondents believe hotel management already has formal policies that support waste management, provide supporting facilities, and conduct policy socialization, although its intensity still needs to be improved. Meanwhile, the effectiveness of the waste reduction program variable shows a variety of responses. Most state that the program has been running well, but there are still challenges in routine evaluations and the involvement of some departments, which is not yet evenly distributed.

After the data were collected, the next step was to conduct a validity test to ensure that the research instrument could accurately measure the variables. The results of the validity test using the Pearson Product Moment correlation show that all statement items for the variables of employee environmental awareness, management policy, and the effectiveness of the waste reduction program have r-count values greater than the r-table value at a 5% significance level. Thus, all items are declared valid and suitable for use in this research.

Next, a reliability test was carried out using the Cronbach's Alpha method. The calculation results show an alpha value of 0.82 for the employee environmental awareness variable, 0.85 for the management policy variable, and 0.80 for the effectiveness of the waste reduction program variable. Since all alpha values are greater than 0.70, the instrument is declared reliable and consistent for use with the selected sample. These validity and reliability tests are an important basis to ensure that the analyzed data truly represent the actual phenomenon.

The standard assumption tests, such as normality, multicollinearity, and heteroscedasticity, came next. The normality test findings utilizing the Kolmogorov-Smirnov test revealed that the residual significance value was 0.175, which was greater than 0.05. This shows that the residual data have a normal distribution, allowing the regression model to be applied further. The normality test is a necessary step in regression analysis to guarantee that errors are random and unbiased.

The results of the multicollinearity test revealed that the Variance Inflation Factor (VIF) value for the employee environmental awareness variable was 1.150, as did the variable for management policy, with a tolerance value of 0.869. VIF < 10 and Tolerance > 0.1 indicate no multicollinearity among the independent variables.

The Glejser test was used to determine heteroscedasticity by examining the residual value for significance. The results showed that the independent variables' significance was greater than 0.05, indicating that the model did not have any heteroscedasticity. As a result, the data passed all classical assumption tests and met the criteria for proceeding to the multiple linear regression analysis stage.

A multiple linear regression analysis was carried out to determine the impact of employee environmental awareness and management policy on the effectiveness of the waste reduction program. The analytical results revealed the following regression equation:
$Y = 2.135 + 0.455X1 + 0.389X2$

This means that for every one-unit increase in the employee environmental awareness variable, the effectiveness of the waste reduction program will increase by 0.455 units, and for every one-unit increase in the management policy variable, the effectiveness will increase by 0.389 units, assuming other variables remain constant.

The t-test results show that the t-count value for the employee environmental awareness variable is 4.123 with a significance of 0.000 < 0.05, so H1 is accepted. This means that employee environmental awareness has a significant influence on the effectiveness of the waste reduction program. Meanwhile, the management policy variable has a t-count value of 3.812 with a significance of 0.001 < 0.05, so H2 is also accepted. Both independent variables have a positive and significant partial effect on effectiveness.

The F-test results show an F-count value of 27.756 with a significance of 0.000 < 0.05. This proves that simultaneously, employee environmental awareness and management policy have a significant influence on the effectiveness of the waste reduction program at HARRIS Hotel Batam Center. Thus, the hypotheses proposed in this study are statistically accepted.

The coefficient of determination (R^2) is 0.613, indicating that 61.3% of the variation in the effectiveness of the waste reduction program can be explained by the variables of employee environmental awareness and management policy. The remaining 38.7% is influenced by other

variables outside this research model, such as organizational culture, external supporting facilities, or guest behavior factors.

These results reinforce the Green Human Resource Management (GHRM) theory, which states that individual environmental awareness contributes significantly to the implementation of sustainability programs. In this context, employees of HARRIS Hotel Batam Center have proven to have a good level of awareness, as indicated by their behavior in sorting waste, minimizing waste, and supporting recycling activities in the workplace.

These findings also support previous research conducted by Sugiharto (2021), which found that waste reduction programs in star-rated hotels will be effective if supported by clear management policies, adequate facilities, and regular supervision. Well-directed policies minimize implementation barriers at the operational level.

The results also show that the synergy between management policy and employee awareness is an essential combination. Although individual awareness is high, without supportive and applicable policies, the results will not be optimal. Conversely, good policies also require employees who are motivated to implement them.

In discussions with management, the researcher found that there are still opportunities for improvement in the evaluation and monitoring stages of the waste reduction program. Some departments do not yet have integrated SOPs in detail, so policy updates are needed to ensure that waste management standards across all hotel operational lines are consistent.

Based on these results, it is recommended that hotel management conduct regular policy socialization, provide incentives for employees who excel in waste reduction, and provide adequate supporting facilities. Thus, employees will be more motivated to keep the work environment clean and environmentally friendly.

Practically, the results of this study contribute to HARRIS Hotel Batam Center in improving the company's image as an environmentally conscious hotel. The effective implementation of the waste reduction program can be a valuable added value in attracting tourists who are increasingly aware of sustainability issues.

4. Conclussion.

Based on the results of data analysis, discussion, and research findings conducted at HARRIS Hotel Batam Center, several important points can be concluded as follows. First, the level of employee environmental awareness at HARRIS Hotel Batam Center is generally considered good. This is reflected in employees' knowledge of environmental issues, their concern for the impact of operational activities on the environment, and their daily behavior that supports waste reduction in the hotel work area. This environmental awareness has been proven to make a significant positive contribution to the effectiveness of the waste reduction program implementation.

Second, the management policy implemented at HARRIS Hotel Batam Center has also supported the achievement of the waste reduction program's objectives. These policies include preparing technical guidelines for waste management, providing supporting facilities such as segregated waste bins, conducting regular policy socialization, and performing routine evaluations and monitoring. The analysis results show that management policy has a significant influence on

program effectiveness, indicating that the role of management as a policymaker is crucial to ensure the program runs optimally.

Third, the influence between the variables of employee environmental awareness and management policy on the effectiveness of the waste reduction program is proven to be significant both partially and simultaneously. This means that the success of the waste reduction program in the hotel is determined not only by the high level of individual employee awareness but also by the clarity, consistency, and sustainability of management policies. These two factors complement each other and cannot stand alone.

Fourth, the coefficient of determination test results shows that most of the variation in the effectiveness of the waste reduction program can be explained by the variables of employee environmental awareness and management policy. Meanwhile, a smaller portion is influenced by external factors outside the research model, such as organizational culture, supporting technology, guest involvement, and local environmental policies.

Thus, the results of this study underline the importance of synergy between management's efforts to formulate clear, measurable, and well-implemented policies, and the high awareness of employees who are the spearhead of the program's implementation in the field. The success of the waste reduction program at HARRIS Hotel Batam Center is expected to become a learning model for other hotels that wish to realize more environmentally friendly business practices.

Finally, the researcher hopes that the results of this study can provide input for hotel management to continuously strengthen sustainability policies, increase environmental socialization and training for employees, and involve all relevant parties more optimally. This research is also expected to serve as a reference for future studies, especially regarding waste management, pro-environmental behavior in the hospitality sector, and the implementation of the Green Human Resource Management (GHRM) concept in Indonesia.

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ANALYSIS OF ROLL (Φ) AND YAW (Ψ) AXES RESPONSES TO STEP AND SQUARE INPUTS USING PID-LEAD, MPC-LEAD, AND MPC-PDLEAD CONTROLLERS WITH CROSS-COUPLING

Fadzilah binti Hashim[1*], Rahimah binti A Rahman[1], Nurul Hidayah binti Zainol[2], Mohd Yusoff bin Mashor[3], Siti Maryam binti Sharun[4]

[1]Electrical Engineering Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim-HiTech, Kedah, Malaysia

[2]Engineering Mini-Circuits Technologies Malaysia Sdn. Bhd. Bayan Lepas Industrial Zone, 11900 Penang, Malaysia

[3]FKTEN, Universiti Malaysia Perlis, 02600 Ulu Pauh Main Campus, Arau, Perlis, Malaysia

[4]Universiti Sultan Zainal Abidin, Gong Badak Campus, Kuala Terengganu, 21300, Malaysia

*Corresponding author e-mail address: fadzilah.hashim@ptsb.edu.my

Abstract

The development of space technology has increasingly become a key indicator of a country's level of advancement. One major challenge during satellite operations is the potential shift in a satellite's position due to various external factors. To address this, the Malaysian Innovative Satellite (InnoSAT) nano-satellite system focuses on implementing an effective control mechanism to maintain stability throughout its orbit. InnoSAT systems are subject to numerous perturbations, including cross-coupling effects, which can significantly influence performance. To ensure realistic behavior is accurately represented, researchers conducted a series of simulations that account for these cross-coupling dynamics. The attitude control system for InnoSAT was initially designed and developed using the state-space method, followed by the integration of cross-coupling effect equations. The proposed attitude control strategies were then evaluated and compared to determine their effectiveness. Specifically, the mean square error (MSE) was calculated for each controller based on the Roll (ϕ) and Yaw (ψ) axis responses. The results demonstrate that the MPC-PDLead controller delivers superior performance in terms of MSE on both axes.

Keywords: InnoSAT; MPC; Cross-coupling effect.

1. Introduction

Due to their affordability in terms of size, design, development, and power efficiency, small satellites have become increasingly popular for research in recent years. As a result, they offer a cost-effective solution for space-based applications. Rapid technological advancements have made the development and deployment of small satellites for both research and everyday use more feasible. Nano- and pico-satellites are the smallest types within the microsatellite category, while mini-satellites fall into other size-based classifications. These categories are primarily distinguished by the size and weight of the satellites. The National Space Agency of Malaysia (ANGKASA) developed the Innovative Satellite (InnoSAT), a nanosatellite, to encourage interest in satellite development among Malaysian universities (Hashim et al., 2015).

Attitude Control Systems (ACS) are essential for the successful operation of satellites and the accomplishment of their missions. Years of ongoing research into the satellite attitude control problem have led to the development of numerous potential solutions (Dastjerdi et al., 2018; Petersen et al., 2017; Song et al., 2018; Hazza et al., 2021; Al-Darraji et al., 2021). Satellite orientation can be managed using a variety of control techniques, including Proportional-Integral-Derivative (PID) controllers (Dastjerdi et al., 2018; Fiori et al., 2018), Linear Matrix Inequality (LMI) methods (Fazlyab et al., 2017), Linear Quadratic Regulators (LQR) (Hashim et al., 2015), gain scheduling/linear parameter-varying approaches, and Model Predictive Control (MPC) (Petersen et al., 2017; Sopasakis et al., 2015; Zidek et al., 2021). To further enhance ACS performance, artificial intelligence techniques such as neural networks (Song et al., 2018; Long et al., 2020) and fuzzy logic systems (Hazza et al., 2021; Navabi et al., 2020) have also been applied. Building on prior investigations into the effectiveness of both lead and MPC controllers (Prakash et al., 2017; Al-Darraji et al., 2021), researchers developed simulations to explore the use of various hybrid controllers, including PID-Lead, MPC-Lead, and MPC-PDLead controllers.

Several previous studies have examined the application of Model Predictive Control (MPC) and Lead controllers in satellite attitude control. Among these, the Lead controller has shown advantages when used to improve satellite performance in terms of attitude stabilization (Binti Hashim et al., 2024). These studies also demonstrate that MPC is widely employed to enhance and stabilize satellite performance.

Sutherland et al. (2018) describe the development of a magnetic attitude control subsystem for a 2U CubeSat. In the presence of gravity gradient torques, the satellite dynamics are open-loop unstable at the intended pointing configuration. However, the linearized time-varying system reveals a valuable interaction between hardware design and control, as it remains fully controllable under easily verifiable conditions. Additionally, the inclusion of passive air drag panels improves the system's ability to reject disturbances. The study outlines the conditions required for perfect controllability in a magnetically actuated satellite equipped with passive air drag panels, demonstrating that the closed-loop system can meet mission objectives. Both Linear Quadratic Regulator (LQR) and Model Predictive Control (MPC) schemes are employed, combined with a nonlinear time-varying input transformation, to present simulation case studies.

Mammarella et al. (2019) evaluate the effectiveness of a tube-based robust Model Predictive Control (TRMPC) algorithm for achieving robust attitude control of a CubeSat in an Earth observation scenario. The TRMPC approach was developed to enable precise attitude tracking for a small satellite operating under additive disturbances and parametric uncertainties. In this study, a 3U CubeSat equipped with a miniature digital camera—requiring a maximum pointing deviation of 0.1 degrees—was used to capture images of the Earth. The performance of the TRMPC controller was assessed within the context of Earth observation, and the results demonstrate that it outperforms a nonlinear Model Predictive Control (NMPC) scheme, particularly in terms of resilience to external shocks.

Turnwald et al. (2025) investigated a six-unit CubeSat developed for an Earth observation mission that demands high-precision pointing accuracy and controlled rotational rates. The study focuses on the application of Model Predictive Control (MPC) for attitude control, emphasizing its feasibility and practical implementation on space-constrained platforms. The MPC-based controller integrates the satellite's body dynamics with reaction wheel effects and employs stabilizing state feedback to maintain a stable closed-loop system capable of accurate trajectory tracking. To meet stability and performance requirements, the nonlinear system is linearized, enabling the formulation of a linear MPC suitable for further control development. The researchers explore various controller frameworks and solver configurations, optimizing parameters to maximize

onboard hardware efficiency. Following a successful feasibility analysis, the study outlines a plan for hardware-in-the-loop testing and an in-orbit demonstration to validate the real-time applicability and advantages of MPC for CubeSat attitude control.

After researching the efficacy of lead and MPC controllers, researchers created a simulation to examine the utilization of several controllers, such as PID-Lead, MPC-Lead, and MPC-PDLead controllers.

2. Methodology

2.1 The Equations of dynamic's InnoSAT

The transfer function must be converted into a state-space representation without considering any cross-coupling effects (Hashim, 2023). This transfer function is defined for the Roll (ϕ), Pitch (θ), and Yaw (ψ) axes, as shown in equations (1), (2), and (3) [5].

$$\phi_{(s)} = \frac{s^2+0.3051s+0.2040}{s^4+1.1050s^2+0.1650} \quad (1)$$

$$\theta_{(s)} = \frac{1}{s^2-7.1138\times10^{-3}} \quad (2)$$

$$\psi_{(s)} = \frac{s^2-0.3051s+0.8088}{s^4+1.1050s^2+0.1650} \quad (3)$$

2.2 PID-Lead Controller Design

The term PID describes its three main components, a proportional control term (K_p), an integral control term (T_i,), and a differential control term (T_{dd}) which was derived by Åström (2002), and then multiplied by the Lead controller to achieve the PID-Lead Controller as Fig. 1, then $G_{cPID}(s)$ can be written as shown in Equation (4) :

$$G_{cPID}(s)=K_p\left(1+\frac{1}{T_i s}+\frac{T_{dd}s}{1+(T_{dd}/N')\,s}\right)\left(\frac{s+0.5}{s+5}\right) \quad (4)$$

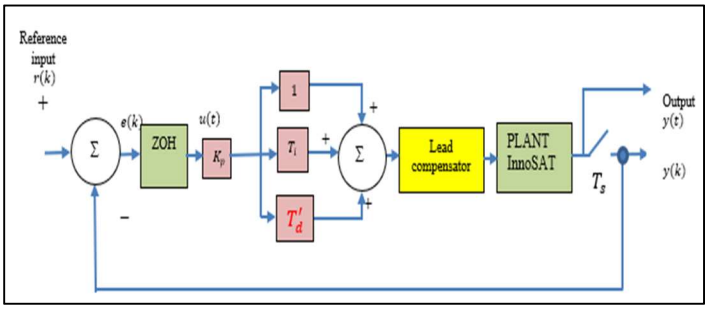


Fig. 1. Block Diagram of a PID-Lead Controller for InnoSAT Plant

2.3 MPC-Lead Controller Design

This research modified the controller by adding a Lead Controller in series with the MPC to produce a better control signal. The purpose of using a Lead Controller is to help MPC improve the system's stability when internal and external disturbances influence the InnoSAT as shown in Fig. 2.

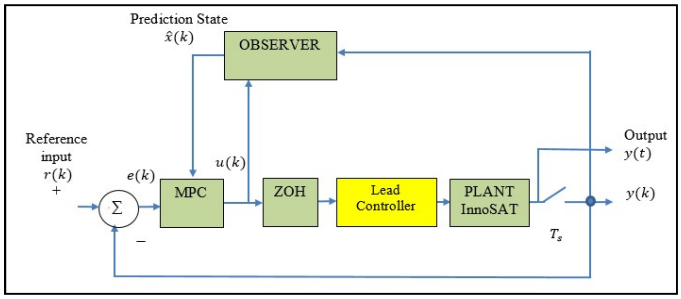


Fig. 2. Block Diagram of MPC-Lead Controller for the InnoSAT Plant

2.4 MPC-PDLead Controller Design

In this research, the MPC-based control schemes were modified to achieve the control performance needed. The MPC-PDLead Controller was designed based on the MPC-Lead Controller, where the Lead Controller was added in series with the PD component. The design of the MPC-PDLead Controller is depicted in Figure 3.

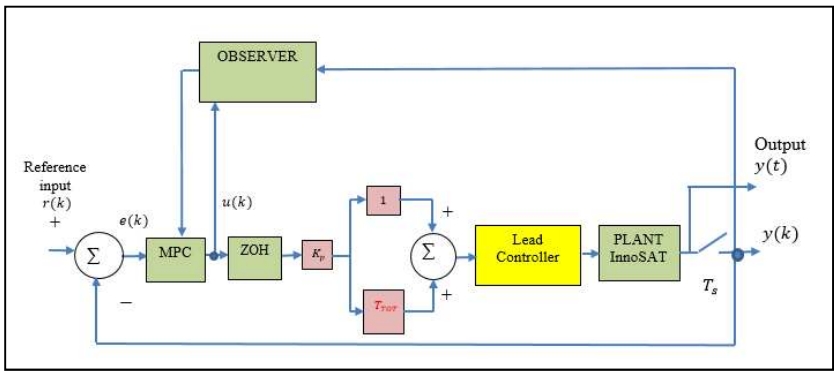


Fig. 3. Block Diagram of MPC-PDLead Controller for the InnoSAT Plant

2.5 Cross-Coupling Controller Design

The cross-coupling effect occurs due to the interaction between the Roll (ϕ) and Yaw (ψ) axes, as shown by the derivatives in the Euler dynamic equations. In contrast, the Pitch (θ) axis is not affected because it aligns primarily with the Earth's magnetic field. To describe this interaction, a Multi-Input Multi-Output (MIMO) approach is used, where the output from the Yaw (ψ) axis feeds into the Roll (ϕ) axis, and vice versa. Although this is a simplified model, actual control systems are much more complex and must include strategies to compensate for cross-coupling effects to maintain stability and performance (Scharfe et al., 1996).

Besides control methods, there is a mechanical way to reduce cross-coupling—using two counter-rotating gyroscopes on each axis. The torque generated by one gyro is balanced by the opposing torque from the other, resulting in no net cross-coupling torque on the satellite (White & Hansen, 1961). To demonstrate the impact of cross-coupling in the InnoSAT system, Figure 4 shows the system's response when a 10% cross-coupled gain is applied, highlighting the outputs of the Roll (ϕ) and Yaw (ψ) axes.

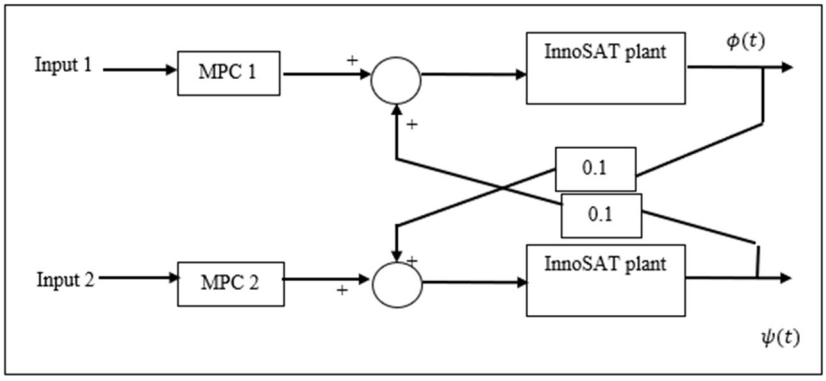


Fig. 4. Block Diagram of Two Axes InnoSAT with Cross-Coupling

The difference equation in discrete form can be used to model the InnoSAT system under the assumption of small Euler angles, as represented in Equation (5). For a more comprehensive representation, the discrete model of the InnoSAT system, incorporating three axes with cross-coupling effects, is provided in Equation (5). In particular, the Roll (ϕ) and Yaw (ψ) axes—both subject to cross-coupling interactions—serve as the primary outputs from the InnoSAT system in this model.

$$\begin{aligned} T_{dx} + T_{cx} &= I_x\ddot{\phi} + 4{\omega_o}^2(I_y - I_z)\phi \\ T_{dy} + T_{cy} &= I_y\ddot{\theta} + 3{\omega_o}^2(I_x - I_z)\theta \\ T_{dz} + T_{cz} &= I_z\ddot{\psi} + {\omega_o}^2(I_y - I_x)\psi \end{aligned} \tag{5}$$

In this study, a coupling factor between the Roll (ϕ) and Yaw (ψ) axes is introduced into Equation (5) to evaluate the satellite's robustness under coupled dynamic conditions. The inclusion of this coupling significantly increases the complexity of the satellite's dynamic behaviour. Therefore, the modified equation based on the formulation by Fadzilah (2024) can be expressed as follows:

$$\begin{aligned} T_{dx} + T_{cx} &= I_x\ddot{\phi} + 4\omega_o^2(I_y - I_z)\phi - \omega_o(I_x + I_z - I_y)\dot{\psi} \\ T_{dy} + T_{cy} &= I_y\ddot{\theta} + 3\omega_o^2(I_x - I_z)\theta \\ T_{dz} + T_{cz} &= I_x\ddot{\psi} + \omega_o^2(I_y - I_x)\psi + \omega_o(I_z + I_x - I_y)\dot{\phi} \end{aligned} \tag{6}$$

Then, the transfer functions for Roll, Pitch and Yaw axes are:

$$\begin{aligned} \phi_{(s)} &= \frac{\left[\frac{T_{dx}}{I_x} + \frac{T_{cx}}{I_x} + \dot{\phi}_{(0)}\right] + s\psi_{(s)}\omega_o(1 - \sigma_x)}{s^2 + 4\omega_o^2\sigma_x} \\ \theta_{(s)} &= \frac{\left[\frac{T_{dy}}{I_y} + \frac{T_{cy}}{I_y} + \dot{\theta}_{(0)}\right]}{s^2 + 3\omega_o^2\sigma_y} \\ \psi_{(s)} &= \frac{\left[\frac{T_{dz}}{I_z} + \frac{T_{cz}}{I_z} + \dot{\psi}_{(0)}\right] - s\phi_{(s)}\omega_o(1 - \sigma_z)}{s^2 + \omega_o^2\sigma_z} \end{aligned} \tag{7}$$

The transfer functions for the Roll, Pitch, and Yaw axes, obtained by substituting the InnoSAT parameter values into Equation (7), are given as follows:

$$\phi_{(s)} = \frac{30.58T_{dx} + 30.58T_{cx} + 5 + 0.3069s\psi_{(s)}}{s^2 + 0.8041} \quad (8)$$

$$\theta_{(s)} = \frac{20.08T_{dy} + 20.08T_{cy} + 5}{s^2 - 7.1138 \times 10^{-3}}$$

$$\psi_{(s)} = \frac{30.21T_{dz} + 30.21T_{cz} + 5 + 0.3033s\phi_{(s)}}{s^2 + 0.2033}$$

3. Results and Discussion

Fig. 5 shows the output and zoomed-out output of the Roll (ϕ) axis step response analysis using three types of controllers—PID-Lead, MPC-Lead, and MPC-PDLead—considering the cross-coupling effect. As illustrated in Fig. 5, the PID-Lead controller exhibits a steady-state error that persists through the final set of sampled data.

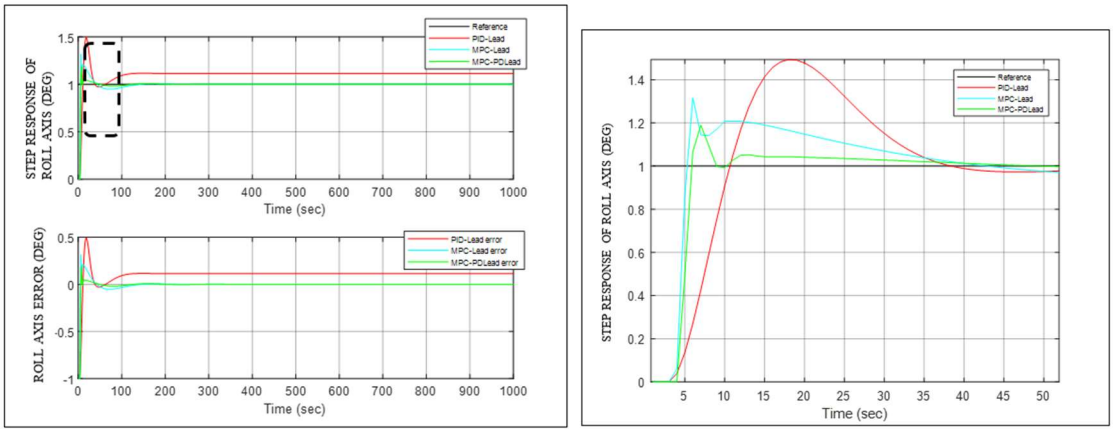


Fig. 5. Performance Comparison of Step response of Roll (ϕ) axis using PID-Lead, MPC-Lead, and MPC-PDLead Controllers with cross-coupling effect

With a maximum overshoot of 31.61% after 6 seconds, the MPC-Lead was the fastest controller at first, followed by the MPC-PDLead with 18.97% after 7 seconds, as shown in Fig. 5. With a maximum overshoot of 49.34% after 18 seconds, the PID-Lead controller was the slowest to achieve maximum overshoot. In the meantime, MPC-PDLead was the fastest controller to meet the settling time criteria, followed by MPC-Lead and PID-Lead. Although the PID-Lead Controller achieved a steady-state condition (steady-state error), it could not converge to zero.

Fig. 6 compares the performance of PID-Lead, MPC-Lead, and MPC-PDLead controllers with cross-coupling effects by looking at the square response of the Roll (ϕ) axis. This figure shows that the PID-Lead Controller has the worst output response, and the MPC-Lead Controller has the greatest. The MPC-Lead Controller not only has a short rise and delay time but also reaches steady state rapidly and has a small maximum overshoot.

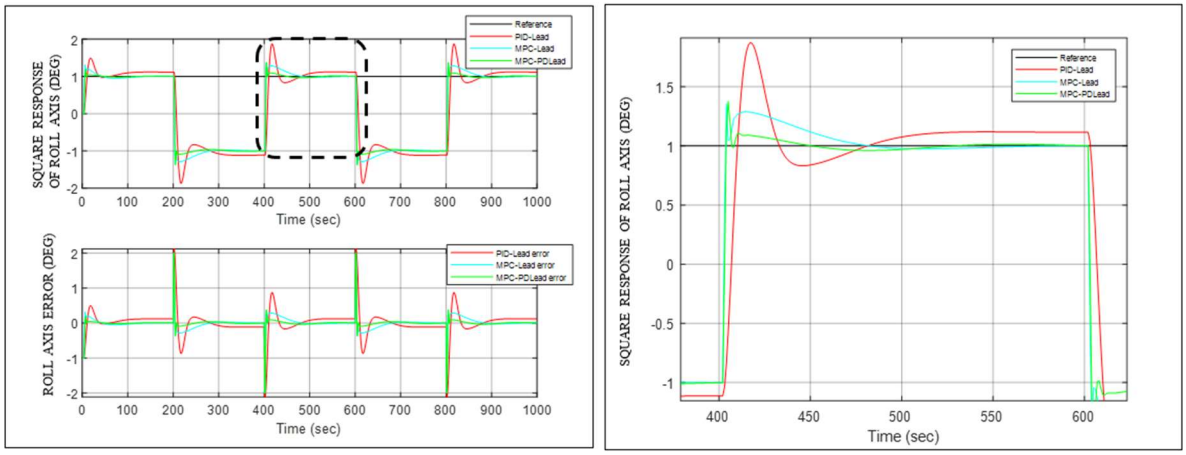


Fig. 6. Performance Comparison of Square response of Roll (ϕ) axis using PID-Lead, MPC-Lead, and MPC-PDLead Controllers with cross-coupling effect

Fig. 6 displays the zoomed-out square response of the Roll (ϕ) axis for PID-Lead, MPC-Lead, and MPC-PDLead controllers. This image illustrates how the PID-Lead Controller is unable to achieve a steady state even after the positive cycle has concluded. On the other hand, MPC-Lead and MPC-PDLead Controllers swiftly stabilize after surpassing the maximum overshoot condition.

Yaw (ψ) axis step response study employing three different types of controllers (PID-Lead, MPC-Lead, and MPC-PDLead) with cross-coupling effect is shown in Fig. 7 along with the zoom-out output. The output and error between "t = 1s" and "1000s" are shown in Figure 7, along with the PID-Lead controller's steady-state error.

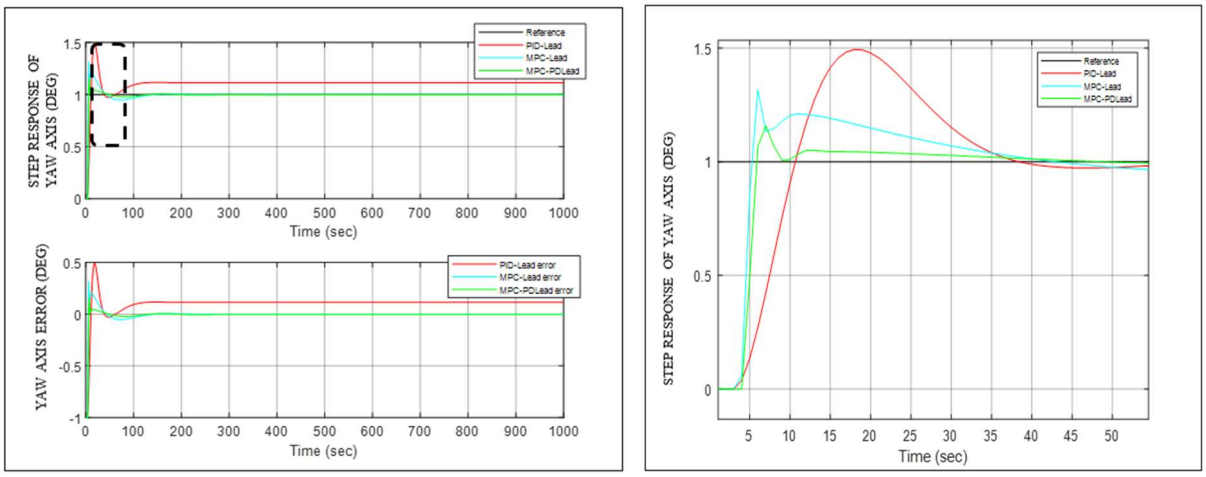


Fig. 7. Performance Comparison of Step response of Yaw (ψ) axis using PID-Lead, MPC-Leads, and MPC-PDLead Controllers with cross-coupling effect

With a maximum overshoot of 31.61% after 60 seconds, MPC-Lead was the fastest controller at first, followed by MPC-PDLead with a maximum overshoot of 15.77% after 70 seconds, as shown in Fig. 8. With 49.34% after 180 seconds, the PID-Lead controller was the slowest to reach maximum overshoot. In the meantime, MPC-PDLead was the fastest controller to meet the settling time criteria, followed by MPC-Lead and PID-Lead. The PID-Lead maintains a steady-state error until the simulation's conclusion, despite having reached the settling time state.

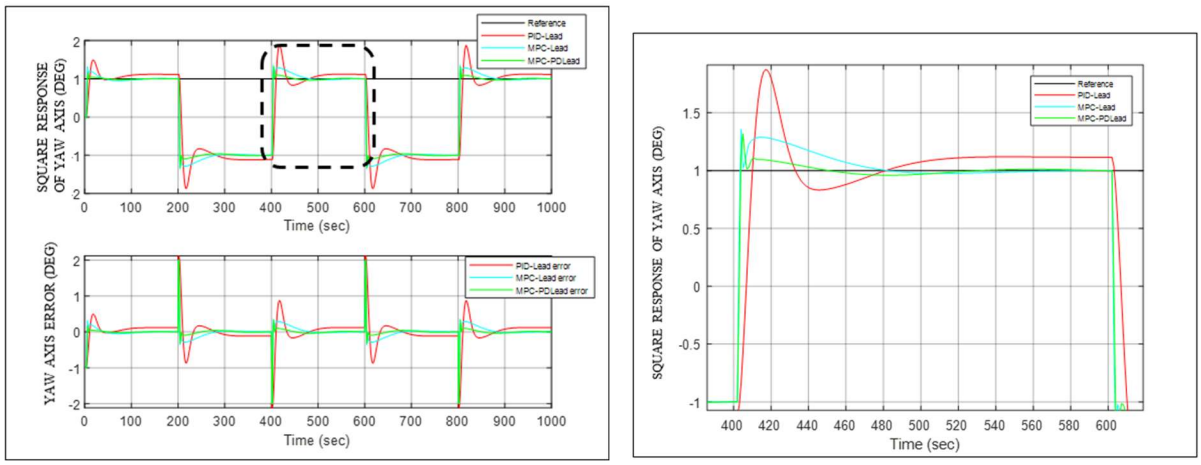


Fig. 8. Performance Comparison of Square response of Yaw (ψ) axis using PID-Lead, MPC-Lead, and MPC-PDLead Controllers with cross-coupling effect

Figure 8 shows how the PID-Lead, MPC-Lead, and MPC-PDLead controllers perform on the Yaw (ψ) axis when considering cross-coupling effects. The PID-Lead controller does not reach steady state even after the positive cycle ends, while the MPC-Lead and MPC-PDLead controllers quickly stabilize after the maximum overshoot.

Tables 1 and 2 display the mean square error (MSE) for different controllers using square and step responses. The MPC-PDLead controller has the lowest MSE during the step response. The MPC-Lead controller also shows improved MSE on the Roll (ϕ) and Yaw (ψ) axes. Overall, the MPC controllers with Lead and PD-Lead components achieve a significant reduction in MSE across all three axes for both step and square inputs.

Table 1. MSE for PID-Lead, MPC-Lead, and MPC-PDLead controllers with Cross-coupling Factor (Step response)

Controllers	Mean Square Error (MSE)	
	Roll (ϕ) axis	Yaw (ψ) axis
PID-Lead	2.0187×10^{-02}	2.0187×10^{-02}
MPC-Lead	4.6972×10^{-03}	4.6972×10^{-03}
MPC-PDLead	4.3582×10^{-03}	4.3582×10^{-03}

Table 2. MSE for PID-Lead, MPC-Lead, and MPC-PDLead controllers with Cross-coupling Factor (Square response)

Controllers	Mean Square Error (MSE)	
	Roll (ϕ) axis	Yaw (ψ) axis
PID-Lead	1.3550×10^{-01}	1.3550×10^{-01}
MPC-Lead	4.7903×10^{-02}	4.7944×10^{-02}
MPC-PDLead	4.2221×10^{-02}	4.1907×10^{-02}

When viewed from the waveform Figs. 5 until 8, at the beginning of the take-off time has shown a deficiency for the PID-Lead controller, not only a slow rise time, but also a PID-Lead Controller has a high percentage of maximum overshoot. The same is the case when considering the relatively high MSE values in Tables 1 and 2. Therefore, the PID-Lead Controller is not suitable for use during the presence of the cross-coupling effect. By referring to the waveforms in Figs. 5

to 8, the MPC-PDLead Controller demonstrated extremely good performance. The same holds when considering the MSE values in Tables 1 and 2, which are comparatively large.

4. Conclusion

A shorter rising time is desired for the system to reach ideal conditions with minimal overshoot, along with the ability to function as effectively as possible to resume normal operations in the event of any anticipated cross-coupling effects. The PD-Lead Controller was utilized, alongside the MPC-PDLead Controller, to achieve the required performance for the InnoSAT facility. Figures 5 through 8 present the output responses of the Roll (ϕ) and Yaw (ψ) axes, while the mean squared error (MSE) values are tabulated in Tables 1 and 2. The initial response of the PID-Lead controller shows a deviation exceeding the 20% maximum overshoot. Referring to the MSE values for the Roll (ϕ) and Yaw (ψ) axes with cross-coupling effects in Tables 1 and 2, the PID-Lead controller exhibited the largest mean square error. Overall, based on the output response characteristics of all tested controllers, the MPC-PDLead controller was shown to be the best among the proposed designs. A potential enhancement for the simulation is integrating the InnoSAT design system into a Graphical User Interface (GUI) that allows users to issue commands during the simulation at any time. Additionally, the GUI could enable users to modify simulation parameters and monitor progress statistics in real time.

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INTELLIGENCE CRACK DETECTION AND CLASSIFICATION IN ASPHALT PAVEMENTS USING AI-POWERED IMAGE ANALYSIS

Nor Aizam binti Muhamed Yusof

Electrical Engineering Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim, Kedah, Malaysia

Corresponding author e-mail address: aizam@ptsb.edu.my

Abstract

Abstract - Asphalt pavement defects such as cracks, rutting, and potholes commonly occur on road surfaces and are significant contributors to traffic accidents. While numerous studies have employed image processing techniques to assess pavement conditions, accurate detection remains challenging due to the presence of visual disturbances like shadows, oil stains, and water spots. To address these limitations, this study explores the artificial intelligence technique, specifically Deep Convolutional Neural Network (DCNN). By utilizing a DCNN, the study focused on how changes in the number of convolutional layers influence crack classification performance, revealing that network depth is a crucial factor in determining overall accuracy. The proposed approach demonstrated robust performance, achieving a classification accuracy of 97.13%, indicating its potential for reliable pavement condition assessment in complex real-world environments.
Keywords*:* Asphalt pavement; Deep convolutional neural network; Pavement crack detection and classification.

1. Introduction

Roads are essential for driving economic growth and development, and they offer substantial benefits to society. Common forms of asphalt pavement deterioration observed on road surfaces include cracks, potholes, raveling, and rutting (Nima Safaei, et al. 2021; Arezoumand, 2021). Among these, early-stage pavement damage such as transverse, longitudinal, and alligator cracks. Over time, the combined effects of ageing and surface degradation make these issues more prevalent across road networks. Therefore, regular road inspection plays a vital role in highway management to ensure safer driving conditions for road users (Lekshmipathy and Samuel, 2020).

In Malaysia, traditional methods of assessing pavement distress primarily relied on field investigations and manual measurements. These inspections, conducted through human observation, are inherently subjective, leading to inconsistent evaluations among different inspectors. Moreover, conducting manual inspections poses safety risks for both inspectors and road users, particularly on high-speed or heavily trafficked roads such as highways. Early detection of pavement cracks is essential for timely maintenance and prevention of more severe damage (Li and collegues, 2018; Roth et al., 2019).

As a result, there is a growing demand for rapid and accurate monitoring technologies to facilitate efficient crack detection and classification. With advancements in computer vision, image processing has become a key computational tool, involving tasks such as image acquisition, enhancement, segmentation, feature extraction, and classification (Karakose at al., 2019).

Despite these advancements, pavement crack detection remains a significant challenge in image processing due to complex backgrounds and varying pixel intensities. While hand-crafted features have been commonly employed and have shown success in automated road surface inspection, they often lack the discriminative power needed to differentiate cracks from complex backgrounds, especially under low-intensity imaging conditions. Consequently, traditional methods have seen only limited success in accurately detecting and classifying different types of cracks (Sun and Qian, 2016).

Thus, there is a continued need for improved methods in automated pavement crack recognition. In recent years, artificial intelligence (AI) has demonstrated impressive performance across numerous domains, and it holds promise for surpassing conventional hand-crafted approaches. Artificial intelligence architectures such as Deep Neural Networks (DNN), Restricted Boltzmann Machines (RBM), Deep Belief Networks (DBN), Recurrent Neural Networks (RNN), and Deep Convolutional Neural Networks (DCNN) have been successfully applied in areas including computer vision, speech recognition, natural language processing, audio analysis, and medical imaging (Takarli et al., 2018). A major advantage of artificial intelligence is its ability to learn features automatically, eliminating the need for manual feature design. However, a key challenge remains that artificial intelligence models typically require large and labeled datasets for effective training. Due to the fact that differentiating among crack types is critical for proper effective road maintenance planning, DCNN is motivated to implement into crack detection problems to produce a promising result for crack classification (Pan et al., 2018).

L. Zhang et al. (2016) proposed a DCNN-based approach using six convolutional layers to detect longitudinal and transverse pavement cracks. They utilized 500 high-resolution pavement images (3264 × 2448 pixels), segmenting them into 99 × 99 patches to generate 640,000 training samples and 200,000 testing samples. Their method achieved precision, recall, and F-score values of 87.0%, 92.5%, and 89.7%, respectively. Nonetheless, challenges persist, particularly in handling complex pavement conditions such as shadows, oil spills, and water spots, which hinder the effectiveness of feature extraction across varying pavement surfaces.

The study by Wang et al. (2015) demonstrated DCNN for recognizing cracks on asphalt surfaces at a subdivided image cell. They proposed 4 convolution layers and 2 fully- connected layers with 1,246,240 parameters in total with 5,000 images. The result showed better performance with an accuracy of 96.32% and 94.29% on training data and testing data respectively.

Meanwhile, Huang & Zhang (2012) applied DCNN using an input image of 64x64 to detect pavement cracks. The images were captured using an I-phone with the pixel of camera was 3264×2448 and prepared 30,000 images as a training dataset. The segmented image size of 64×64 showed better comprehensive performance for recall and F-score. The experimental result achieved 97.2%, 97.6% and 90.1% correct rate of classification for longitudinal crack, transverse crack and alligator crack, respectively.

However, most studies in the area of DCNN have used bigger training dataset and a convolution layer for the network to ensure the network can learn better to predict pavement cracks. Therefore, in this work, we try to work with this gap and aim to design an efficient method in order to explore how the numbers of convolution layers affects DCNN with respect to classification performance.

The main purpose of this study is to develop pavement crack classification using a lower number of convolutional layers, considering to reduce the processing time of the network with acceptable performance. Section 2 explains in detail the image acquisition including the methodology used in this study. The practical experiment and results will be presented in Section 3 to prove the

feasibility of the proposed procedure and find out the best model for the detection and classification of asphalt pavement. Finally, Section 4 concludes the findings of the study.

2. Methodology

This section provides a detailed explanation of the proposed methodological framework, which consists of three (3) stages: 1) data augmentation, 2) pavement crack detection using DCNN, and 3) pavement crack classification using DCNN. Each stage of the methodology is elaborated in the following sub-sections.

2.1 Data Augmentation

The first stage of any vision-based system is image acquisition. In this study, images were captured using a handheld digital camera, the Nikon Coolpix S6150, under natural lighting conditions. This stage involves preparing raw RGB pavement images for further processing. The crack images were taken with the camera positioned perpendicular to the ground surface, utilizing a high-resolution colour (RGB) camera with a resolution of 3456 × 4608 pixels.
The images include complex backgrounds such as shadows, oil spills, and water spots. Furthermore, the consistency in the distance between the camera and the pavement surface was maintained, with the camera held approximately 100 cm above the ground, to achieve good image contrast. A total of 4,000 RGB images comprising transverse cracks, longitudinal cracks, and alligator cracks were collected from roads located in the Kedah and Penang districts.

a. Crack and non-crack training dataset
   A sufficiently large and diverse training dataset is crucial for effectively training and validating DCNN algorithms. The selection and quantity of training data significantly influence the performance of the network. In this work, the proposed method was trained and tested on a binary dataset categorized into crack and non-crack. In this work, the numbers of training dataset are 8000 patches in total, consisting of 4000 crack patches and 4000 non-crack patches. Table 1 tabulates the number of training and testing dataset for crack and non-crack patches.

Table 1. Number of training and testing dataset

	Crack	Non-crack
Training set	4000	4000
Testing set	500	500

b. Transverse, longitudinal and alligator training dataset
   In this work, the proposed method was trained and tested on a multi-class dataset categorized into transverse crack, longitudinal crack, and alligator crack. The same DCNN architecture was used to generate binary images as input for evaluating classification performance. Accordingly, the training dataset consisted of 3,000 binary images, while the testing dataset comprised 450 images. Table 2 summarizes the number of training and testing samples for each category: transverse crack, longitudinal crack, and alligator crack.

Table 2. Number of training and testing dataset for transverse, longitudinal and alligator

Dataset	transverse	longitudinal	alligator	total
Training dataset	1000	1000	1000	3000
Testing dataset	150	150	150	450

2.2 Pavement Crack Detection Using DCNN

A Deep Convolutional Neural Network (DCNN) is composed of multiple layers, including convolutional, pooling, and fully connected layers. Generally, the convolutional layers are responsible for extracting image features at various levels of abstraction (Zou et al., 2015; Pan et al., 2018). They utilize adjustable kernels, also referred to as filters, to generate feature maps. The Rectified Linear Unit (ReLU) activation function was applied to the outputs of each convolutional and pooling layer to introduce nonlinearity into the model. The pooling layer operates on non-overlapping regions, serving as a statistical summarization to reduce the number of feature parameters and help prevent overfitting. The final stages of the DCNN consist of fully connected layers followed by a softmax layer (Fan and Wu, 2018).

Furthermore, the performance of crack detection was evaluated using three (3) key metrics: recall, precision, and accuracy. Recall measures the percentage of actual crack grids that were correctly identified by the DCNN. Precision indicates the percentage of crack pixels correctly classified relative to the total number of detected cracks in the dataset. Accuracy represents the overall percentage of correctly classified crack and non-crack instances relative to the total number of samples. The recall, precision, and accuracy are calculated as follows:

$$\mathrm{Re}\,call = \frac{TP}{TP + FN} \tag{1}$$

$$\mathrm{Pr}ecision = \frac{TP}{(TP + FP)} \tag{2}$$

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \tag{3}$$

where TP, FN, TN, and FP represent the following: TP (True Positive) refers to crack pixels correctly identified as crack structures; FN (False Negative) refers to crack pixels incorrectly identified as non-crack structures; TN (True Negative) refers to non-crack pixels correctly identified as non-crack structures; and FP (False Positive) refers to non-crack pixels incorrectly identified as crack structures.

2.3 Pavement crack classification using DCNN

After completing crack detection, the output images from the first DCNN are fed into a second DCNN for crack classification. Before classification, binary images representing transverse, longitudinal, and alligator cracks are prepared and used as input for the second DCNN, which is trained to distinguish between different types of pavement cracks. To assess the impact of convolutional and pooling layers, this study trained a shallow network with four (4) layers and a deeper network with six (6) layers, allowing for a comparison to optimize the DCNN structure and enhance pavement crack classification performance. The classification performance for each crack type is evaluated by measuring the classification accuracy, defined as follows:

$$Classification\ accuracy = \frac{Number\ of\ crack\ samples\ correctly\ classified}{Number\ of\ crack\ samples} \tag{4}$$

3. Result and Discussion

In this study, the layers of convolution were manually adjusted. The DCNN was evaluated using 1,000 testing images to analyze the network's performance in detecting cracks and non-cracks, based on a training dataset of 8,000 images. Recall, precision, and accuracy were calculated to assess the crack detection performance, aiming to validate the effectiveness of the network, with the results summarized in Table 3.

Table 3. Recall, Precision and Accuracy using convolution layers

Conv Layer	Re (%)	Pr (%)	Acc (%)
4 layers	98.10	99.50	98.45
5 layers	97. 90	99.00	98.40
6 layers	96.10	97.80	96.95

Table 3 summarizes the experimental results for Recall (Re), Precision (Pr), and Accuracy (Acc) based on different numbers of convolutional layers. From the results in Table 3, it was observed that networks with four (4) and five (5) convolutional layers achieved nearly identical performance, demonstrating a strong ability to distinguish between positive and negative samples due to the high sensitivity of the feature extractors. However, increasing the number of convolutional layers to six (6) led to a decline in performance. Specifically, in this study, adding more convolutional layers did not necessarily reduce the risk of generating false-positive errors. Instead, the network tended to excessively attenuate the images due to repeated down-sampling, leading to the loss of critical image information throughout the convolutional process.

To examine the performance of the pavement classification, 450 raw images are used. The testing results are presented in Table 4 summarises the classification accuracies of the proposed DCNN which demonstrates that all of them can perform a high-accuracy classification.

Table 4. Classification accuracies using DCNN

Conv Layer	Performance (%)			Overall Acc (%)
	T	L	A	
4 layers	99.2	99.2	93.0	97.13
5 layers	96.8	97.3	91.0	95.03
6 layers	94.0	95.0	86.0	91.67

Table 4 shows crack classification using DCNN to classify pavement crack into transverse (T), longitudinal (L) and alligator (A). From the experimental result, the classification of alligator cracks has a lower accuracy than others due to the network failing to find the continuous cracks. This could be that the feature extractor does not grasp the hairline and fine cracks sufficiently. Therefore, it contributes to more difficulties in correctly classified alligator cracks where they have the similarity contrast between the crack and the background. The research shows that the proposed four layers DCNN is the optimal one (97.13%). The result shows that network detects nearly all the cracks correctly, with few errors, but, indicating a significant computational speed in time efficiency and also involves fewer parameters network.

From the comparative studies which used various convolution layers, the proposed DCNN method showed robust performance compared to the previous studies. Table 5 lists the comparison of the performance of the network.

Table 5. Comparison result using DCNN

Method	Performance (%)			Overall Acc (%)
	T	L	A	
Li et al., 2019	98.0	97.7	91.3	95.67
X.Wang et al., 2018	97.2	97.6	90.1	94.97
Our method	99.2	99.2	93.0	97.13

From Table 5, Li et al. (2019) achieved an accuracy of 95.67% in classifying three types of cracks using 1,500 testing images. Their model employed a six-layer DCNN trained on a dataset of 26.9K images. Similarly, Wang et al., (2018) demonstrated strong performance on 310 testing images, achieving 94.97% accuracy for classifying transverse, longitudinal, and alligator cracks using a four-layer DCNN trained on 30K images. In comparison, our proposed method successfully classified three types of cracks with a promising accuracy of 97.13%, utilizing only 8K training images and a four-layer DCNN. This approach demonstrates high performance in crack detection and classification while maintaining an acceptable processing time.

4. Conclusion

The experimental results reveal that increasing the number of layers in a DCNN does not necessarily guarantee improved performance. Instead, optimal accuracy is achieved when the network architecture is appropriately tailored to the complexity of the problem and the nature of the training dataset. In this study, all three proposed DCNN architectures achieved overall accuracies exceeding 91.67%. The highest accuracy, 97.13%, was obtained using a four-layer network, which also maintained efficient processing times. These results demonstrate that the four-layer network not only enhanced performance but also reduced the number of parameters, contributing to better generalization in detecting fine or hairline pavement cracks at the pixel level. This suggests strong potential for implementing the method as a road monitoring tool to support surveyors in future pavement distress evaluations. Comparative analysis also showed that our approach outperformed other DCNN architectures in crack classification on the test data. Future development of the network will focus on extending its capabilities to detect and classify block cracks, providing a more realistic and practical solution for surveyors conducting road inspections.

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DESIGN OF A QR-BASED JUICE ORDERING INFORMATION SYSTEM AT OMA JUICE

Salsa Agzania*, Guidio Leonarde Ginting

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, Medan, Sumatera Utara, Indonesia

*Corresponding author e-mail address: sagzania@gmail.com

Abstract

This research focuses on the design and implementation of a QR code-based juice ordering information system at Oma Juice, aiming to improve operational efficiency, reduce unnecessary costs, and increase customer satisfaction. The background of the study highlights the limitations and inefficiencies present in the current manual ordering process, which often leads to slow service, order inaccuracies, and lack of structured transaction data. To address these issues, a qualitative research method was adopted, involving observation, interviews with employees and customers, and a literature review to identify and analyze user needs comprehensively. Through the analysis of current business workflows and customer interactions, the research identifies key pain points that can be optimized through digital transformation. The result of this research is a prototype of an ordering system that utilizes QR codes to enable customers to place orders independently, thus speeding up transactions, reducing human error, and generating real-time data for management insights. This innovation is expected to support better decision-making and improve overall service quality.
Keywords: QR; System; Ordering.

1. Introduction

The development of the culinary business sector in Indonesia, particularly in the area of fresh beverages, continues to show a significant upward trend. One of the most popular choices among consumers is fruit juice due to its high nutritional value and refreshing taste. Oma Juice, a fresh juice business established in 2018 and located in Tembung, Pasar VI, contributes to this demand by offering a variety of high-quality natural juices and fruit soups. Their flagship products include orange, mango, apple juice, and other fruit combinations that are served fresh to meet customer needs for healthy drinks.

Currently, the ordering process at Oma Juice is still done manually. Customers must visit the outlet in person, select their desired menu items from a printed list, and verbally communicate their order to the cashier, who then records it in a notebook or on paper. This manual method often leads to inefficiencies, especially during peak hours, and is prone to errors such as incorrect entries, overlooked orders, or misplaced notes. These issues can lead to long queues, delayed service, and decreased customer satisfaction, ultimately affecting the outlet's service capacity and competitiveness.

In the face of increasing competition, innovation in service systems is necessary. Many businesses in the fresh beverage industry have adopted digital ordering systems using QR codes, allowing customers to scan and place orders directly without assistance from staff. This technology not only streamlines the ordering process but also reduces human error and enhances

customer convenience. By adopting this digital approach, Oma Juice can improve operational efficiency and provide faster, more accurate service.

Previous studies have highlighted the advantages of implementing QR-based ordering systems. Puspita (2023) examined the use of QR codes in boosting sales for SMEs in Medan, emphasizing its role in simplifying digital transactions. Similarly, Ali, Andryana, and Sholihati (2023) designed a web-based food ordering system that integrates QR code technology to reduce order input errors. Another study by Khoiri (2022) implemented a QR code ordering system in a coffee shop to improve service speed and minimize physical interaction. These findings support the adoption of QR code-based systems as a viable solution to address service inefficiencies.

Based on the existing problems in Oma Juice's ordering process and the insights from previous research, this study aims to design and develop a QR code-based juice ordering information system. The system is expected to simplify the ordering process, reduce recording errors, improve transaction efficiency, and ultimately enhance customer satisfaction. Through this innovation, Oma Juice can maintain its competitive edge and continue to grow in the digital era.

2. Methodology

This study uses a qualitative approach with a descriptive method, aiming to design and develop a QR-based juice ordering information system at Oma Juice. This approach was chosen because it allows the researcher to gain an in-depth understanding of the problems encountered in the manual ordering process, as well as to design a system solution that aligns with the actual operational needs. The research was conducted at Oma Juice, a fresh beverage business located in Tembung, Medan, during the period of March to May 2025. During this time, the researcher carried out a series of activities including observation, data collection, system analysis, system design, and testing (Sugiyono, 2020) and (Ismail, 2020).

The data used in this research consisted of both primary and secondary data. Primary data were obtained through direct observation of the ordering process at Oma Juice and interviews with the owner and staff regarding the ordering system currently in use. Secondary data were collected through literature reviews relevant to information system development, QR code technology, and web-based system implementation in the context of micro and small businesses. Data collection techniques combined observation, interviews, and literature study to provide a comprehensive picture of the system requirements and the challenges in service delivery (Rohmah, 2024).

The data collected were then systematically analyzed to identify user needs and the features that needed to be developed in the system. The analysis process began with data reduction, in which non-essential or redundant information from interviews and observations was eliminated. Key recurring issues were categorized, such as long queues, human errors in manual note-taking, and delays in service. These categories were then mapped into specific system requirements, for example, automating order recording and enabling self-service through digital menus. This translation from qualitative data to technical requirements ensured that the system design was closely aligned with user pain points.

The system was developed using a web-based approach with the use of QR codes as an access medium. Customers can scan a QR code available at the outlet to directly access the digital ordering page. They can then choose the desired menu items, and the system will automatically record each transaction into the database. This not only makes it easier for customers to place

orders but also helps Oma Juice staff manage transaction data more efficiently, quickly, and with minimal errors.

Overall, the research methodology used in this study provides a solid framework for designing a digital ordering system tailored to real-world conditions and business needs. By combining field data collection and literature-based analysis, the resulting system is expected to enhance the efficiency of the ordering process and provide customers of Oma Juice with a faster and more convenient ordering experience.

3. Results and Discussion

The implementation of a QR-based juice ordering information system at Oma Juice has proven successful in addressing the inefficiencies of the previous manual process. The system digitalizes the juice ordering process, replacing handwritten notes with an interactive, web-based platform accessible via QR code scanning. Customers can simply scan the code available at the outlet to access the digital menu and place their orders without queuing or verbally interacting with the cashier. This new method improves order speed, accuracy, and customer convenience (Natalina, Zunaidi, and Rahmah 2021).

During the development phase, the system was designed using a Data Flow Diagram (DFD) to describe how data moves within the system. The DFD illustrates the interactions between external entities such as customers and the admin with the core processes like order placement, order management, and receipt generation (Safwandi, 2021).

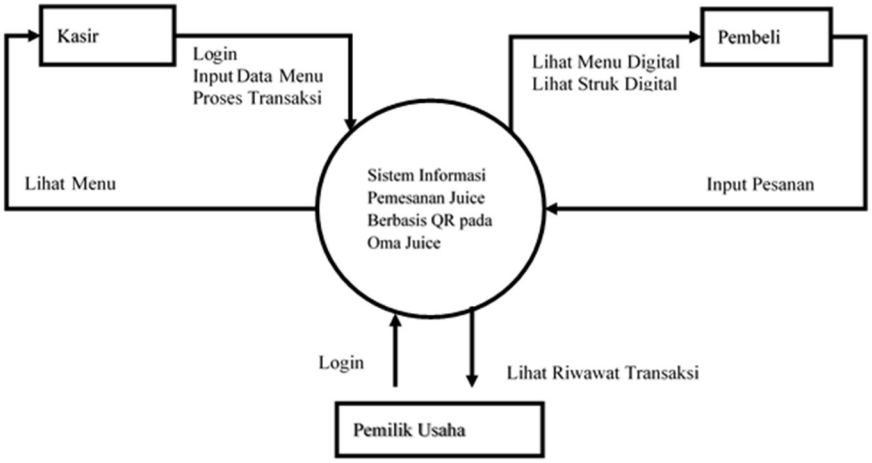


Fig. 1. Data Flow Diagram (DFD)

The database structure consists of five main tables: user, menu, transaksi, transaksi_detail, and struk. The user table stores administrator login data, while the menu table manages the product catalog. The transaksi table records overall customer transactions, and its details (such as item quantities and prices) are stored in transaksi_detail. Meanwhile, the struk table is responsible for generating a unique daily receipt number based on the transaction date (Doe, 2020).

Table 1. User

Kolom	Tipe Data	Keterangan
id_user	INT	PRIMARY KEY, AUTO_INCREMENT
username	VARCHAR(50)	NOT NULL, UNIQUE, nama pengguna (admin, dll)
password	VARCHAR(255)	NOT NULL, menyimpan hash password

Table 2. Menu

Kolom	Tipe Data	Keterangan
id_menu	INT	PRIMARY KEY, AUTO_INCREMENT
nama_menu	VARCHAR(100)	NOT NULL, nama menu jus
harga	DECIMAL(10,2)	NOT NULL, harga per item jus
gambar	VARCHAR(255)	Nama file gambar/menu (opsional)

Table 3. Transaction

Kolom	Tipe Data	Keterangan
id_transaksi	INT	PRIMARY KEY, AUTO_INCREMENT
tanggal_transaksi	DATETIME	NOT NULL, default CURRENT_TIMESTAMP, waktu transaksi dibuat
status_pemesanan	ENUM	NOT NULL, default 'masuk', nilai: 'masuk', 'proses', 'selesai'
status_pembayaran	ENUM	NOT NULL, default 'belum bayar', nilai: 'belum bayar', 'sudah bayar'
jenis_pembayaran	VARCHAR(50)	Jenis metode pembayaran (misal: tunai, QRIS, dll) (opsional)
keterangan_opsional	TEXT	Keterangan tambahan (opsional)

Table 4. Transaction detail

Kolom	Tipe Data	Keterangan
id_detail	INT	PRIMARY KEY, AUTO_INCREMENT
id_transaksi	INT	NOT NULL, FOREIGN KEY ke transaksi(id_transaksi)
id_menu	INT	NOT NULL, FOREIGN KEY ke menu(id_menu)
harga_per_qty	DECIMAL(10,2)	NOT NULL, harga satuan per item pada saat transaksi
jumlah	INT	NOT NULL, jumlah item dibeli
total_harga	DECIMAL(10,2)	NOT NULL, hasil dari harga_per_qty × jumlah
keterangan_opsional	TEXT	Keterangan tambahan (opsional)

Table 5. Struk

Kolom	Tipe Data	Keterangan
id_struk	INT	PRIMARY KEY, AUTO_INCREMENT
id_transaksi	INT	NOT NULL, FOREIGN KEY ke transaksi(id_transaksi)
tanggal	DATE	NOT NULL, default CURRENT_DATE, tanggal struk dicetak
no_struk	INT	NOT NULL, nomor struk unik per tanggal
(UNIQUE)	(tanggal, no_struk)	Kombinasi tanggal dan nomor struk harus unik

The system interface was designed to be user-friendly for both customers and administrators. The key pages include the admin login page, dashboard, juice product management, transaction management (incoming, processing, and completed orders), and a digital ordering page for customers. Admins can also view transaction history and print digital receipts.

The system was implemented using PHP and MySQL for the backend, while HTML, CSS, and JavaScript handled the frontend. Functional testing was carried out by simulating actual customer orders and validating the flow from order placement to receipt generation. The results show that the system successfully records orders, updates transaction statuses, and generates structured digital receipts. Screenshots of the implemented system include the login page, admin dashboard, menu listings, order management pages, digital menu for customers, and receipt view (W3Schools, 2020; Blum, 2021).

In addition to technical testing, informal usability testing was conducted with a group of five regular Oma Juice customers. Participants were asked to place orders using the QR code-based system

and then provide feedback regarding ease of use, clarity of menu presentation, and overall satisfaction. The feedback indicated that the majority found the system intuitive and significantly faster than the manual process. Minor suggestions such as adding item descriptions and confirming order summaries before submission, were noted for future enhancement.

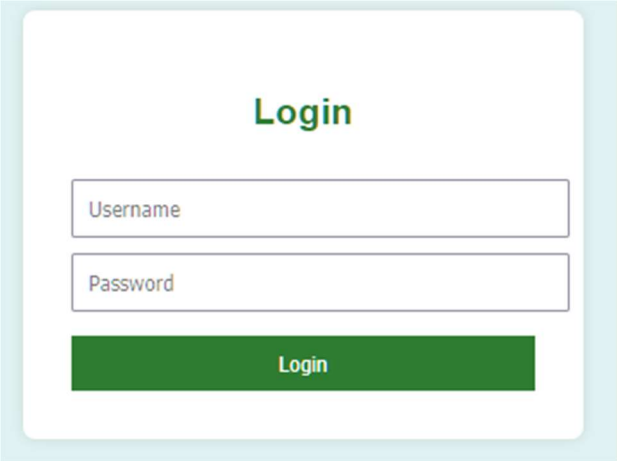


Fig. 2. Login page

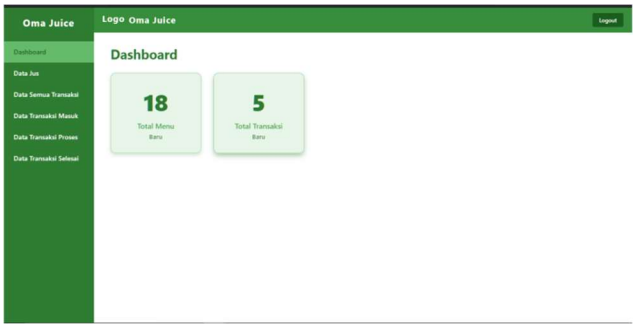


Fig. 3. Dashboard Page

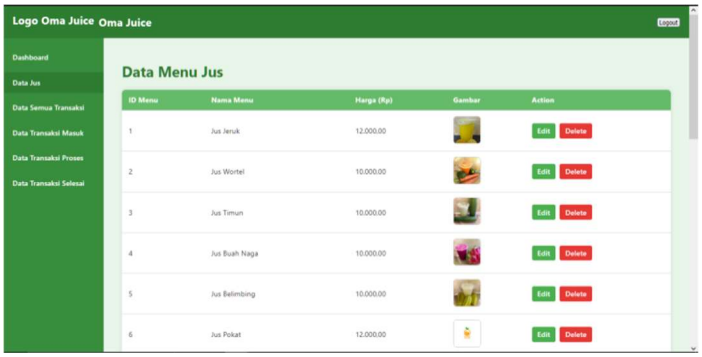


Fig. 4. Menu Page

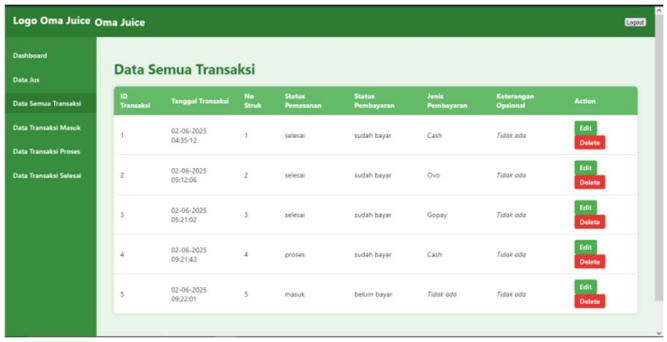


Fig. 5. Transaction Page

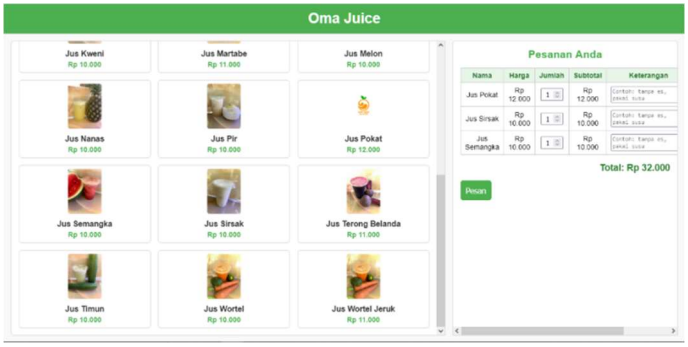


Fig. 6. Digital Menu Page



Fig. 7. Digital Struk Page



Fig. 8. Qr Code

Overall, the developed system effectively solves the previously identified problems at Oma Juice. It streamlines the ordering process, minimizes human error, enhances customer service speed, and improves overall satisfaction. With features like order confirmation, receipt tracking, and

secure admin access, the system provides a modern, efficient ordering experience. Nevertheless, future improvements could include integration with digital payment methods and a dedicated mobile application to further expand accessibility and convenience.

From a technical perspective, the system was designed with basic security measures, such as password hashing for admin login and input validation to prevent SQL injection. While currently implemented at a single outlet, the modular design of the system allows for scalability. With minimal adjustments, the system could be deployed across multiple Oma Juice branches, enabling centralized transaction tracking and performance analytics.

4. Conclusion

Based on the research conducted on the design of a QR-based juice ordering information system at Oma Juice, it can be concluded that the system was successfully designed and implemented effectively to replace the previously used manual ordering process. This system provides an efficient digital solution by allowing customers to scan a QR code to access the menu and place orders independently. With this implementation, the order recording process becomes faster, more accurate, and less prone to errors, thereby improving operational efficiency and service quality at Oma Juice.

The system development includes several main features such as menu data management, digital ordering, automatic transaction recording, digital receipt generation, and order status monitoring. The implementation results show that the system helps reduce customer queues, speeds up service, and enhances comfort and satisfaction for customers when interacting with the service. In addition, it also provides convenience for the admin in monitoring and managing transaction data in real time.

This research also proves that the use of QR code technology can be an effective alternative to support digital transformation in small businesses like Oma Juice. The system that was built successfully addresses the research problems, namely how to design, develop, and implement an efficient QR-based ordering system that meets business needs. These findings are expected to serve as a reference for the development of similar systems and as a foundation for Oma Juice to further adopt broader and more integrated digital systems in the future.

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DESIGN OF AN AI-BASED E-COMMERCE SYSTEM USING THE DECISION TREE ALGORITHM TO IMPROVE PRODUCT RECOMMENDATION ACCURACY AND INCREASE SALES

Nurhalijah*, Robbi Rahim

Management Study Program, Sekolah Tinggi Ilmu Manajemen Sukma, Medan, Sumatera Utara, Indonesia

*Corresponding author e-mail address: nurhalijahlijah440@gmail.com

Abstract

The development of information technology is driving the transformation of e-commerce; however, many platforms still struggle to effectively recommend products based on user preferences. This study designs an AI-based e-commerce system with a Decision Tree algorithm to enhance recommendation accuracy and boost sales. This study uses a qualitative methodology that includes observation, in-depth interviews, and desk research to collect relevant data related to user needs and best practices in recommendation system development. The results indicate that the proposed system delivers more relevant recommendations compared to conventional methods, while also increasing user engagement and sales potential. In conclusion, the Decision Tree algorithm proves effective in strengthening e-commerce recommendation systems by making them more personalized and adaptive.
Keywords: AI; Commerce; Decision.

1. Introduction

The rapid developments in information and communication technology have driven transformation in various sectors, including the business world. One of the most notable innovations is the emergence of e-commerce systems that enable people to buy and sell products online. This innovation not only simplifies the transaction process for customers but also enables business owners to expand their market reach. As a result, implementing smart strategies to attract consumers and increase sales has become a necessity for businesses operating in this digital era.

However, behind that convenience, significant challenges must be faced, namely, how to provide accurate and relevant product recommendations to consumers. Inaccurate product recommendations can diminish user experience and hinder sales growth. In this context, the utilization of artificial intelligence (AI) technology becomes a potential solution.

AI enables in-depth analysis of consumer behavior and preferences, allowing systems to provide more personalized and targeted recommendations. One approach in AI that can be used to build recommendation systems is the Decision Tree algorithm. This algorithm has advantages in terms of interpretability and ease of implementation. With Decision Trees, transaction data and user preferences can be analyzed to produce effective recommendation patterns. Additionally, this algorithm is also useful for market segmentation based on relevant attributes.

Several previous studies have emphasized the significance of AI and Decision Tree algorithms in intelligent systems. For instance, Kharisma et al. (2023) applied Decision Tree for sentiment analysis in app reviews. Rosidin et al. (2024) highlighted AI's transformative role in business

process automation across sectors like manufacturing and customer service. Meanwhile, Wibowo (2024) discussed AI innovations in e-commerce, including customer-focused product search, visual recognition, and secure digital transactions.

This research aims to design an AI-based e-commerce system that uses the Decision Tree algorithm to enhance the accuracy of product recommendations and boost sales. This system is expected to provide a better shopping experience for users and support entrepreneurs in developing effective business strategies amid the growing competition in the digital marketplace.

2. Methodology

This study adopts a qualitative approach with a descriptive method to design and develop an AI-based e-commerce system integrated with the Decision Tree algorithm. The objective of this method is to provide a structured understanding of how intelligent recommendation features can be embedded into a web-based shopping system to improve the accuracy of product suggestions and increase conversion rates (Djusfi et al.,2021;Laiya and Manueke, 2022).

This research was conducted on an e-commerce platform that served as the object of study for the implementation of an Artificial Intelligence (AI)-based system using the Decision Tree algorithm. This research was carried out from March to May 2025.

This research employs a qualitative approach with a descriptive method to design and develop an AI-based e-commerce system integrated with the Decision Tree algorithm. The purpose of this method is to provide a structured understanding of how intelligent recommendation features can be integrated into web-based shopping systems.

This research utilizes both primary and secondary data. Primary data is obtained through direct observation and interviews with related parties. Secondary data comes from literature studies, such as journals, books, and relevant scientific documents. The sources of data include internal data from the e-commerce system as well as external data from outside the organization.

The data collection was carried out through observation of the running system and interviews with users and system managers. In addition, a literature review was conducted to obtain theoretical foundations regarding AI, Decision Tree algorithms, and product recommendation systems. Data analysis was performed by reducing the data to relevant parts, presenting it in an easily understandable format, and drawing conclusions from the results. An evaluation was conducted to assess the accuracy of the system in providing product recommendations. The framework of this research includes the application of AI and Decision Tree algorithms. User and transaction data is processed to form a recommendation model that is then integrated into the system. The model is tested to evaluate its effectiveness in improving the accuracy of recommendations and sales.

The development process began by identifying the functional requirements of the system, which include product management, user registration, transaction processing, and personalized product recommendations. A dataset consisting of 1,000 real product records was prepared to simulate the online catalog, each containing attributes such as name, category, price, and rating. From this, a sample of 20 products, along with 5 user records and 10 transaction logs, was selected as representative data for implementation and testing.

The Decision Tree algorithm was implemented using a rule-based classification approach. For new users, the system collects at least three product categories of interest as the basis for generating initial recommendations. For returning users, the system utilizes previous transaction data to identify product categories they frequently engage with. These two types of data—user interest and transaction history—are used as decision parameters to classify and determine the most appropriate products to recommend. All recommendation activity and decision outcomes are recorded in a dedicated log for evaluation purposes (Nuraeni, Sudiarjo, and Rizal 2021; Eriana and Zein, 2023).

3. Results and Discussion

This research produces an Artificial Intelligence (AI) based e-commerce system using the Decision Tree algorithm, designed to improve accuracy in providing product recommendations to users. This system is developed using a user data-based approach, product data, and transaction history. The data used includes primary data (derived from user observations and interviews), as well as secondary data in the form of references from previous research. Implementation is carried out systematically, starting from data collection, preprocessing, model training, testing, to integration into a web-based e-commerce system.

The results of the system test show that the Decision Tree Algorithm can form product recommendation patterns based on important attributes such as product category and rating. This indicates that product ratings significantly influence consumer purchasing decisions. Through decision tree formation, the system can map the relationship between user interests and relevant products. For example, users who like electronic products with high ratings will be recommended similar products in the same category and quality.

The system is built with key e-commerce features such as a product homepage, product detail page with recommendations, a cart system, checkout, and an admin dashboard. The recommendation feature is divided into two: for new users and for returning users. For new users, the system uses category preferences selected during registration to provide initial recommendations. Meanwhile, for returning users, the system leverages historical transaction data that has been previously made, allowing for more personal and relevant recommendations. This data is processed by a Decision Tree to generate recommendations based on the decision paths that have been trained.

Technically, the system has successfully saved recommendation logs into the database, allowing admins to see the reasons behind each recommended product. Furthermore, the 'similar products' feature on the detail page also enhances the system's accuracy in offering choices. Based on the results of implementation and testing, the system provides more accurate recommendation results compared to static methods without AI. Users acknowledge that the products displayed align with their needs and interests, thereby increasing the likelihood of purchases and interactions.

However, this system still has some limitations. First, the use of a single algorithm (Decision Tree) makes the system less flexible in handling large or complex datasets. Second, user interactions such as clicks, visit duration, or comments have not been used as additional learning data. Therefore, the suggestion for future development is to integrate additional algorithms, such as Random Forest or deep learning models, to improve accuracy, as well as to add user interaction features so that the system can learn more dynamically from real-time behavior.

The AI-based e-commerce system was successfully developed and implemented using a structured logic flow driven by user preferences and historical transaction data. As part of the implementation, 1,000 product records were prepared, but for testing purposes, a sample dataset consisting of 20 real products, 5 user records, and 10 sample transactions was used. Each user was required to select a minimum of three preferred product categories at registration, forming the input for initial classification.

A decision tree model was developed manually by using a rule-based classification approach derived from these input data. The model utilized two main features: user-selected product categories and previously purchased product categories. The system determined recommendations for each user depending on whether or not they had a transaction history.

Table 1. Sample User Data

ID User	Name	Email	Registration Date	Status
1	Ali Rahman	ali@example.com	2025-03-01	New
2	Siti Aminah	siti@example.com	2025-03-02	Returning
3	Budi Santoso	budi@example.com	2025-03-03	Returning
4	Rina Maharani	rina@example.com	2025-03-04	New
5	Fahri Nugraha	fahri@example.com	2025-03-05	Returning

Table 2. Sample Transaction Data

ID Transaksi	ID User	Tanggal Transaksi	Produk Dibeli	Kategori Produk
501	1	2025-03-15	ASUS TUF Gaming	Electronics
502	1	2025-03-16	Powerbank Anker	Accessories
503	2	2025-03-17	Wardah Cream	Beauty
504	2	2025-03-18	Hijab Polos	Fashion
505	3	2025-03-19	Kaos Polos	Men's Fashion
506	3	2025-03-20	Jaket Hoodie	Fashion
507	4	2025-03-21	Serum Somethinc	Skincare
508	5	2025-03-22	Kamera Canon EOS M10	Electronics
509	1	2025-04-01	Samsung A32	Electronics
510	5	2025-04-02	Celana Jeans Slim Fit	Men's Fashion

Table 3. Categorization of Product Recommendations

ID User	Category Interest	Last Purchased Product	Recommended Category
1	Electronics, Audio, Gadget	Samsung A32	Electronics
2	Beauty, Fashion, Skincare	Hijab Polos	Fashion
3	Casual, Fashion, Men	Jacket Hoodie	Men's Fashion
4	Skincare, Face, Glow	Serum Somethinc	Skincare
5	Electronics, Camera, Audio	Kamera Canon EOS M10	Electronics

Based on this data, the entropy and information gain were calculated manually to determine the best splitting attribute. The category interest field proved to be the most dominant attribute with the highest gain value, thus selected as the root of the decision tree.

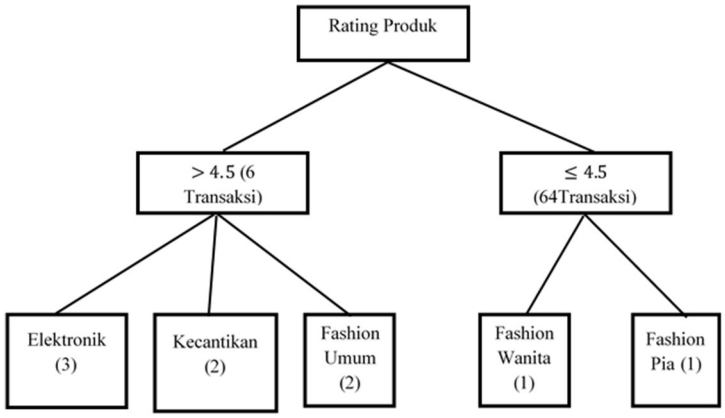


Fig. 1. Decision Tree Model for Product Recommendation

In the implemented system, users are classified into either “new” or “returning” groups. New users who do not have transaction history receive recommendations based on their stated category interests. Returning users are given recommendations based on the categories of products they previously purchased.

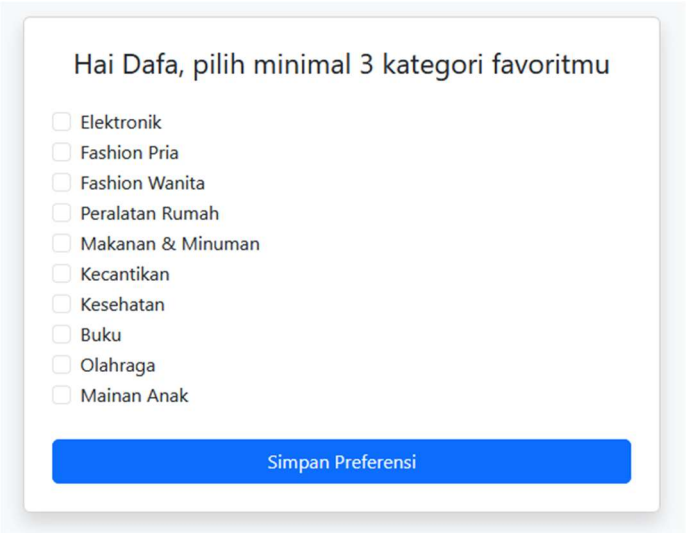


Fig. 2. User Category Preference Selection Page

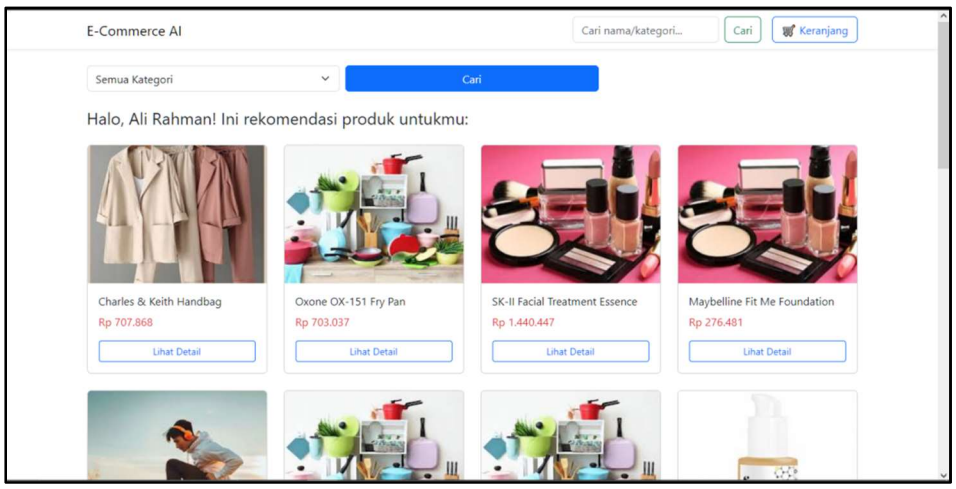


Fig. 3. Main Page Displaying Personalized Recommendations

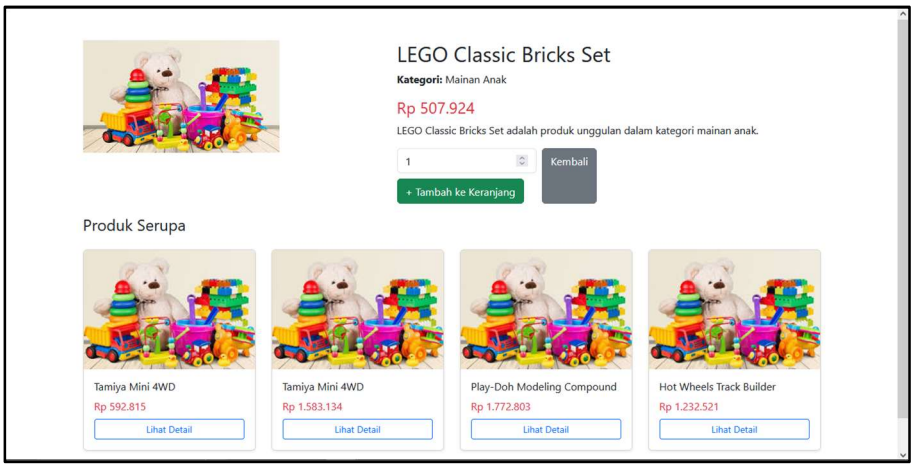


Fig. 4. Product Detail Page with Similar Product Recommendations



Fig. 5. Shopping Cart and Checkout Page

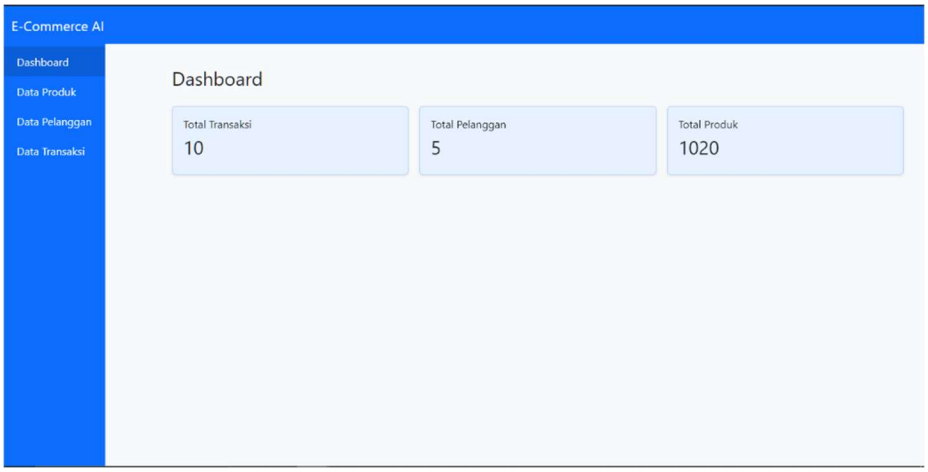


Fig. 6. Admin Dashboard Displaying System Metrics

The implementation of a rule-based Decision Tree model in this e-commerce system proved effective for generating personalized product recommendations. The simplicity and interpretability of the Decision Tree approach made it suitable for classification based on either user interest or transaction history. By using only two key decision variables—category interest and purchase history—the system could recommend products that were both relevant and dynamic to each user's behavior.

New users received recommendations aligned with their stated interests, ensuring engagement even without historical data. Returning users, on the other hand, were shown items based on previous purchasing behavior, improving the contextual relevance of the recommendations. This dual-path recommendation strategy aligned with the principles of content-based filtering while maintaining algorithmic transparency.

The integration of recommendations into multiple parts of the user interface—including the main page and product detail page—enhanced the overall shopping experience. These features demonstrated how basic AI techniques could significantly influence user interaction and potentially increase conversion rates, even in systems without complex machine learning infrastructure.

4. Conclusion

This research successfully designed an artificial intelligence-based e-commerce system with a Decision Tree algorithm that can improve the accuracy of product recommendations and drive sales. This system leverages user interest data and transaction history to generate relevant and personalized recommendations for both new and existing users. Test results show that this approach is effective, easy to implement, and capable of improving the shopping experience and efficiency of system management by administrators.

The artificial intelligence-based e-commerce system with the Decision Tree algorithm designed in this research successfully addressed the problem of providing relevant product recommendations to users. By utilizing interest data and transaction history, the system was able to generate more targeted recommendations than conventional methods.

The Decision Tree algorithm was chosen due to its ability to process data in a structured and easily interpretable manner, enabling the system to provide recommendations to both new and existing users. Test results show that this approach improves personalization and efficiency in the product search process.

The implementation of this recommendation system not only improves the user shopping experience but also directly contributes to increased sales potential for businesses. This demonstrates that the appropriate use of AI can provide added value in the increasingly competitive e-commerce market.

In conclusion, the developed system demonstrates that integrating AI technology with the right algorithm can be an effective solution to improve the accuracy of product recommendations and support the sustainable growth of digital businesses.

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ENHANCING SPEAKING PROFICIENCY AND SOFT SKILLS THROUGH PROJECT-BASED LEARNING IN ENGLISH LANGUAGE TEACHING

Ruzlinda binti Mustaffa[1]*, Suryani binti Sabri[1], Nurhaida binti Abdullah Hadi[2]

[1]General Studies Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim, Kedah, Malaysia.

[3]Corporate Industrial Services and Employability Centre, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim, Kedah Malaysia.

*Corresponding author e-mail address: ruzlinda@ptsb.edu.my

Abstract

Polytechnic graduates in Malaysia often face workplace challenges due to insufficient English-speaking proficiency and underdeveloped soft skills, which are crucial for professional success alongside technical expertise. This quantitative study investigates how Project-Based Learning (PBL) within English Club activities improves speaking proficiency and impacts soft skills development among TVET students. Data were collected from 25 polytechnic English club members involved in PBL activities, using a structured 5-point Likert scale questionnaire. Responses were analysed using descriptive statistics. Results indicate that participants perceived significant improvements in linguistic components (pronunciation, grammar, vocabulary, coherence) and affective aspects (confidence, motivation, enjoyment, comfort in speaking English). The study also demonstrated considerable self-reported development in key soft skills, particularly teamwork, group communication, listening, problem definition, and leadership. The study concludes that PBL in a supportive English club environment effectively fosters both speaking proficiency and essential soft skills. These findings underscore the pedagogical value of PBL in equipping TVET graduates with the communicative and professional competencies required in today's dynamic workplace.
Keywords: Project-Based Learning; Speaking Proficiency; TVET.

1. Introduction

In the evolving landscape of English Language Teaching (ELT), the integration of communicative competence and soft skills has become increasingly important, particularly in Technical and Vocational Education and Training (TVET). TVET students, particularly in polytechnics, are expected to be equipped not only with technical expertise but also the ability to communicate effectively in English and demonstrate key soft skills such as teamwork, leadership, and problem-solving. Project-based Learning (PBL) is a student-centred approach that promotes active engagement, collaboration, and authentic language use, making it a promising strategy for achieving these objectives.

The English Language club in the polytechnic serves as a valuable platform for implementing PBL activities beyond the formal classroom setting. Traditional English classrooms often focus on grammar rules, vocabulary memorisation, and rote learning, which may not prepare students for real-life communication, often neglecting the development of students' communication skills and soft skills. Through PBL, students can enhance their speaking proficiency while simultaneously developing essential soft skills needed for the workplace.

Despite the potential of PBL in English Club settings, there is limited empirical research examining its effectiveness in the context of Malaysian TVET institutions, particularly in the polytechnic system.

1.1 Problem Statement

TVET students often struggle with English speaking proficiency due to limited opportunities for authentic language use and overemphasis on rote learning. A traditional classroom may not have given the students ample chances to use and apply the language in real-world situations. Although crucial for workplace and career success, soft skills are often underdeveloped within the traditional education setting. Students' primary focus is on their core knowledge within their field of studies; inadvertently, the holistic development of their communicative competence and essential soft skills like problem-solving, teamwork and leadership are being neglected. Therefore, create a gap between educational provision and industry demands. This highlights a critical need for innovative teaching strategies that simultaneously build students' language proficiency and essential soft skills outside the language classroom setting for more authentic student participation.

1.2 Research Objectives

The study aims to:

a) Examine how PBL enhances speaking proficiency among English club members.
b) Investigate the impact of PBL on students' soft skills development.

1.3 Research Questions

a) How does PBL enhance speaking proficiency among English club students?
b) How does participation in PBL activities contribute to the development of soft skills?

1.4 Significance of the Study

The findings of this study are expected to contribute to the field of English Language Teaching (ELT) by providing insights into effective, student-centred practices suitable for polytechnic students. It will help the educators, curriculum designers, and policy makers understand the role of English Club and PBL in promoting not only students' language proficiency, but also soft skills needed for their future careers. Furthermore, the study can serve as a basis for enhancing co-curricular language programmes and inform future training and instructional design within the polytechnic environment.

1.5 Scope and Limitations

This study focuses on students enrolled in a polytechnic who are active English Club members. This study investigated their experience with PBL in improving speaking proficiency and soft skills. The study is limited to self-reported data collected through a questionnaire and does not include direct assessments of language performance or longitudinal tracking.

2. Literature Review

Project-Based Learning (PBL) is now being considered as an effective instructional approach in English Language Teaching (ELT), due to its potential to improve language proficiency and 21st-century competencies, for instance, soft skills. Parallel with the high demand in global communication and employability, educators are integrating language instruction with authentic settings to enhance collaboration, creativity, as well as critical thinking. This literature review

explores existing research on the role of PBL in language education, its impact on soft skills development, and its implementation in specific learning environments such as Technical and Vocational Education and Training (TVET) English clubs.

2.1 The Role of PBL in English Language Teaching

Project-Based Learning (PBL) has progressed as a transformative approach in English Language Teaching (ELT), focusing on the students' development through authentic real-life tasks. Via involvement in meaningful projects, PBL promotes active involvement, collaboration, and practical language use.

Research reveals that through PBL, learners of English as a Foreign Language (EFL) can efficiently improve their speaking proficiency. For example, a study by Supiani (2018) found that Indonesian university students showed noticeable improvement in fluency, confidence, and vocabulary use after participating in PBL activities such as group presentations and collaborative tasks. More recently, Khoiriyah and Husamah (2018) highlighted that PBL enhances students' critical thinking and speaking skills in English through student-centred learning experiences that mimic real-world communication scenarios.

Similarly, research carried out by Abu Bakar et al. (2019) with diploma students in a Malaysian technical college, where PBL was implemented, showed a significant improvement in oral communicative competence has been observed. The study highlighted increased student motivation and positive perceptions towards PBL as an effective teaching strategy.

Similarly, a systematic literature review conducted by Sedubun and Norhayati (2023) concludes that PBL promotes meaningful language use, learner autonomy, and communicative competence. However, some challenges were identified, such as time constraints and the competence of teachers to ensure the effectiveness of PBL implementation.

2.2 Soft Skills Development through PBL

Apart from language proficiency, PBL has highly contributed to the development of essential soft skills, including critical thinking, leadership, collaboration, creativity, and problem-solving. These skills are obviously valuable in the 21st-century workforce and are integral to holistic language education.

Astaifi (2024) investigated the impact of PBL on Moroccan EFL students, finding that engaging in projects focusing on real-life issues, such a child marriage, boosted students' critical thinking and soft skills. The study highlighted the role of PBL in adopting analytical and evaluative abilities through collaborative learning.

Song et al. (2024) conducted a literature review highlighting PBL's effectiveness in improving both critical thinking and language skills among EFL learners. Integrating authentic tasks and collaborative projects was found to be instrumental in developing the mentioned competencies.
Furthermore, Firdaus and Septiady (2023) reported that PBL not only enhanced students' speaking capabilities but also improved cooperation, problem-solving skills, and creativity. Their mixed-method study with accounting students has proven PBL's capacity to promote active and innovative involvement.

2.3 PBL in the TVET English Club Context

In the context of Technical and Vocational Education and Training (TVET), graduates ought to be proficient in English and soft skills, as these two are crucial for graduates who aim to enter the

global job market. As a club that functions as an extracurricular platform for TVET institutions, the English club helps to enhance these competencies in a more relaxed and student-driven environment.

Therefore, the incorporation of PBL into English clubs offers students practical opportunities to apply their English language skills while taking part in projects that stimulate real-life tasks. This approach associates well with the philosophy of vocational education, where hands-on activity is highly focused on.

Recent studies affirm that English clubs using a PBL method can shift from passive to dynamic learning spaces that foster communication, creativity, and confidence. For instance, Kusumawati (2021) demonstrated that PBL Speaking tasks encourage active participation, increase speaking performance, and develop group communication skills among vocational students. Similarly, Suryani and Argawati (2023) highlighted that aligning PBL with students' technical interests not only improved language use in context but also promoted greater learner engagement and motivation.

Despite its benefits, the implementation of PBL in English clubs within the TVET context faces some challenges. These include limited resources, inconsistent student participation, and time-management issues (We, 2020). Mohd and Rahman (2024) highlighted that insufficient infrastructure, planning, materials, and teacher training made PBL implementation inconsistent and fragmented. Nevertheless, when these issues are addressed, PBL has the potential to create a supportive learning environment that enhances both speaking skills and soft skills relevant to the workplace.

3. Methodology

3.1 Data Collection

This study employed a quantitative survey design. Data were collected by using a structured questionnaire distributed to 25 English club members in the polytechnic. The participants had engaged in a variety of PBL-based activities throughout the semester. The sample, while small, is representative of the club's active members and reflects the practical realities of English Club-based intervention. To assess the development of soft skills among students, this study adapted a set of questionnaire items from Woodward et al. (2010), originally designed to measure the effectiveness of PBL in fostering soft skills competencies in Information Systems education. To ensure content and face validity, the adapted questionnaire was reviewed by two experts in English Language Teaching to ensure relevance and appropriateness for the context.
The questionnaire employed a 5-point Likert scale to measure respondents' level of agreement with each of the statements in the questionnaire, an approach supported by Likert (1932) for capturing nuanced attitudes in survey research. The questionnaire was divided into three sections. The first section collected demographic information about the respondents, while the second section focused on students' perceptions of the effectiveness of Project-Based Learning (PBL) in enhancing their speaking competency, and the third section explored students' perceptions of the impact of PBL on their personal growth and development of soft skills. The questionnaire was distributed at the end of the semester, following participants' involvement in a variety of PBL activities (e.g., group projects, presentations, English Club events). Data collection was conducted in person during a regular English Club session.

3.2 Data Analysis

Descriptive statistics (means, standard deviations, frequencies) were used to summarise

responses. Tables were produced to facilitate trend analysis. Inferential statistics (e.g., correlation analysis) were not conducted due to the small sample size and exploratory nature of the study. All analyses were performed using SPSS v30.

The next section discusses the outcomes of a study that measured whether students' self-assessed speaking skills and soft skills improved with the use of Project-Based Learning (PBL) activities in an English Club. Information was gathered from a questionnaire given to 25 active members of the English Club, all of whom took part in PBL activities over a semester. Participants in the survey used a 5-point scale to indicate their views on various questions.

3.3 Speaking Proficiency:

This subsection investigates the first research question, "How does PBL enhance speaking proficiency among English club students? " It provides statistics such as means (M) and standard deviations (SD) to measure the speaking skills of participants in different areas of proficiency.

The data in the Speaking Proficiency Items table describes the students' improvements in their English-speaking skills as a result of taking part in project-based learning activities. Important details such as the mean and standard deviation are part of the analysis, providing an understanding of how students view their growth in speaking ability.

Table 1. Perceived Enhancements in Speaking Proficiency

Survey Item	Mean	Standard Deviation
Pronunciation improved	4.67	0.48
Grammar improved	4.42	0.58
More appropriate word usage	4.50	0.72
Able to speak longer sentences	4.54	0.51
Speaking is more coherent	4.54	0.51
Project was challenging	3.67	0.97
Faced several problems during project	2.71	1.49
Enjoyed the experience	4.76	0.44
Workload was manageable	4.58	0.50
Gained new knowledge	4.65	0.57
More motivated to speak English	4.60	0.58
Want more opportunities to practice speaking	4.48	0.51
More confident speaking in front of class	4.56	0.51
Spend more time learning English	4.48	0.59
Able to solve most learning problems on my own	4.52	0.51
Able to plan my study better	4.40	0.50
Can work better with others	4.52	0.65
More open to others' opinions	4.65	0.49
Developed discipline (punctuality & responsibility)	4.58	0.50
Other skills (information, data, tech) improved	4.52	0.59
Join English Club out of own desire	4.64	0.57
Excited to organize more English projects	4.56	0.51
More relaxed & comfortable speaking English	4.75	0.44

Can share knowledge and expertise better	4.56	0.51
Feel more fluent in speaking English	4.52	0.59

Generally, respondents stated that participating in PBL greatly helped them to improve their English-speaking abilities. As indicated in Table 1, the mean scores of most items on speaking ability were quite high. For example, there were perceived improvements in core linguistic elements, such as pronunciation (M=4.67, SD=0.48), grammar (M=4.42, SD=0.58), and the use of more appropriate vocabulary (M=4.50, SD=0.72). In addition, they were able to make longer sentences (M=4.54, SD=0.51) and to speak more coherently (M=4.54, SD=0.51). These numbers indicate a relatively constant self-assessment of a quantifiable improvement in core oral communication skills.

Additionally, students reported that emotional aspects of learning were positively rated. Compared to other items tested in speaking, responses to “Enjoyed the experience” (M=4.76, SD=0.44) and “Feel more relaxed & comfortable speaking English” (M=4.75, SD=0.44) were seen as most favourable. This suggests that these PBL activities created a positive and supportive learning environment, which is exactly what is needed to learn a language. On top of that, students felt more confident talking in class ("More confident speaking in front of class," M=4.56, SD=0.51) and were more motivated to speak in English ("More motivated to speak English," M=4.60, SD=0.58). Additionally, there was a definite desire for additional speaking practice opportunities ("Want more opportunities to practice speaking," M=4.48, SD=0.51).

Furthermore, students considered the PBL activities’ workload to be suitable (M=4.58, SD=0.50), appreciated discovering new information (M=4.65, SD=0.57), and noticed an improvement in how easily they could speak (M=4.52, SD=0.59), and improved their speaking fluency (M=4.52, SD=0.59). Since many participants scored high on (“Join English Club out of their own desire”) (M=4.64, SD=0.57), high intrinsic motivation helped contribute to their active participation and opinions during PBL.

However, two items show interesting results. The mean for the statement "Project was challenging" was 3.67 (SD=0.97) while the item “Faced several problems during the project” had the lowest average score of all the speaking proficiency-related items (M=2.71). This score for the former is higher than the neutral midpoint of the Likert scale, which means that while the students thought the projects were challenging, but, on average, did not go through many debilitating difficulties. This scenario helps student learning. The standard deviation of 0.97 indicates a moderate spread of opinions regarding the challenging nature of the project.

Alternatively, the situation of an item facing multiple challenges during a project scored the lowest among the other speaking proficiency-related items (M=2.71). This means that, on average, the students didn't think they were having major setbacks during the PBL activities. This item also had the highest standard deviation (SD=1.49) of any in this subsection, which means that students' experiences varied a lot.

From the results, it is seen that students experienced major improvements in their English speaking after taking part in PBL activities. Another improvement was their growing enthusiasm and confidence while speaking to an audience. Even though the activities were not easy, students believed the projects were worthwhile and attainable thanks to the way PBL allowed for equal focus on school requirements and practical use. All things considered, PBL has shown that students’ English-speaking ability has improved, with more skills in using English smoothly and clearly. They are the main aspects of good communication skills and having more confidence in language. The results suggest that PBL is designed to correct the weaknesses found in typical classroom settings, making learning more interactive and effective for students.

3.4 Soft Skills Development

This subsection explores the second research question: "How does participation in PBL activities contribute to the development of soft skills?". The results include statistics on survey questions tied to important soft skills for both academic and work-related achievement.

The soft skills development table summarizes what the students said after participating in project-based learning (PBL).

Table 2: Perceived Development of Soft Skills

Survey Item	Mean	Standard Deviation
Participated effectively in groups/teams	4.46	0.66
Used group communication skills effectively	4.54	0.51
Can define problems effectively (goals & constraints)	4.36	0.57
Team utilized critical evaluation & decision-making	4.48	0.59
Able to manage time and resources	4.24	0.78
Team members followed instructions effectively	4.63	0.58
Communicated with team members at all stages	4.67	0.48
Strong listening ability	4.54	0.51
Appropriate nonverbal communication	4.21	0.72
Gave and received constructive criticism effectively	4.42	0.65
Demonstrated leadership skills in project	4.40	0.50

Table 2 shows that students feel strongly that PBL helps them improve soft skills. Across every area, mean scores remained high. Remarkably, participants gave strong, positive feedback for items related to working together and interacting with others. Very high ratings were given, for instance, to "Communicated with team members at all stages" (M=4.67, SD=0.48) and "Team members followed instructions effectively" (M=4.63, SD=0.58). Similarly, students reported “using group communication skills effectively” (M=4.54, SD=0.51) and felt that their listening skills had improved ("Strong listening ability," M=4.54, SD=0.51).

In addition, positive results occurred for teamwork skills, for example, in a group, described by "Participated effectively in groups/teams" (M=4.46, SD=0.66) and team problem-solving, including contributions seen in "Team utilised critical evaluation & decision-making" (M=4.48, SD=0.59). Students also recognised benefits in offering and receiving helpful comments ("I could give and receive feedback well," M=4.42, SD=0.65). They also denoted improvement in providing meaningful criticism and developed leadership abilities ("Offered and accepted helpful responses to others’ work," M=4.43, SD=0.50). In addition, students demonstrated a better ability to identify an issue as a goal and its relevant limitations (M=4.36, SD=0.57). Defining the problem allows a project to stay focused and provide new ideas.

Two of the soft skill items from the cluster reported lower agreement scores and higher differences in opinions. Managing time and resources was given a rating of 4.24 (SD=0.78). This is still a good result, although it is in the lower part of this section and shows there were more extreme answers from others. As a result, some students found it more difficult to manage time and resources under the PBL format than they did with other soft skills.

Likewise, the rating for "Appropriate nonverbal communication" was the lowest at (M=4.21, SD=0.72). This suggests that, among the soft skills, changes or appearances of change in

nonverbal communication were less noticeable. The standard deviation reveals that student opinions about this aspect of communication vary somewhat.

In general, students believed they improved many important soft skills through PBL, including the ability to collaborate better, communicate more efficiently, address challenges, and organize their time. Academics and work skills have both been boosted, which matches the goals of PBL.

4. Discussion

This section looks at the findings from Section 4 in light of existing studies and the special environment of a TVET polytechnic English Club. The report covers the most significant results, points out the study's limitations, and proposes what new research could achieve in the future.

4.1 Project-Based Learning and Speaking Proficiency

The study clearly indicates that the English club students perceived noticeable improvement in their speaking proficiency, with the students reporting significant improvements in pronunciation, grammar, fluency, coherence, and, most particularly, confidence, as indicated by the high mean scores in Table 1. Mustafa et al. (2024) discovered that having students do real group work together in PBL reduced EFL learners' anxiety and encouraged them to speak out and participate more. Mafruudloh and Fitriati (2020) and Huang and Sun (2022) consider speaking with people and making presentations essential for developing speaking skills. The results indicate that PBL's experiential method helps students develop their ability to communicate in the language they are learning. The study conducted by Cole (2024) demonstrated how PBL can help improve students' English-speaking skills. He discovered that working on projects that let students practice English in real ways resulted in a huge improvement in their language use, especially when it came to speaking clearly and coherently.

The results show clear evidence that PBL activities had a strong, positive impact on speaking proficiency. Across all speaking-related survey items, the overall mean score was 4.55, indicating that students perceived substantial improvements as a result of their participation. Key indicators of improvement include high mean scores for "Pronunciation improved" (M=4.67, SD=0.48), "Grammar improved" (M=4.42, SD=0.58), "Speaking is more coherent" (M=4.54, SD=0.51), and "Feel more fluent in speaking English" (M=4.52, SD=0.59).The affective domain was also positively impacted, with "Enjoyed the experience" (M=4.76, SD=0.44), "More confident speaking in front of class" (M=4.56, SD=0.51), and "More relaxed & comfortable speaking English" (M=4.75, SD=0.44) receiving especially high ratings.

These findings directly answer RQ1 by confirming that PBL, implemented in the English Club context, is perceived by students to meaningfully enhance their English-speaking proficiency, both in terms of linguistic accuracy and fluency, as well as motivation and confidence. This aligns with prior studies (Supiani, 2018; Cole, 2024), which reported similar gains in EFL speaking through PBL.

4.2 Project-Based Learning and Soft Skills Development

The second research question investigated how PBL helps students develop soft skills. Data in Table 2 indicate that students experienced improved abilities in several soft skills, mainly with regard to teamwork, communication, and understanding different issues.
The overall mean score for the soft skills section was 4.44, reflecting strong student agreement that PBL fostered growth in this domain. Teamwork and communication were most highly rated:

"Communicated with team members at all stages" (M=4.67, SD=0.48), "Team members followed instructions effectively" (M=4.63, SD=0.58), and "Used group communication skills effectively" (M=4.54, SD=0.51). Leadership and critical thinking also saw notable gains: "Demonstrated leadership skills in project" (M=4.40, SD=0.50), and "Team utilized critical evaluation & decision-making" (M=4.48, SD=0.59). Listening and feedback skills improved as well, with "Strong listening ability" (M=4.54, SD=0.51) and "Gave and received constructive criticism effectively" (M=4.42, SD=0.65). This data answers RQ2 by demonstrating that PBL activities in the English Club not only promote language gains, but also provide robust opportunities for the development of key soft skills—especially teamwork, leadership, communication, and critical thinking

The findings are consistent with other recent results demonstrating that PBL helps students acquire 21st-century skills. For example, Astaifi (2024) reported that PBL boosted critical thinking and soft skills, while Song et al. (2024) emphasized PBL's role in developing critical thinking through collaborative endeavours. In a similar study, Firdaus and Septiady (2023) see that PBL resulted in students working together more and being better at handling problems. The current study's findings regarding improved teamwork and communication skills align well with Puangpunsi (2021), who highlighted PBL's provision of a natural, collaborative environment conducive to such development.

It is important that new graduates from TVET have these skills since they are preparing for global jobs with challenging demands. English Club activities, which create real work situations, help perfect the technical skills participants get from TVET. These abilities target the professional skills discussed by Cappel (2002). The high score for "Team members followed instructions effectively" (M=4.63) suggests that students were structured in their efforts and disciplined in their work, which supported their collaboration. Furthermore, the reasonably high score for "Demonstrated leadership skills in project" (M=4.40) indicates that PBL supports the development of leadership skills important for future professionals.

Taken together, the high overall mean scores for both speaking proficiency and soft skills underscore the value of PBL as an integrated approach for holistic student development in TVET English learning environments. The quantitative evidence answers both research questions affirmatively, providing direct support for the study's objectives and highlighting the English Club's potential as a site for meaningful, real-world learning. The lowest mean for "Appropriate nonverbal communication" suggests that this skill might be less consciously addressed or developed during the PBL activities. Most nonverbal behaviours are related to culture and learned effortlessly, so they are rarely seen as one of the main benefits of project work unless addressed in detail.

5. Conclusion

The finding of this study strongly suggests that PBL, when implemented in a supportive and authentic learning environment, namely the English club, significantly enhances both students' speaking proficiency and soft skills. The activities that were supportive and collaborative environments fostered significant self-reported improvements in language use and essential 21st-century competencies. However, the study's conclusions are constrained by its reliance on self-reported data from a small, non-representative sample and the absence of objective performance assessments.

Despite these limitations, this study reinforces the pedagogical value of PBL in English language teaching, particularly within TVET contexts. It highlights PBL's potential to provide meaningful, real-world learning experiences that better prepare graduates for the communicative and professional demands of the modern workplace.

5.1 Limitations of the Study and Suggestions for Future Research

This study delivers useful preliminary information on the benefits of PBL in a polytechnic English Club, but some limitations need to be recognised, which suggest paths for further research.

First, relying on self-reported facts is a primary limitation. Although students' responses are valuable, their thoughts can be biased or influenced by other factors such as social desirability or recall bias. Second, the study is based on a small N of 25 participants from a small population within a polytechnic's English Club. These students, by virtue of their voluntary participation in the English Club ("Join English Club out of own desire," M=4.64), may possess higher intrinsic motivation, pre-existing language skills, or more positive attitudes towards English learning than the general polytechnic student population. Due to self-selection bias, the findings cannot be applied to everyone. Third, the study's design included an absence of direct assessments of language performance or soft skills. The growth seen by some was not reflected in official exam results, scores, or evaluations of behaviour in soft skills. Furthermore, since participants are studied only at one time, the study provides a single view of student perceptions.

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KESAHAN DAN KEBOLEHPERCAYAAN INSTRUMEN APLIKASI BAHAN BERGUNA DALAM KURSUS PENGURUSAN SISA MAKANAN BERTERASKAN EKONOMI KITARAN

Norzaharah binti Ab Hamid[1,3], Fathiyah Mohd Kamaruzaman[1]*, Mohamad Zuber Abd Majid[1], Mohamad Sattar Rasul[1], Liu Zhi Yi[1,2]

[1]Fakulti Pendidikan, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

[2]Urban Vocational College of Sichuan, 610110 China

[3]Kementerian Pendidikan Malaysia, 62604 Wilayah Persekutuan Putrajaya, Malaysia

*Corresponding author e-mail address: fathiyah@ukm.edu.my

Abstrak

Aplikasi bahan berguna seperti kitar semula dan pulihara merupakan indikator utama pelaksanaan ekonomi kitaran dalam pendidikan. Walaupun prinsip ini semakin diterapkan dalam sektor dasar dan industri, penerapannya dalam pendidikan masih terbatas. Kajian ini bertujuan menilai kesahan dan kebolehpercayaan konstruk aplikasi bahan berguna dalam kursus Pengurusan Sisa Makanan berteraskan ekonomi kitaran. Kajian ini melibatkan 122 guru vokasional seluruh Malaysia menggunakan reka bentuk tinjauan secara keratan rentas. Pembangunan instrumen merangkumi penjanaan item berdasarkan literatur, semakan pakar melalui kaedah Delphi, serta penilaian kesahan muka, kandungan dan konstruk. Hasilnya, 22 daripada 23 item melepasi nilai I-CVI ≥ 0.83 dengan nilai S-CVI/Ave 0.91, menunjukkan kesahan kandungan yang tinggi. Dua belas item akhir dianalisis melalui Analisis Faktor Eksploratori (EFA) menggunakan *principal component analysis* dengan rotasi varimax. Dua faktor dikenalpasti, iaitu kitar semula dan pulihara, yang menjelaskan 76.79% varians keseluruhan. Nilai KMO ialah 0.856 dan ujian Bartlett signifikan ($p < .001$). Nilai Alpha Cronbach keseluruhan ialah 0.911, menunjukkan kebolehpercayaan dalaman yang sangat tinggi. Instrumen ini berpotensi digunakan untuk menilai tahap integrasi amalan ekonomi kitaran dalam pengajaran dan menyokong pembangunan kurikulum TVET ke arah pendidikan mampan. Kajian ini diharap dapat menyumbang transformasi dalam pendidikan vokasional yang menghubungkan kemahiran, teknologi, dan pembangunan mampan.

Kata kunci: Ekonomi kitaran sisa makanan; Kurikulum pendidikan TVET; Aplikasi bahan berguna.

1. Pengenalan

Pembaziran makanan merupakan isu global yang semakin membimbangkan kerana mengancam keselamatan makanan dan membebankan sumber semula jadi. Lebih satu pertiga makanan yang dihasilkan telah dibazirkan, sekali gus meningkatkan pelepasan gas rumah hijau (Krishna & Puram, 2025), Di Malaysia, isu ini diberi perhatian menerusi Dasar Agromakanan Negara 2.0 yang selari dengan Matlamat Pembangunan Mampan (SDG) 12.3 untuk mengurangkan separuh pembaziran makanan global menjelang tahun 2030 (Bahagian Dasar dan Perancangan Strategik, 2021).

Pendidikan dilihat sebagai saluran strategik untuk memupuk kefahaman dan amalan ekonomi kitaran dalam kalangan pelajar, khususnya melalui pendidikan dan latihan teknikal dan vokasional

(TVET). Kursus seperti Katering dan Penyajian, dan Program Vokasional Menengah Atas Penyediaan dan Penghasilan Makanan memberi peluang kepada pelajar untuk belajar secara praktikal tentang pengurusan sisa makanan. Instrumen kajian ini dibangunkan berasaskan teori konstruktivisme yang menekankan pembelajaran melalui pengalaman bermakna, bagi memperkukuh pengajaran guru vokasional.

Dalam konteks pendidikan TVET, kefahaman yang jelas tentang konsep sisa makanan adalah penting bagi membolehkan pelajar mengaplikasi bahan berguna (kitar semula dan pulihara) secara berkesan dalam latihan mereka. Ekonomi kitaran merujuk kepada satu pendekatan pembangunan lestari yang bertujuan meminimumkan pembaziran dan memaksimumkan penggunaan semula sumber (Ossio et al., 2023). Berbeza dengan model linear "ambil-guna-buang", ekonomi kitaran menekankan pemuliharaan nilai bahan sepanjang kitaran hidupnya, termasuk dalam sektor makanan.

Walaupun konsep ekonomi kitaran semakin meluas penggunaannya dalam sektor industri, kebanyakan kajian terdahulu lebih memberi tumpuan kepada aplikasi dalam bidang komersial dan teknikal, bukan dalam konteks pendidikan vokasional. Pelaksanaan prinsip aplikasi bahan berguna seperti amalan kitar semula dan pemuliharaan sisa makanan masih kurang diberi penekanan dalam pengajaran bilik darjah. Hal ini berpunca akibat ketiadaan instrumen yang sah dan boleh dipercayai untuk menilai tahap integrasi prinsip tersebut dalam pengajaran. Kebanyakan instrumen sedia ada lebih tertumpu kepada konteks industri atau pendidikan tinggi, dan tidak mengambil kira keperluan pedagogi peringkat sekolah menengah. Oleh itu, kajian ini dijalankan untuk membangunkan dan mengesahkan instrumen yang dapat mengukur konstruk aplikasi bahan berguna dalam pengajaran, menggunakan pendekatan analisis faktor eksploratori (EFA), agar dapat menyokong integrasi pendidikan ekonomi kitaran dalam sistem pendidikan TVET.

1.1 Aplikasi Bahan Berguna

Aplikasi bahan berguna merangkumi aktiviti seperti kitar semula dan pulihara bahan. Kitar semula merujuk kepada aktiviti memproses semula sisa makanan agar dapat dikembalikan ke dalam rantaian bekalan makanan atau diubah menjadi produk yang berguna. Bag et al. (2021) menyatakan kitar semula bertujuan untuk mendapatkan kualiti yang sama dengan produk asal. Ia merangkumi tindakan harian seperti pengasingan bahan, pemilihan produk boleh kitar semula, dan penggunaan semula bahan.

Konstruk pulihara dalam ekonomi kitaran merujuk kepada usaha menukar sisa makanan kepada sumber baharu yang berguna. Ia melibatkan transformasi sisa menjadi input seperti tenaga, kompos, atau produk sekunder. Cordova-Buiza et al. (2022) menyatakan bahawa teknologi bio digunakan untuk menghasilkan tenaga daripada sisa organik. Pulihara juga merangkumi kreativiti dalam mencipta produk baharu daripada bahan buangan.

2. Kaedah Kajian

2.1 Reka Bentuk Kajian

Kajian rintis ini menggunakan reka bentuk tinjauan secara keratan rentas dengan kaedah persampelan mudah (*convenience sampling*). Kaedah ini dipilih kerana kumpulan sasaran iaitu guru vokasional mudah diakses melalui platform dalam talian. Responden terdiri daripada guru yang mengajar Sains Rumah Tangga, Katering & Penyajian, serta Pembuatan Roti di Sekolah

Menengah Kebangsaan (SMK) seluruh Malaysia. Mereka dipilih kerana terlibat secara langsung dalam pengajaran amali makanan, selaras dengan konstruk aplikasi bahan berguna dalam ekonomi kitaran.

Pemilihan saiz sampel berpandukan kepada nisbah item-responden minimum 1:5 seperti disarankan oleh Costello & Osborne (2005). Instrumen kajian rintis ini mengandungi 12 item, justeru sekurang-kurangnya 60 responden diperlukan. Saiz ini turut disokong oleh de Winter et al. (2009) dan Hair et al. (2014) yang mencadangkan sampel melebihi 100 mencukupi untuk analisis faktor eksploratori (EFA). Sebanyak 122 responden memberikan maklum balas, melepasi keperluan minimum dan mencukupi bagi tujuan EFA. Persetujuan dimaklumkan secara bertulis dan kerahsiaan data dipelihara.

2.2 Prosedur Kajian

Proses pembangunan instrumen melalui dua langkah utama. Pertama, semakan literatur sistematik dijalankan menggunakan pangkalan data Scopus, Web of Science, PubMed dan Google Scholar. Artikel yang dipilih berdasarkan tempoh lima tahun terkini, melibatkan tema makanan, ekonomi kitaran, kitar semula, pulihara, dan instrumen pengukuran. Dapatan disusun dalam jadual spesifikasi item seperti berikut:

Jadual 1. Jadual spesifikasi item

Konstruk	Item	Penyataan item	Sumber
Kitar semula	K1	Mengitar semula untuk mendapatkan kualiti yang sama.	(Bag et al., 2021)
	K2	Kitar semula tin aluminium dengan menghantarnya ke pusat kitar semula.	(Amirudin & Gim, 2019)
	K3, K4	Membeli produk yang berunsur kebolehkitaran iaitu berupaya dikitar semula. Mengumpulkan kertas untuk dikitar semula.	(Cordova-Buiza et al., 2022)
	K5	Menggunakan bekas kitar semula untuk menyimpan bahan mentah.	(Barr et al., 2013)
	K6	Memakai apron daripada kain kitar semula.	(Ahamad & Ariffin, 2018)
	K7 - K10	Mengumpulkan barangan elektronik untuk dihantar ke pusat kitar semula elektronik. Menggunakan tong kitar semula mengikut kategorinya. Mengasingkan sisa untuk dikitar semula. Mengasingkan botol kaca untuk dikitar semula.	(Manshoven & Gillabel, 2021)
Pulihara	P1	Menggunakan pembakaran bahan untuk mendapatkan tenaga.	(Bag et al., 2021)
	P2	Pembakaran sisa dapat dimanfaatkan untuk menjana tenaga elektrik bagi kegunaan domestik.	(Amirudin & Gim, 2019)
	P3, P4	Pulihara tenaga daripada pembakaran sisa kayu untuk pemanasan. Pulihara gas daripada sisa organik melalui proses anaerobik untuk digunakan sebagai tenaga.	(Cordova-Buiza et al., 2022)
	P5 – P13	Pulihara tenaga dari panas dapur untuk pemanasan air dengan menggunakan sistem penukar haba. Mengumpulkan air hujan untuk menyiram pokok. Memproses sisa buah-buahan untuk dijadikan jus. Menggunakan minyak masak terpakai untuk menghasilkan sabun. Menggunakan sisa makanan sebagai kompos.	(Barr et al., 2013)

	Menggunakan tulang lembu dalam membuat stok perang.
	Menggunakan sisa kopi untuk membuat skrub.
	Menggunakan buah-buahan yang layu sebagai pupur muka.
	Mengumpulkan biji buah-buahan sebagai benih tanaman baharu.

Langkah kedua adalah pelaksanaan Delphi terubah suai sebanyak tiga pusingan antara Mei hingga Ogos 2024. Seramai 13 panel pakar menilai setiap item menggunakan skala Likert lima mata (1 = sangat tidak setuju hingga 5 = sangat setuju), serta memberi cadangan penambahbaikan. Hasilnya, 12 item akhir dimuktamadkan mewakili dua konstruk iaitu kitar semula dan pulihara.

3. Kesahan Instrumen

3.1 Kesahan Muka

Kesahan muka dijalankan bagi memastikan kefahaman dan kejelasan item. Menurut Yusoff (2019) jumlah pakar antara 3-10 sudah memadai, dan dipilih berdasarkan kepakaran, latihan dan pengalaman dalam bidang berkaitan. Justeru empat orang pakar dilantik iaitu dua pakar Bahasa (Jurulatih Utama Bahasa Melayu dan Ketua Bidang Bahasa), seorang guru pakar kursus masakan, dan seorang wakil industri makanan. Mereka menilai aspek kebolehbacaan, kejelasan bahasa, dan kesesuaian istilah dalam konteks pendidikan vokasional. Beberapa item telah diperhalusi berdasarkan maklum balas panel.

3.2 Kesahan Kandungan

Kesahan kandungan dinilai oleh enam pakar berdasarkan kepakaran TVET, pengalaman kerja melebihi lima tahun, dan jawatan akademik atau profesional lanjutan (Mohd Effendi @ Ewan Mohd Matore et al., 2017). Setiap item dinilai dari segi kaitan, kejelasan, kesederhanaan dan kekaburan menggunakan skala empat mata (1 = tidak relevan hingga 4 = sangat relevan). Nilai *Item-Content Validity Index* (I-CVI) dan *Scale-Content Validity Index* (S-CVI) dikira menggunakan formula:

a. I-CVI = Bilangan pakar yang beri skor 3 atau 4 / Jumlah pakar
b. S-CVI/Ave = Jumlah semua I-CVI / Bilangan item

Berdasarkan kriteria yang ditetapkan oleh Lynn (1986) dan Polit & Beck (2006) nilai minimum I-CVI yang diterima adalah 0.83 bagi enam orang pakar. Item yang tidak memenuhi tahap minimum ini dikeluarkan daripada senarai akhir instrumen.

3.3 Kesahan konstruk

Kesahan konstruk pula dinilai menggunakan Analisis Faktor Eksploratori (EFA), bagi menentukan sama ada struktur item yang dibangunkan benar-benar membentuk konstruk yang sah. Selain itu, EFA juga membolehkan pembinaan teori konstruk secara empirik dan memudahkan pemahaman terhadap hubungan antara item melalui pembentukan skor faktor (Thompson, 2004). Ujian KMO dan Bartlett's Test dijalankan untuk menilai kesesuaian data. Nilai eigen > 1, *factor loading* ≥ 0.60, dan *communalities* > 0.30 digunakan sebagai kriteria mengekalkan item (Mohd Matore et al., 2019). Item yang memuat pada lebih satu faktor atau di bawah nilai minimum, digugurkan.

3.4 Kebolehpercayaan Instrumen

Kebolehpercayaan merujuk kepada kestabilan dan konsistensi instrumen dalam mengukur konstruk yang sama secara berulang. Dalam kajian ini, kebolehpercayaan dinilai menggunakan pekali Alpha Cronbach bagi mengukur konsistensi dalaman item-item dalam konstruk. Nilai Alpha Cronbach yang melebihi 0.70 dianggap menunjukkan kebolehpercayaan yang memadai (Joseph F. Hair Jr et al., 2010). Nilai yang terlalu tinggi (melebihi 0.90) turut diperiksa bagi mengelakkan pertindihan maksud antara item.

3.5 Pengumpulan Data

Pengumpulan data telah dijalankan dari September hingga Oktober 2024 menggunakan borang soal selidik secara dalam talian melalui pautan Google Form. Guru vokasional yang mengajar mata pelajaran Sains Rumah Tangga, Katering & Penyajian, serta Pembuatan Roti di Sekolah Menengah Kebangsaan (SMK) di seluruh Malaysia diminta memberi penarafan terhadap setiap item menggunakan skala Likert lima mata (1 = sangat tidak setuju hingga 5 = sangat setuju). Sebanyak 300 e-mel dihantar kepada guru-guru terlibat dan 122 borang soal selidik lengkap diterima, mewakili kadar respons sebanyak 40.7%. Data demografi yang dikumpulkan termasuk jantina, bangsa, pengalaman mengajar, dan kelulusan akademik. Kelulusan etika diperoleh daripada Jawatankuasa Etika Fakulti Pendidikan UKM.

3.6 Analisis Data

Data dianalisis menggunakan SPSS versi 29. Analisis melibatkan statistik deskriptif dan analisis faktor eksploratori (EFA). Statistik deskriptif digunakan untuk menggambarkan profil responden dan skor keseluruhan. EFA dijalankan menggunakan *Principal Component Analysis* (PCA) dengan rotasi *varimax*. Ujian *Kaiser-Meyer-Olkin* (KMO) dan *Bartlett's Test of Sphericity* digunakan bagi menilai kesesuaian data. Ujian *Bartlett's Test of Sphericity* < 0.05 menunjukkan bahawa terdapat korelasi yang mencukupi antara item (Bartlett, 1950), manakala nilai KMO melebihi 0.60 mengesahkan bahawa persampelan adalah sesuai untuk analisis lanjut (Kaiser, 1974). Faktor dikekalkan berdasarkan nilai eigen > 1.0, scree plot, dan *factor loading* ≥ 0.6 (Mohd Matore et al., 2019). Item dengan communalities di bawah 0.3 atau *cross-loading* yang signifikan digugurkan bagi membina struktur konstruk yang kukuh dan sah secara empirik.

4. Dapatan

4.1 Ciri Demografi

Maklumat demografi yang dikumpulkan adalah jantina, bangsa, pengalaman mengajar dan kelulusan akademik. Ciri demografi ditunjukkan dalam jadual 2 berikut:

Jadual 2. Ciri demografi responden

Pemboleh Ubah	Kategori	N	Bilangan (%)
Jantina	Perempuan	93	76
	Lelaki	29	24
Bangsa	Melayu	101	83
	Cina	5	4
	India	2	2
	Lain-lain	14	11
Pengalaman mengajar	<5 tahun	43	35

	6-10 tahun	22	18
	>10 tahun	57	47
Kelulusan akademik	Ijazah sarjana muda	114	93
	Ijazah sarjana	8	7

Jadual 2 menunjukkan seramai 122 orang responden telah mengambil bahagian, terdiri daripada 76% perempuan dan 24% lelaki. Dari segi kaum, majoriti adalah berbangsa Melayu (83%), diikuti oleh kaum lain seperti Cina (4%), India (2%), dan lain-lain (11%). Dari aspek pengalaman mengajar, 47% responden mempunyai lebih daripada 10 tahun pengalaman, manakala 35% mempunyai kurang daripada 5 tahun, dan 18% antara 6 hingga 10 tahun. Kebanyakan responden mempunyai kelulusan akademik pada peringkat ijazah sarjana muda (93%), manakala selebihnya memiliki ijazah sarjana (7%). Data ini memberikan gambaran umum tentang latar belakang profesional dan pendidikan responden kajian.

4.2 Dapatan kesahan

a) Kesahan muka

Dapatan kesahan muka menunjukkan bahawa pakar memberikan maklum balas terhadap beberapa item yang memerlukan penambahbaikan, khususnya dari segi struktur ayat, kesesuaian konteks bilik darjah, dan kejelasan istilah. Item-item tersebut telah disemak dan ditambah baik berdasarkan saranan yang diberikan. Pakar bahasa yang dilantik turut menilai aspek penggunaan laras bahasa dan ketepatan tatabahasa dalam soal selidik. Secara keseluruhan, mereka menyatakan bahawa bahasa yang digunakan adalah jelas dan mudah difahami, serta tempoh masa untuk menjawab soal selidik adalah sesuai dan mencukupi.

b) Kesahan kandungan

Dapatan kesahan kandungan ditunjukkan dalam Jadual 3.

Jadual 3. Nilai iCVI dan SCVI bagi kontruk aplikasi bahan berguna

Kod item	Pakar A	Pakar B	Pakar C	Pakar D	Pakar E	Pakar F	Ne	iCVI	terima/ tolak
K1	1	0	1	1	1	1	5	0.83	Terima
K2	1	1	1	1	1	1	6	1.00	Terima
K3	1	1	1	1	0	1	5	0.83	Terima
K4	1	1	1	1	1	1	6	1.00	Terima
K5	1	1	1	1	0	1	5	0.83	Terima
K6	1	1	1	1	1	1	6	1.00	Terima
K7	1	1	1	1	1	1	6	1.00	Terima
K8	1	1	1	1	1	1	6	1.00	Terima
K9	1	1	1	1	1	1	6	1.00	Terima
K10	1	1	1	1	0	1	5	0.83	Terima
P1	1	0	1	1	1	1	5	0.83	Terima
P2	1	0	1	1	0	1	4	0.67	Tolak
P3	1	1	1	1	0	1	5	0.83	Terima
P4	1	1	1	1	1	1	6	1.00	Terima
P5	1	1	1	1	0	1	5	0.83	Terima
P6	1	0	1	1	1	1	5	0.83	Terima
P7	1	0	1	1	1	1	5	0.83	Terima
P8	1	0	1	1	1	1	5	0.83	Terima

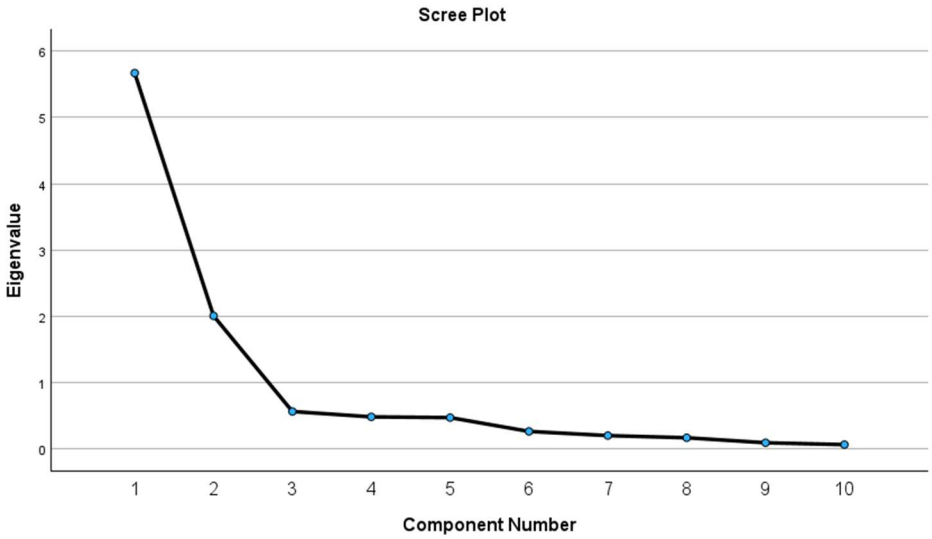
P9	1	0	1	1	1	1	5	0.83	Terima
P10	1	0	1	1	1	1	5	0.83	Terima
P11	1	0	1	1	1	1	5	0.83	Terima
P12	1	0	1	1	1	1	5	0.83	Terima
P13	1	0	1	1	1	1	5	0.83	Terima
								20.91/ 23 item	S-CVI/Ave = 0.91

Nota: Ne = bilangan pakar yang bersetuju; iCVI = Bilangan pakar yang beri skor 3 atau 4 dibahagi dengan jumlah kesemua pakar

Berpandukan Jadual 3 di atas, 22 daripada 23 item mencapai nilai I-CVI ≥0.83, melepasi nilai minimum 0.80 seperti disarankan oleh Lynn (1986) dan Polit & Beck (2006). Manakala hanya satu item (P2) tidak memenuhi nilai minimum yang disarankan dan telah ditolak. Nilai S-CVI/Ave ialah 0.91, yang membuktikan bahawa keseluruhan instrumen mempunyai kesahan kandungan yang tinggi dan sesuai untuk digunakan dalam kajian seterusnya. 22 item ini telah dibawa ke pusingan Delphi terubah suai, dimurnikan mengikut saranan pakar, dianalisis hingga menghasilkan 12 item yang mencapai konsensus. Item ini kemudiannya diberi kod baharu dan dibawa ke kajian rintis untuk diuji kesahan konstruk.

4.3 Kesahan konstruk

Analisis faktor eksploratori (EFA) telah dijalankan menggunakan kaedah *principal component analysis* dengan putaran *varimax* ditunjukkan seperti Rajah 1.



Rajah 1. Scree plot

Rajah 1 menunjukkan analisis scree plot menghasilkan dua komponen utama dengan nilai *eigen* melebihi 1, iaitu komponen pertama (5.671) dan komponen kedua (2.008). Selebihnya menunjukkan nilai yang menurun secara mendatar, mencadangkan bahawa struktur dua faktor adalah paling sesuai untuk data ini. Rajah scree plot ini terhasil setelah dua item iaitu K1 dan K2 digugurkan. Ini kerana kedua-dua item itu membentuk satu komponen tanpa ada item lain. Justeru dua item itu digugurkan kerana dua item semata-mata adalah tidak mencukupi untuk mewakili faktor secara stabil. Menurut Alhija (2010), MacCallum et al. (1999) dan Raubenheimer (2004) sesuatu faktor perlu diwakili oleh sekurang-kurangnya tiga hingga lima item bagi

memastikan kestabilan dan kesahan konstruk. Justeru pengguguran item ini dianggap wajar bagi mengekalkan kejelasan dan kekukuhan struktur faktor instrumen. Setelah pengguguran item, nilai Kaiser-Meyer-Olkin (KMO) yang diperoleh adalah 0.856, menunjukkan bahawa persampelan adalah mencukupi untuk analisis faktor. Ujian Bartlett juga signifikan ($\chi^2 = 1097.048$, $df = 45$, $p < .001$), mengesahkan kesesuaian data untuk dianalisis. Model dua faktor ini menjelaskan 76.79% varians keseluruhan, dengan nilai KMO 0.856 dan ujian Bartlett yang signifikan ($p < .001$), menunjukkan kesesuaian data untuk analisis lanjut. Model dua faktor yang terbentuk menjelaskan 76.79% daripada varians keseluruhan (Jadual 4).

4.4 Dapatan kebolehpercayaan

Nilai Alpha Cronbach bagi dua faktor yang diperoleh selepas analisis faktor eksploratori (EFA) adalah 0.911 bagi keseluruhan skala yang mengandungi 10 item, menandakan tahap kebolehpercayaan dalaman yang sangat tinggi (Jadual 4). Secara khusus, Faktor 1 (Pulihara) mencatatkan nilai 0.923, manakala Faktor 2 (Kitar Semula) mencatatkan 0.912. Kedua-dua nilai ini menunjukkan bahawa item-item dalam setiap faktor mempunyai konsistensi dalaman yang tinggi, iaitu menunjukkan keseragaman dalam mengukur konstruk yang sama. Ini juga menandakan bahawa instrumen yang dibangunkan adalah stabil, boleh dipercayai, dan sesuai digunakan dalam kajian lanjut.

Jadual 4: Struktur faktor dan Alpha Cronbach bagi skala 10 item

Rotated Component Matrix[a]	Component		Alpha cronbach
	1	2	
Konstruk 1: Pulihara			0.923
P2 Mikroorganisme mengurai sisa makanan menjadi gas yang boleh digunakan untuk tenaga bio.	.899		
P4 Pulihkan tenaga untuk menyuburkan tanah contohnya menggunakan sisa makanan sebagai kompos.	.885		
P5 Pulihkan alam sekitar melalui penanaman biji benih tumbuhan.	.852		
P3 Pulihkan tenaga dari pemprosesan minyak masak terpakai untuk menghasilkan sabun, lilin, lipstik dll.	.835		
P1 Bakar sisa untuk tenaga haba contohnya membakar tempurung kelapa untuk menghasilkan api.	.783		
konstruk 2: Kitar semula			0.912
K6 Gunakan tong kitar semula mengikut kategori yang betul.		.920	
K5 Himpunkan barangan yang sesuai untuk dihantar ke pusat kitar semula.		.894	
K3 Kumpulkan minyak masak terpakai untuk dihantar ke pusat kitar semula supaya dapat diproses menjadi biodiesel.		.857	
K7 Asingkan sisa yang terhasil daripada bahan masakan untuk dikitar semula.		.783	
K4 Gunakan produk kitar semula contohnya menggunakan straw yang diperbuat daripada hampas kopi.		.743	
Nilai eigen	5.671	2.008	
Varians dijelaskan (%)	56.708	20.082	
Jumlah alpha cronbach			0.911

Nota. Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

5. Perbincangan

Kajian ini menunjukkan bahawa instrumen yang dibangunkan mempunyai tahap kesahan dan kebolehpercayaan yang tinggi. Dua konstruk utama iaitu kitar semula dan pulihara telah dikenal pasti. Nilai Alpha Cronbach bagi kedua-dua konstruk melebihi 0.9, membuktikan bahawa item adalah konsisten dalam mengukur konsep aplikasi bahan berguna. Penemuan ini menunjukkan bahawa amalan pengurusan sisa melalui pendekatan kitar semula dan pulihara adalah relevan dalam konteks pendidikan vokasional. Kajian ini selari dengan kajian terdahulu yang menunjukkan bahawa strategi seperti pengasingan sisa, penggunaan produk mesra alam, dan penghantaran bahan ke pusat kitar semula adalah berkesan dalam menyokong amalan ekonomi kitaran (Ayoush et al., 2023; Bentil et al., 2024; Ouro-Salim & Guarnieri, 2023; Valls-Val et al., 2023). Ini sekaligus menunjukkan bahawa guru memerlukan indikator khusus untuk menyokong pengajaran berasaskan ekonomi kitaran, terutamanya dalam bidang penyediaan dan penghasilan makanan. Secara teorinya, dapatan ini selari dengan konsep ekonomi kitaran yang menolak sistem linear "ambil–guna–buang." Ini selaras dengan teori konstruktivisme yang menyarankan pembelajaran melalui pengalaman dan aktiviti bermakna, seperti penghasilan baja kompos atau sabun daripada sisa. Secara keseluruhannya, kajian ini menunjukkan bahawa instrumen yang dibina sesuai digunakan dalam konteks pendidikan TVET.

6. Kesimpulan

Instrumen yang dibina didapati sah, boleh dipercayai dan praktikal untuk menilai aplikasi bahan berguna dalam pengurusan sisa makanan berasaskan ekonomi kitaran. Instrumen ini menyokong pengajaran guru vokasional dan selari dengan agenda Pembangunan Mampan (SDG 12.3). Implikasinya, instrumen ini dapat membantu merancang pengajaran dan membina kurikulum berasaskan kelestarian. Namun, kajian terhad kepada satu bidang kursus dan belum melalui analisis faktor pengesahan. Kajian lanjutan disarankan melibatkan populasi lebih luas dan menggunakan Analisis Faktor Pengesahan (CFA) bagi mengukuhkan struktur model serta menilai kesannya terhadap amalan pengajaran guru.

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KEBOLEHPASARAN GRADUAN: ANALISIS KETIDAKSEPADANAN PEKERJAAN DI POLITEKNIK TUANKU SULTANAH BAHIYAH

Zarina binti Ismail

Jabatan Kejuruteraan Elektrik, Politeknik Tuanku Sultanah Bahiyah, 09000,Kulim,Kedah

Corresponding author e-mail address: zarina_ismail@ptsb.edu.my

Abstrak

Dalam dunia pekerjaan yang semakin kompleks dan mencabar, isu ketidaksepadanan antara bidang pengajian dan pekerjaan yang diceburi semakin membimbangkan, terutamanya dalam kalangan graduan institusi TVET seperti Politeknik Tuanku Sultanah Bahiyah (PTSB). Kajian ini bertujuan untuk meneliti tahap dan trend ketidaksepadanan pekerjaan dalam kalangan graduan PTSB dari tahun 2020 hingga 2024, merangkumi 12 program pengajian yang ditawarkan. Menggunakan pendekatan kuantitatif, data dikumpul melalui soal selidik yang diedarkan secara dalam talian kepada 5,111 orang graduan konvokesyen. Instrumen soal selidik adalah berasaskan format Kajian Pengesanan Graduan TVET yang menilai kesepadanan antara bidang pengajian dan pekerjaan yang diperolehi graduan. Analisis data dijalankan menggunakan perisian IBM Statistical Package for Social Science (SPSS) Versi 23 secara deskriptif bagi mendapatkan peratusan. Hasil kajian mendapati bahawa kadar kebolehpasaran graduan PTSB kekal tinggi (89.8%–98.1%), namun tahap kesepadanan bidang masih sederhana. Hanya 52.5% graduan bekerja dalam bidang yang selari dengan pengajian mereka, manakala 47.5% dilaporkan berada dalam pekerjaan yang tidak sepadan. Perbezaan ketara turut dilihat berdasarkan jantina dan program pengajian, dengan graduan wanita dan bidang bukan teknikal mencatatkan kadar ketidaksepadanan yang lebih tinggi. Dapatan ini membuktikan bahawa ketidaksepadanan pekerjaan bukan sekadar cabaran statistik, tetapi juga merupakan realiti sosial yang menyentuh motivasi, hala tuju kerjaya, dan potensi sebenar graduan. Kajian ini mencadangkan penekanan terhadap pembangunan kemahiran merentas bidang, latihan prakerjaya, dan kerjasama erat antara institusi pendidikan dan industri sebagai langkah penting ke arah melahirkan graduan yang bukan sahaja boleh bekerja, tetapi mampu berkembang dalam bidang yang selari dengan potensi mereka.
Kata kunci: Kebolehpasaran; Ketidaksepadanan; Graduan.

1. Pengenalan

Perluasan pesat pendidikan tinggi di Malaysia telah membuka jalan kepada peningkatan jumlah graduan yang memasuki pasaran pekerjaan. Dalam era ekonomi digital yang berkembang pesat, fenomena ini adalah satu perkembangan positif kepada negara, kerana permintaan terhadap pekerja berkemahiran semakin meningkat untuk memenuhi keperluan industri. Jadual 1 berikut menunjukkan kadar kebolehpasaran graduan institut pengajian di Malaysia melibatkan Institut Pendidikan Tinggi (IPT) tempatan dan Institut Latihan Kemahiran (ILKA). Namun, di sebalik pencapaian ini, isu ketidakpadanan pekerjaan di kalangan graduan terus menjadi perdebatan hangat. Menurut Shahril et al., (2023), ketidakpadanan pekerjaan berpotensi menurunkan tahap motivasi pekerja, terutamanya apabila pekerja ini menerima gaji yang lebih rendah daripada yang sepatutnya. Keadaan ini bukan sahaja menjejaskan produktiviti syarikat pekerjaan tersebut, malah turut memberi impak negatif yang lebih besar terhadap keseluruhan rantaian ekonomi negara. Menurut kajian Aminu (2019), perubahan dalam struktur ekonomi serta pertumbuhan

ekonomi yang pesat adalah antara faktor utama yang menyumbang kepada ketidaksepadanan antara pendidikan dan pekerjaan.

Jadual 1. Kadar kebolehpasaran graduan TVET

Tahun	2019	2020	2021	2022	2023
Bilangan Graduan	330557	305301	318034	324504	324408
Graduate Employability (GE)	86.2%	84.4%	85.5%	90.2	89.9%

Nota. Sumber: Unit Kebolehpasaran Graduan, Jabatan Pendidikan Politeknik dan Kolej Komuniti (JPPKK), Kementerian Pendidikan Tinggi (KPT), 2024.

Dapat dilihat daripada Jadual 2, adalah merupakan kadar kebolehpasaran dan kesepadanan yang diperolehi daripada keseluruhan graduan politeknik Malaysia bagi tahun 2021 sehingga tahun 2023. Berdasarkan Jadual 2, dapat dilihat satu perkembangan yang memberangsangkan apabila kadar kebolehpasaran graduan politeknik Malaysia meningkat secara konsisten dari 93.7% pada tahun 2021 kepada 97.1% pada tahun 2023. Ini menunjukkan bahawa semakin ramai graduan berjaya menempatkan diri dalam dunia pekerjaan selepas tamat pengajian, satu pencapaian yang wajar dibanggakan. Namun di sebalik angka yang positif ini, realitinya hampir separuh daripada graduan masih bekerja dalam bidang yang tidak sepadan dengan pengajian mereka. Sepanjang tiga tahun ini, hanya sekitar separuh sahaja yang mendapat pekerjaan selari dengan latar belakang akademik graduan tersebut. Ini memberi gambaran bahawa walaupun graduan berjaya mendapatkan pekerjaan, belum tentu ia benar-benar mencerminkan apa yang telah dipelajari dan usahakan selama sesi pembelajaran. Salah satu isu yang menghantui graduan selepas menamatkan pengajian adalah cabaran untuk mendapatkan pekerjaan yang sepadan (Mohamad, 2022).

Jadual 2. Kadar kebolehpasaran graduan politeknik Malaysia

Tahun	Kadar kebolehpasaran	Kesepadanan	
		Ya	Tidak
2021	93.7%	53.0%	47.0%
2022	96.2%	51.0%	49.0%
2023	97.1%	52.3%	47.8%

Nota. Sumber: Unit Kebolehpasaran Graduan, Jabatan Pendidikan Politeknik dan Kolej Komuniti (JPPKK), Kementerian Pendidikan Tinggi (KPT), 2024.

Adalah penting untuk menangani isu kebolehpasaran dan kebolehdapatan graduan, termasuk ketidakpadanan pekerjaan, terutamanya setelah pelaburan besar yang telah dilakukan. Ini melibatkan secara individu mahupun melalui subsidi kerajaan dalam mempersiapkan graduan menghadapi dunia kerja. Dari perspektif pelaburan, keadaan ini mencerminkan pulangan yang rendah atau tidak baik, sekaligus menimbulkan kerugian bagi negara, kerana modal insan tidak dapat diagihkan dengan efisien dan menghadkan potensinya. Sebagaimana penulisan oleh Shahidan dan Ismail (2021), menekankan bahawa masalah ketidakpadanan pekerjaan dan kelayakan berlebihan di kalangan graduan di Malaysia adalah merupakan isu yang serius dan perlu ditangani untuk memastikan pembangunan kerjaya graduan dan juga pertumbuhan ekonomi negara. Isu ini juga dipersetujui oleh Abu Rahim, Abdul Wahab, dan Jani (2023), dimana telah dijalankan kajian dikalangan pekerja muda di Malaysia. Pola ketidaksepadanan adalah berbeza-beza mengikut bidang pengajian, dengan bidang yang lebih umum mempunyai kadar ketidaksepadanan yang lebih tinggi, manakala bidang yang tertentu pula memberikan padanan pekerjaan yang lebih baik (Salas-Velasco, 2021) .

1.1 Penyataan masalah

Ketidakpadanan pekerjaan dan jurang bidang pengajian adalah serius, terutamanya dalam kalangan graduan baharu (Abu Rahim & Yi, 2024). Bank Dunia dalam laporan Malaysia Economic Monitor menyatakan bahawa satu perempat pemegang ijazah di Malaysia bekerja dalam bidang pekerjaan yang tidak sepadan kelayakan dan trend ini juga sama pada pemegang diploma (MalaysiaKini, 2024). Setiap tahun, sekurang-kurangnya satu pertiga daripada graduan baharu terpaksa mengambil pekerjaan yang tidak setara dengan kelayakan mereka (Abu Rahim, 2023). Peluang graduan untuk mendapatkan pekerjaan yang menawarkan gaji yang setara dengan kelulusan semakin mencabar. Ini turut menyumbang kepada peningkatan pengangguran dalam kalangan siswazah, selain mereka terpaksa menerima pekerjaan yang tidak sepadan dengan bidang pengajian serta dibayar gaji yang tidak seimbang dengan kelayakan yang dimiliki. Kebanyakan pekerjaan yang tersedia adalah bergaji rendah, terutamanya dalam kategori pekerjaan berkemahiran rendah atau separa mahir, berbanding dengan kelayakan akademik yang mereka miliki (Ahmad & Bon, 2024). Persekutuan Majikan-majikan Malaysia (MEF) sendiri turut menyatakan hasrat untuk menjalankan kajian membabitkan isu kesepadan kemahiran graduan Pendidikan dan Latihan Teknikal dan Vokasional (TVET) dengan keperluan industri sebagaimana dinyatakan oleh Pengerusinya, Datuk Dr. Syed Hussain Syed Husman (Berita Harian, 2024)

1.2 Objektif

Ramai graduan hari ini terpaksa akur menerima pekerjaan yang tidak setimpal dengan kelayakan mereka, malah sanggup bekerja dengan gaji yang lebih rendah daripada apa yang sepatutnya. Dalam usaha untuk membina kehidupan selepas tamat pengajian, mereka juga sering terjerumus ke dalam sektor pekerjaan yang langsung tiada kaitan dengan bidang yang dipelajari. Bagi sesetengah individu, ini bukan soal pilihan, tetapi soal keperluan untuk terus hidup dan berdikari. Situasi ini menggambarkan tekanan yang dihadapi oleh graduan dalam menyesuaikan diri dengan pasaran kerja yang semakin tidak menentu, di samping menunjukkan wujudnya jurang nyata antara laluan akademik dan peluang pekerjaan yang tersedia (Khazanah Research Institute, 2024). Jadual 3 berikut adalah merupakan kadar kebolehpasaran PTSB bagi 5 tahun 2020 sehingga tahun 2024. Daripada maklumat ini, didapati bahawa kebolehpasaran PTSB adalah meningkat daripada tahun ke tahun. Kajian ini dijalankan adalah untuk melihat trend ketidaksepadanan pekerjaan mengikut bidang yang diikuti oleh graduan PTSB ini selama 5 tahun dan ketidaksepadanan mengikut kepada pecahan program pengajian yang diikuti. Kajian ini juga akan melihat ketidaksepadanan daripada sudut jantina pelajar PTSB.

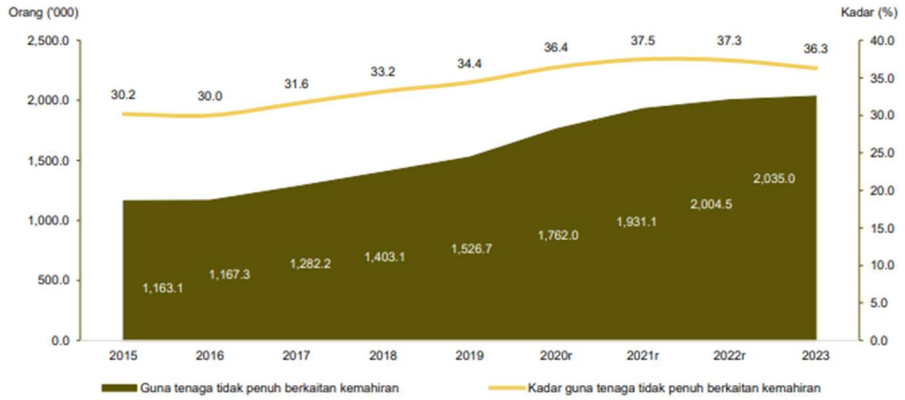
Jadual 3. Data kebolehpasaran graduan PTSB 2020-2025

Tahun Konvokesyen	Kebolehpasaran Graduan (%)
2020	89.8
2021	87.8
2022	95.4
2023	94.9
2024	98.1

2. Kajian Literatur

Ketidakpadanan pekerjaan bermaksud percanggahan antara kelayakan individu (pencari kerja) dan kriteria kelayakan yang diperlukan oleh pasaran kerja (Salas-Velasco, 2021). Secara umum, mengikut kepada (Jabatan Perangkaan Malaysia, 2024) ketidaksepadanan pekerjaan merujuk kepada situasi di mana seseorang terpaksa menerima pekerjaan yang memerlukan kemahiran yang lebih rendah berbanding tahap pendidikannya. Ini dikatakan dapat diukur melalui indikator

guna tenaga tidak penuh berdasarkan kemahiran, iaitu bagi mereka yang berpendidikan tinggi tetapi bekerja dalam kategori pekerjaan yang memerlukan kemahiran sederhana atau rendah. Rajah 1, menunjukkan graf guna tenaga tidak penuh berkaitan kemahiran Malaysia bagi tahun 2015 sehingga 2023. Daripada rajah tersebut dapat dilihat bahawa berlaku peningkatan pada guna tenaga tidak penuh berkaitan kemahiran meningkat sebanyak 1.5% dengan berlaku pertambahan 30.4 ribu bagi mencatatkan 2.03 juta orang berbanding tahun 2022 iaitu 2.00 juta orang. Namun begitu, sumbangan guna tenaga tidak penuh berkaitan kemahiran terus menurun sebanyak 1% kepada 36.3% berbanding tahun sebelumnya.



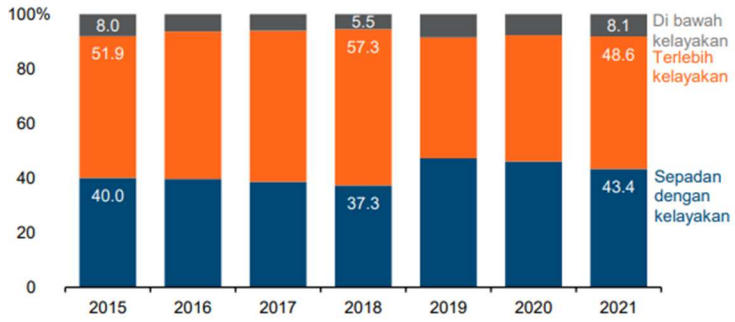
Rajah 1. Graf guna tenaga tidak penuh berkaitan kemahiran, Malaysia, 2015-2023.
Nota. Sumber: Sumber: Jabatan Perangkaan Malaysia, 2024

Pihak industri kerap kali membangkitkan isu ketidaksepadanan dari segi pengetahuan serta kemahiran yang dimiliki oleh graduan IPT dengan keperluan sebenar industri di dunia pekerjaan sebenar (Abdullah & Abd Majid, 2022). Menurut kajian Universiti UK, masalah sebenar ketidaksepadanan pekerjaan adalah disebabkan oleh lambakan graduan daripada kursus yang sama, menyebabkan majikan menjadi lebih berhati-hati dalam menyaring calon untuk mencari yang paling pekerja yang paling layak dan bersesuaian (Steed, 2018).

Secara idealnya, pemain utama dalam pasaran buruh perlu menyelaraskan keperluan industri dengan hasil pendidikan dan latihan graduan (Gomez & Luna, 2023). Pemain utama ini adalah terdiri daripada, majikan/industri, institusi Pendidikan, organisasi latihan dan pembangunan dan kerajaan/pembuat dasar serta pihak berkepentingan lain (persatuan professional, badan akreditasi dan agensi yang menyumbang kepada penyelarasan keperluan kemahiran. Sebagai contoh, institusi pendidikan menyediakan graduan dengan program latihan industri (Chen et al., 2018), dan pembangunan kurikulum berdasarkan maklum balas daripada pihak berkepentingan yang relevan. Walaupun amalan terbaik ini diterapkan, ketidakpadanan kemahiran dan tenaga kerja masih berterusan. Menjadi tanggungjawab individu untuk merancang dan membentuk strategi dalam usaha memperoleh pekerjaan di pasaran dan ia merupakan isu penting dalam pembangunan sumber manusia yang perlu diberikan perhatian kerana ianya membawa kesan dan implikasi yang berbeza kepada setiap individu (Yusof & Jamaluddin, 2017).

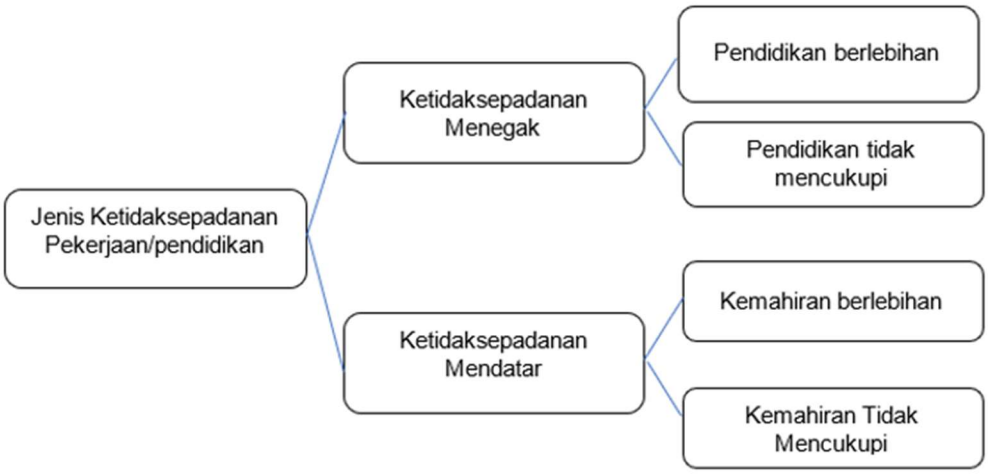
Kajian oleh Abdul Kadir et.al, (2020) pula menemukan bahawa persoalan kepada ketidaksepadanan yang wujud pada masa ini adalah disebabkan oleh kekurangan pekerjaan dan keperluan untuk menjana pendapatan. Graduan pada masa kini terdesak untuk mencari pekerjaan dan jika ada tawaran kerja yang gajinya kurang daripadanya sepatutnya, kebanyakan graduan akan menerimanya untuk terus hidup dalam ekonomi semasa ini. Gaji kebanyakannya bergantung pada industri pekerjaan kerana permintaan lebih daripada penawaran dan disebabkan ini terdapat institusi pekerjaan yang mengambil kesempatan daripada ini situasi

dengan menawarkan gaji yang lebih rendah. Menurut Data Kajian Pengesanan Graduan oleh Kementerian Pendidikan Tinggi pada Rajah 2, hampir separuh daripada graduan mendapati diri mereka terlebih berkelayakan untuk pekerjaan pertama yang mereka ceburi selepas tamat pengajian. Ketidaksepadanan antara tahap pendidikan dan keperluan pasaran kerja ini bukan sahaja menjejaskan kecekapan pasaran buruh, tetapi juga membatasi potensi pembangunan modal insan di Malaysia (Abu Rahim & Yi, 2024).



Rajah 2. Kadar Kesepadanan KPT
Nota. Sumber: Kajian Pengesanan Graduan, KPT

Ketidaksepadanan pekerjaan juga menyumbang kepada isu pengangguran dalam kalangan graduan. Terdapat tiga kategori ketidakpadanan pekerjaan iaitu ketidaksepadanan pendidikan-pekerjaan yang merujuk kepada ketidakpadanan antara pendidikan yang diperoleh dan keperluan pekerjaan, ketidakpadanan kelayakan-pekerjaan yang berlaku apabila graduan terlebih kelayakan atau tidak cukup layak untuk pekerjaan tersebut, dan ketidakpadanan bidang pengajian-pekerjaan, iaitu ketidakpadanan antara bidang pengajian dan bidang pekerjaan (Abdul Kadir et al., 2020). Pertubuhan Buruh Antarabangsa (ILO) mengklasifikasikan ketidakpadanan pekerjaan kepada dua jenis: pertama, ketidakpadanan antara permintaan dan penawaran kemahiran berdasarkan perbandingan tahap pendidikan antara individu bekerja dan menganggur; kedua, ketidakpadanan kemahiran melalui perbandingan antara tahap pendidikan yang dimiliki individu dengan tahap pendidikan yang diperlukan bagi sesuatu pekerjaan (Shahidan et al., 2019). Menurut kepada kajian oleh Kaharudin et al., (2023) menunjukkan ketidaksepadanan pendidikan-pekerjaan terdiri daripada ketidaksepadanan menegak (*vertical mismatch*) dan ketidaksepadanan mendatar (*horizontal mismatch*) seperti Rajah 3 di bawah.



Rajah 3. Jenis ketidaksepanan pekerjaan/Pendidikan

Ketidaksepadanan menegak merujuk kepada situasi di mana kelayakan pendidikan seseorang melebihi atau kurang daripada tahap pendidikan yang diperlukan bagi sesuatu pekerjaan. Ketidaksepadanan ini diukur berdasarkan perbandingan tahap pendidikan yang diperoleh dengan tahap yang diperlukan untuk melaksanakan tugas tertentu. Istilah ini juga dikenali sebagai Ketidaksepadanan dari segi kuantiti pendidikan, berbanding jenis pendidikan. Sebaliknya, Ketidaksepadanan mendatar berlaku apabila bidang pekerjaan seseorang tidak selaras dengan bidang pengajiannya. Sebagai contoh, seorang guru berkelulusan ijazah yang bekerja sebagai kerani mengalami Ketidaksepadanan menegak, manakala jika guru tersebut bekerja sebagai ahli statistik, situasi tersebut diklasifikasikan sebagai Ketidaksepadanan mendatar.

Majikan yang mengambil pekerja dengan kelayakan berlebihan sering meraih manfaat jangka pendek kerana pekerja ini dapat menyumbang kepada peningkatan prestasi syarikat. Namun, dalam jangka masa panjang, ketidaksepadanan ini boleh menyebabkan masalah seperti ketidakpuasan kerja dan gaji yang tidak setimpal. Fenomena ketidaksepadanan pekerjaan juga memberi kesan negatif kepada ekonomi secara keseluruhan, di mana potensi sebenar pekerja tidak digunakan secara optimum, mengakibatkan pembaziran sumber manusia dan penempatan kerja yang tidak efisien (Velciu, 2017). Ini juga dipersetujui oleh Hanafi, Mohd Ismail, & Zuraiju, (2024), di mana dikatakan isu ketidaksepadanan antara pekerjaan dan kemahiran memberi kesan negatif bukan sahaja kepada individu yang tidak dapat memperoleh pendapatan tinggi yang setimpal dengan kelulusan yang dimiliki, tetapi juga menyumbang kepada kelembapan ekonomi dan kemajuan negara akibat kekurangan tenaga kerja mahir. Kajian terdahulu oleh Mohd Salahuddin et al., (2023) telah menunjukkan bahawa ketidaksepadanan kemahiran adalah pembolehubah penting untuk memahami dan menyiasat kemahiran kebolehpasaran dan prestasi kerja. Kajian ini mendedahkan bahawa kemahiran kebolehpasaran dan ketidaksepadanan pekerjaan turut menyumbang dengan ketara kepada pengangguran siswazah di Malaysia.

Pada masa kini, kebanyakan industri tidak lagi hanya menitikberatkan kemahiran teknikal semata-mata, sebaliknya graduan diharapkan untuk menguasai kemahiran insaniah (Hanafi et al., 2024). Kemahiran insaniah ini merangkumi aspek seperti komunikasi, pemikiran kritikal, membuat keputusan, penyelesaian masalah, kepimpinan, kerja berpasukan, serta pengurusan masa. Sebagai contoh, kemahiran dalam pengurusan masa dapat membantu individu menyelesaikan tugasan dengan lebih teratur, sekaligus meningkatkan produktiviti kerja secara keseluruhan. Mereka juga perlu membangunkan kemahiran insaniah seperti komunikasi, penyelesaian masalah, kerja berpasukan, dan fleksibiliti untuk meningkatkan kebolehpasaran selaras dengan keperluan pasaran kerja.

Graduan juga perlu membina diri dengan memiliki pakej personaliti yang lengkap. Ilmu yang diperoleh di dalam bilik kuliah sahaja tidak mencukupi. Semua pencari kerja pada asasnya sama, masing-masing memiliki ijazah. Akhirnya, penampilan, keterampilan diri, serta kebijaksanaan calon menjadi faktor penentu yang mampu menarik perhatian majikan untuk memilih mereka (Abd Hamid, 2022). Menurut penulisan Prof. Madya Dr. Ilhaamie Abdul Ghani Azmi, (2024) model kesepadanan pekerjaan Holland, personaliti individu perlu sesuai dengan jenis pekerjaan tertentu agar mereka dapat bertahan dan berfungsi dengan baik dalam pekerjaan tersebut. Kegagalan dalam mengenal pasti kesesuaian personaliti seseorang terhadap pekerjaan yang dilakukan akan mengakibatkan kerugian kepada sesuatu perniagaan ataupun pekerja itu sendiri seperti produktiviti yang rendah (Mohd Mahyideen, et al., 2020).

Adalah penting untuk membina hubungan yang kukuh antara institusi akademik dan industri, kerana kerjasama ini dapat membantu institusi pendidikan menyediakan graduan yang lebih

selaras dengan keperluan pasaran kerja (Chaudry et al., 2022). Sebagaimana cadangan Kaharudin et al., (2023), pihak berkepentingan seperti pembuat dasar, institusi pendidikan, dan graduan perlu mengambil inisiatif untuk melakukan penambahbaikan yang sewajarnya terhadap senario Ketidaksepadanan pekerjaan yang berlaku dalam pasaran buruh. Tindakan penambahbaikan yang dilaksanakan secara bersama dapat memaksimumkan potensi sumber tenaga serta mengoptimumkan produktiviti, sekaligus menyumbang kepada peningkatan ekonomi negara. Sebagaimana penubuhan Majlis TVET Kebangsaan dan Badan Koordinasi TVET Kerajaan-industri (GITC), di mana usaha mengukuhkan hubungan industri untuk menangani Ketidaksepadanan kemahiran dan memadankan modal insan yang dipacu permintaan sedang menjadi tumpuan utama (Berita Harian, 2024). Dicadangkan pula oleh Wicaksono et al., (2023), Syarikat dan universiti boleh menyediakan latihan asas untuk graduan serta pekerja baharu agar mereka dapat menyesuaikan diri dengan lebih cepat di tempat kerja dan mengelakkan penalti gaji. Selain itu, pekerja juga diharapkan menyertai pelbagai program latihan sebelum memasuki pasaran kerja.

Namun begitu, kebanyakan kajian terdahulu lebih banyak menumpukan perhatian kepada institusi pengajian tinggi awam, manakala kajian khusus terhadap institusi TVET seperti politeknik masih kurang diberi perhatian. Dalam masa yang sama, aspek perbandingan tahap kesepadanan pekerjaan berdasarkan jantina dan program pengajian juga belum banyak diteroka secara mendalam, khususnya dalam konteks pendidikan tinggi teknikal dan vokasional di Malaysia. Menyedari jurang ini, kajian ini tampil untuk mengisi kekosongan tersebut dengan menganalisis corak ketidaksepadanan dalam kalangan graduan politeknik, berdasarkan latar belakang program dan demografi mereka. Usaha ini diharap bukan sahaja dapat memberikan gambaran yang lebih holistik, tetapi juga menjadi asas kepada cadangan penambahbaikan dalam penyelarasan antara sistem pendidikan dan keperluan pasaran kerja sebenar.

3. Metodologi Kajian

Kajian ini dijalankan menggunakan pendekatan kuantitatif melalui kaedah tinjauan sebagai medium untuk mengumpul data para graduan yang telah menamatkan pengajian dalam tempoh lima tahun, khususnya dari kohort graduan yang tamat pada tahun 2020 sehingga 2024. Soal selidik adalah merupakan instrument kajian yang diguna pakai, di mana soalan ini dibina oleh pihak Kementerian Pengajian Tinggi, Malaysia. Data diperolehi melalui soal selidik ini yang diselesaikan oleh graduan PTSB dan dilaksanakan secara atas talian melalui Sistem Kajian Pengesanan Graduan (SKPG) TVET. Seramai 5111 orang responden (menjawap soal selidik) terlibat dalam kajian ini, mewakili hampir keseluruhan populasi seramai 5551 orang pada tahun berkenaan. Kajian ini menggunakan teknik pensampelan banci (census sampling) kerana keseluruhan populasi graduan dari tahun 2019 hingga 2024 dijadikan sasaran kajian. Pendekatan ini membolehkan penyelidik mendapatkan dapatan yang tepat dan menyeluruh berkenaan tahap kesepadanan pekerjaan mengikut program pengajian dan demografi responden dan boleh dicapai sepenuhnya melalui system SKPG.

Para responden terdiri keseluruhan 12 program yang terdapat di PTSB. Soal selidik yang dijawap ini terdiri daripada enam bahagian, iaitu bahagian latar belakang, bahagian maklumat terkini tentang status pekerjaan graduan, bahagian pekerjaan graduan, sektor pekerjaan, dan pendapatan mereka dan bahagian mengumpul maklumat tentang sebab-sebab mengapa graduan belum atau tidak bekerja. Bahagian seterusnya adalah berkaitan tawaran lanjut pengajian, dan bahagian terakhir adalah pengalaman graduan semasa pengajian di institusi. Dapatan data yang diperolehi ditunjukkan dalam bentuk deskriptif peratusan di mana soalan-

soalan ini telah difokuskan jawapannya, dan dianalisis menggunakan perisian IBM Statistical Package for Social Science (SPSS) Versi 23.

4. Keputusan dan Perbincangan

4.1 Maklumat demografi responden graduan

Seramai 5,551 graduan PTSB telah menamatkan pengajian peringkat diploma antara tahun 2020 hingga 2024 dan seterusnya melangkah ke alam pekerjaan. Graduan ini terdiri daripada 12 program pengajian yang ditawarkan di institusi ini. Daripada jumlah keseluruhan tersebut, seramai 5,111 graduan telah memberikan maklum balas terhadap soal selidik yang diedarkan. Melalui analisis maklumat demografi yang ditunjukkan dalam Jadual 4, didapati majoriti responden adalah dalam kalangan wanita, iaitu sebanyak 50.3% (n=2,573), manakala selebihnya adalah lelaki sebanyak 49.7% (n=2,538). Dapatan daripada kajian ini juga menunjukkan bahawa tahap kebolehpasaran graduan PTSB secara umumnya berada dalam keadaan yang baik, sebagaimana ditunjukkan dalam Jadual X sebelum ini. Keputusan ini memberikan gambaran positif terhadap keupayaan graduan untuk menyesuaikan diri dengan kehendak pasaran kerja selepas tamat pengajian.

Jadual 4. Taburan responden mengikut jantina tahun 2020 hingga 2024 (n=5111)

Jantina	Tahun Konvokesyen											
	2020		2021		2022		2023		2024		Jumlah	
	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.	%
Lelaki	479	48	505	46.5	534	51.1	524	49.7	496	53.4	2,538	49.7
Perempuan	519	52	581	53.5	510	48.9	530	50.3	433	46.6	2,573	50.3

4.2 Analisis ketidaksepadanan graduan bekerja

Kadar kebolehpasaran PTSB ini dilihat dalam keadaan yang baik dan untuk kadaran ini dianalisis, ianya dipecahkan kepada 4 status (bekerja, melanjut pengajian, meningkatkan kemahiran dan menunggu penempatan pekerjaan) seperti Jadual 5. Dapatan data ini menunjukkan 3666 (71.7%) responden adalah bekerja. Data graduan bekerja ini berlaku peningkatan pada setiap tahun kecuali pada tahun 2023(75.1%) dan tahun 2024(70.5%), berikutan berlaku peningkatan pada graduan yang melanjutkan pengajian. Daripada data status pekerjaan ini, data graduan bekerja bagi tahun 2020 sehingga tahun 2024 dikaji kepada tahap kesepadanan pekerjaan yang diperolehi oleh graduan. Setelah data responden bekerja diperolehi, data ini dianalisis semula berdasarkan kepada soalan soal selidik yang telibat pada bahagian bekerja. Soalan tersebut adalah 'Adakah anda bekerja dalam bidang yang sama dipelajari di institusi?'. Daripada soalan ini, akan diperolehi data sepertimana Jadual 6 di bawah.

Jadual 5. Status kebolehpasaran graduan 2020 hingga 2024 (n=5111)

Tahun Konvokesyen	Bekerja		Melanjutkan pengajian		Meningkatkan kemahiran		Menunggu penempatan pekerjaan		Belum bekerja		Jumlah	
	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.	%
2020	628	62.9	258	25.9	1	0.1	9	0.9	102	10.2	998	100
2021	787	72.5	145	13.4	5	0.5	16	1.5	133	12.2	1,086	100
2022	804	77.0	188	18.0	1	0.1	3	0.3	48	4.6	1,044	100

2023	792	75.1	198	18.8	4	0.4	6	0.6	54	5.1	1,054	100
2024	655	70.5	249	26.8	2	0.2	5	0.5	18	1.9	929	100
JUMLAH	3,666	71.7	1,038	20.3	13	0.3	39	0.8	355	6.9	5,111	100

Setelah tapisan data ini dilakukan, maka data kesepadanan dan ketidaksepadanan responden yang bekerja diperolehi. Daripada Jadual 6 berikut, didapati daripada seseluruhan 3666 graduan yang memperolehi pekerjaan ini sepanjang 5 tahun (2020-2024), 47.5% responden mempunyai ketidaksepadanan mengikut bidang yang dipelajari graduan. Manakala 52.5% adalah sebaliknya. Dan daripada ini juga dapat dilihat bahawa nilaian ini adalah konsisten setiap tahun, kecuali pada tahun 2021. Peratusan ketidaksepadanan ini dilihat adalah baik iaitu kurang 50% setiap tahun, kecuali pada tahun 2021 yang mempunyai ketidaksepadanan 51%. Tren ketidaksepadanan ini didapati menurun secara tahunan, kecuali tahun 2021. Bermula tahun 2020, ketidaksepadanannya iaitu 48.7%, tahun 2022 dengan 46.3% dan seterusnya tahun 2023 dengan ketidaksepadanan 46.2%. Nilaian ini menurun lagi 1% pada tahun 2024 dengan 54.8%. Tren sepanjang 5 tahun ini menunjukkan sedikit peningkatan dalam kesepadanan, namun kadar ketidaksepadanan masih kekal tinggi dan melebihi empat orang daripada setiap sepuluh graduan.

Daripada keseluruhan data, kesimpulan dapat dibuat bahawa, dapatan menunjukkan tahap ketidaksepadanan antara bidang pengajian yang diikuti oleh graduan PTSB dengan pekerjaan diceburi berada pada tahap rendah menghampiri sederhana dan menunjukkan bahawa isu ketidaksepadanan pekerjaan masih merupakan cabaran yang perlu dilihat dalam kalangan graduan ini. Jadi masih terdapat jurang yang perlu diatasi agar graduan dapat benar-benar memanfaatkan ilmu dan kemahiran yang telah dipelajari semasa di politeknik. Daripada sudut realiti sebenar, keadaan ini turut mencerminkan cabaran sebenar yang dihadapi oleh graduan apabila terpaksa menyesuaikan diri dalam bidang kerja yang mungkin tidak sepenuhnya seiring dengan pengajian yang dipelajari, sekali gus memberi kesan terhadap motivasi dan hala tuju kerjaya jangka panjang.

Jadual 6. Status kesepadanan graduan 2020 hingga 2024 (n=3666)

Anda Bekerja Dalam Bidang Yang Sama Dipelajari Di Institusi?						
	Ya		Tidak		Jumlah	
Tahun	Bil.	%	Bil.	%	Bil.	%
2020	322	51.3	306	48.7	628	100.0
2021	386	49.0	401	51.0	787	100.0
2022	432	53.7	372	46.3	804	100.0
2023	426	53.8	366	46.2	792	100.0
2024	359	54.8	296	45.2	655	100.0
Jumlah	1925	52.5	1741	47.5	3666	

Jadual 7. Status kesepadanan graduan 2020 hingga 2024 mengikut jantina (n=3666)

Anda Bekerja Dalam Bidang Yang Sama Dipelajari Di Institusi?													
	Ya						Tidak						Jumlah Keseluruhan
	Jantina				Jumlah		Jantina				Jumlah		
	Lelaki		Perempuan				Lelaki		Perempuan				
Tahun	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.	%	Bil.
2020	178	55.3	144	44.7	322	100.0	116	37.9	190	62.1	306	100.0	628
2021	230	59.6	156	40.4	386	100.0	160	39.9	241	60.1	401	100.0	787

2022	256	59.3	176	40.7	432	100.0	165	44.4	207	55.6	372	100.0	804
2023	245	57.5	181	42.5	426	100.0	156	42.6	210	57.4	366	100.0	792
2024	201	56.0	158	44.0	359	100.0	153	51.7	143	48.3	296	100.0	655
Jumlah	1,110	57.7	815	42.3	1,925	100.0	750	43.1	991	56.9	1,741	100.0	3,666

Daripada keseluruhan data ini pula, dilakukan pecahan data mengikut kepada pecahan jantina, iaitu lelaki dan perempuan. Dapatan kajian (Jadual 7) menunjukkan wujudnya perbezaan yang konsisten dalam kadar ketidaksepadanan pekerjaan antara graduan lelaki dan perempuan dalam tempoh lima tahun kajian (2020–2024). Graduan perempuan secara konsisten mencatatkan kadar ketidaksepadanan yang lebih tinggi berbanding graduan lelaki. Sebagaimana ditunjukkan pada Jadual 7, pada tahun 2020, 62.1% graduan perempuan dilaporkan tidak bekerja dalam bidang yang sepadan dengan pengajian yang dipelajari, berbanding hanya 37.9% graduan lelaki. Corak ini kekal berterusan sehingga tahun 2023. Namun begitu, pada tahun 2024, jurang perbezaan ini mula menunjukkan tanda peningkatan apabila kadar ketidaksepadanan bagi perempuan adalah 48.3% manakala bagi lelaki menurun kepada 51.7%. Selain itu, peratusan graduan perempuan yang bekerja dalam bidang sepadan juga meningkat kepada 44%, iaitu perbaikan berbanding tahun-tahun sebelumnya. Jelas di sini, bahawa dapat dilihat ketidaksepadanan peratusannya adalah lebih jelas kepada graduan wanita.

Perbezaan ini berkemungkinan besar dipengaruhi oleh beberapa faktor struktur dan sosiobudaya. Antaranya termasuk kecenderungan graduan perempuan terhadap pekerjaan yang menawarkan fleksibiliti waktu dan lokasi, yang mungkin tidak semestinya selari dengan bidang teknikal yang dipelajari. Cabaran untuk mendapatkan pekerjaan dalam sektor yang berasaskan teknologi dan sering didominasi oleh tenaga kerja lelaki turut menyukarkan graduan wanita untuk menempatkan diri dalam bidang yang selari dengan pengajian mereka. Di samping itu, tanggungjawab terhadap keluarga, kekangan untuk berpindah tempat kerja jauh dari rumah, serta persepsi terhadap suasana kerja yang mungkin tidak mesra wanita juga menjadi antara faktor yang menyebabkan ramai wanita terpaksa memilih pekerjaan di luar bidang kelayakan mereka. Halangan-halangan ini bukan sahaja memberi kesan kepada kesepadanan kerjaya, tetapi juga kepada keyakinan diri dan hala tuju masa depan mereka. Abdullah dan Abd Majid (2022) menekankan bahawa antara isu utama yang membelenggu graduan institusi pengajian tinggi di Malaysia adalah Ketidaksepadanan antara bidang pengajian dengan pekerjaan yang diceburi. Isu ini dilihat lebih ketara dalam kalangan graduan wanita yang sering berhadapan dengan kekangan struktur dan sosial yang mengehadkan akses kepada peluang pekerjaan dalam bidang yang dipelajari, terutamanya dalam sektor teknikal dan berasaskan STEM. Tambahan pula, kajian ini turut mencadangkan keperluan untuk melaksanakan strategi dan dasar yang lebih inklusif serta sensitif terhadap jantina. Ini termasuk penyediaan program pembangunan kerjaya yang bersesuaian dengan keperluan wanita, penyelarasan kurikulum dengan kehendak industri, dan pengurangan jurang antara institusi pendidikan dan pasaran kerja sebenar. Penekanan terhadap dasar responsif jantina dilihat penting dalam memastikan setiap individu, tanpa mengira jantina, mempunyai peluang yang adil dan saksama dalam membina kerjaya yang sejajar dengan kelayakan mereka.

Setelah data secara mengikut jantina dilihat, data ketidaksepadanan mengikut program pula dianalisis. Jadual 8 berikut adalah merupakan dapatan kesepadanan mengikut program yang diperolehi daripada kaji selidik yang telah dibuat. Dapat dilihat daripada purata kesepadanan dalam 5 tahun tersebut, terdapat 5 program pengajian diploma yang memperolehi kesepadanan

yang tinggi, iaitu Kejuruteraan Mekanikal (pembuatan), Kejuruteraan Mekatronik, Kejuruteraan Elektrik dan Elektronik, Kejuruteraan Elektrik dan Kejuruteraan Mekanikal. Dengan nilaian peratusan kesepadanan adalah, 66.6%, 64.7%,67.1%, 61.1% dan 58.8% masing-masing. Dapat disimpulkan bahawa graduan bidang teknikal telah mencatatkan peratusan 'Tidak' yang rendah dan ini menunjukkan bahawa majoriti graduannya bekerja dalam bidang yang sama dengan pengajian yang diikuti. Ini memberikan gambaran bahawa terdapat kesesuaian antara program yang di tawarkan dengan keperluan industri sebenar. Manakala kadar ketidaksepadanan yang tinggi pula dikuasai oleh program pengajian Kejuruteraan Awam dengan 63.5%, diikuti oleh Geomatik, 56.3% dan Kejuruteraan Elektronik (Komputer), 53.3%. Selain itu program pengajian Diploma Pemasaran juga turut mencapatkan ketidaksepadanan yang tinggi iaitu 51.7%. Perkara ini berlaku berkemungkinan adalah disebabkan oleh kekurangan peluang kerja yang khusus dalam bidang tersebut. Berkemungkinan juga graduan ini menyertai bidang lain yang lebih terbuka seperti perniagaan (usahawan) atau pentadbiran. Industri sekarang telah berlaku perubahan lanskap industri dimana kebanyakannya lebih berbentuk kepada automasi dan digital. Dan data ini sekiranya di plotkan pada graf seperti Rajah 4, dapat dilihat penyusunan peratusan ini daripada tahap kesepadanan yang tinggi ke rendah dan daripada sini dapat dilihat program pengajian yang mempunyai ketidaksepadanan yang sangat jelas.

Jadual 8. Status kesepadanan graduan 2020 hingga 2024 mengikut program pengajian

Program Pengajian	Bekerja: Adakah Anda Bekerja Dalam Bidang Yang Sama Dipelajari Di Institusi?											
	Tahun Konvokesyen											
	2020		2021		2022		2023		2024		Purata	
	Ya	Tidak	Ya	Tidak	Ya	Tidak	Ya	Tidak	Ya	Tidak	YA	Tidak
	%	%	%	%	%	%	%	%	%	%	%	%
Diploma Akauntansi	48.8	51.2	43.4	56.6	40.7	59.3	53.3	46.7	57.4	42.6	47.4	52.6
Diploma Geomatik	47.2	52.8	53.7	46.3	40.3	59.7	40.0	60.0	37.3	62.7	43.7	56.3
Diploma Kejuruteraan Awam	28.4	71.6	29.6	70.4	39.1	60.9	30.8	69.2	54.4	45.6	36.5	63.5
Diploma Kejuruteraan Elektrik	56.3	43.8	61.9	38.1	75.3	24.7	63.5	36.5	48.5	51.5	61.1	38.9
Diploma Kejuruteraan Elektrik Dan Elektronik	65.9	34.1	59.1	40.9	72.7	27.3	70.5	29.5	67.3	32.7	67.1	32.9
Diploma Kejuruteraan Elektronik (Komputer)	34.5	65.5	50.0	50.0	44.8	55.2	60.5	39.5	43.6	56.4	46.7	53.3
Diploma Kejuruteraan Elektronik (Komunikasi)	52.9	47.1	48.4	51.6	55.9	44.1	55.6	44.4	52.2	47.8	53.0	47.0
Diploma Kejuruteraan Mekanikal	64.0	36.0	54.9	45.1	64.2	35.8	52.8	47.2	57.9	42.1	58.8	41.2
Diploma Kejuruteraan Mekanikal (Pembuatan)	78.6	21.4	65.0	35.0	61.8	38.2	72.2	27.8	55.6	44.4	66.6	33.4
Diploma Kejuruteraan Mekatronik	70.9	29.1	52.9	47.1	58.2	41.8	65.8	34.2	75.6	24.4	64.7	35.3
Diploma Pemasaran	32.4	67.6	45.0	55.0	60.8	39.2	50.7	49.3	52.8	47.2	48.3	51.7
Diploma Pengajian Perniagaan	57.6	42.4	51.4	48.6	51.6	48.4	55.1	44.9	58.2	41.8	54.8	45.2
Jumlah	51.3	48.7	49.0	51.0	53.7	46.3	53.8	46.2	54.8	45.2	52.5	47.5

Daripada Rajah 4, data menunjukkan peningkatan yang menggalakkan dalam kebolehpasaran bidang berkaitan, terutamanya bagi program kejuruteraan. Purata peratusan kesepadanan dalam bidang berkaitan mencecah 60%-70% adalah merupakan satu pengukuran kukuh tentang keberkesanan program dalam memenuhi kehendak pasaran kerja. Perkara ini berlaku disebabkan mungkin beberapa faktor, seperti kurikulum yang selaras dengan kehendak industri

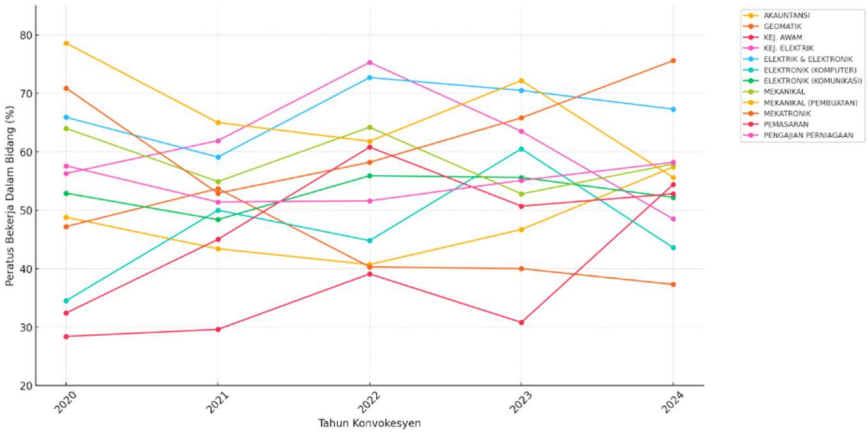
semasa. Selain itu, hubungan aktif antara PTSB dengan industri juga mungkin menyebabkan perkara ini mempengaruhi kesepadanan ini. Di mana kerjasama latihan industri yang berlaku bersama industri dan juga keterlibatan pensyarah jemputan industri yang turut terlibat sama bersama dalam aktiviti PTSB. Namun, wujud jurang ketara yang perlu ditangani bagi program tertentu seperti Geomatik dan Kejuruteraan Awam. Peluang pekerjaan untuk bidang Geomatik adalah terhad dan sangat khusus kerana dalam industri tertentu sahaja yang memerlukan kemahiran ini, maka peluang kerja menjadi sangat tidak meluas. Sekiranya, tiada kekosongan jawatan atau kekurangan projek aktif, maka graduan program pengajian ini terpaksa bekerja dalam bidang berlaian atau bertukar kerjaya. Dijangkakan juga bahawa, program pengajian Geomatik dan Kejuruteraan Awam ini adalah bergantung kepada sektor pembinaan, infrastruktur dan sektor awam. Sekiranya berlaku kelembapan dalam projek awam atau pembinaan, juga boleh menyebabkan pengurangan pengambilan tenaga kerja baru dalam bidang ini. Ini lah merupakan salah satu punca kebolehpasaran lebih rendah berlaku dibandingkan dengan bidang teknikal lain yang lebih luas.



Rajah 4. Purata peratusan kesepadanan graduan mengikut program pengajian dari tahun 2020 hingga 2024

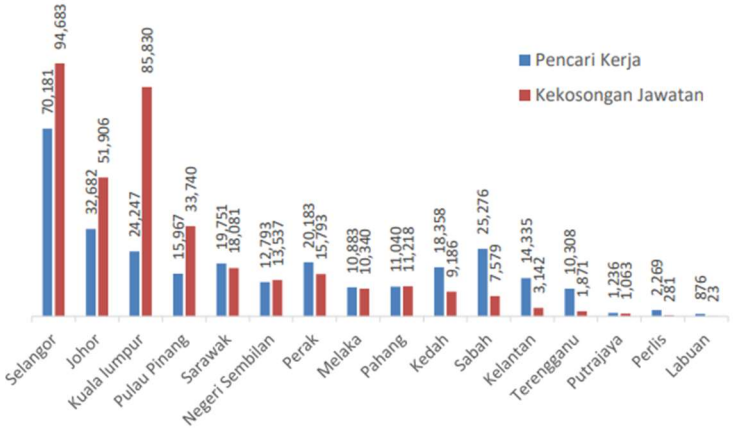
Dapatan data peratusan ini juga dianalisis dengan menggunakan graf, Rajah 5. Daripada graf ini dapat dilihat tren peratusan graduan yang bekerja dalam bidang program pengajian yang sama bagi setiap program daripada tahun 2020 hingga 2024. Graf menunjukkan bahawa, Diploma Kejuruteraan Mekanikal (Pembuatan) dan Diploma Kejuruteraan Mekatronik menunjukkan peratus tertinggi dan konsisten dalam kesepadanan kalangan graduan yang berkerja. Dan ada juga program pengajian yang memberikan kesepadanan yang stabil setiap tahun, iaitu Diploma Akauntasi, Pengajian Perniagaan dan Pemasaran. Peningkatan ini dapat dilihat adalah secara beransur-ansur setiap tahun.

Setelah dilihat daripada dapatan ini, mungkin terdapat lebihan graduan berbanding permintaan industri dan menyebabkan graduan beralih ke sektor lain. Faktor utama yang menyumbang kepada ketidaksepadanan pekerjaan dalam pasaran buruh adalah ketidakseimbangan antara permintaan dan penawaran kemahiran. Perkara ini dapat dilihat melalui Rajah 6, di mana ianya merupakan graf kekosongan jawatan dan pendaftran pencari kerja (aftif) mengikut negeri bagi Julai 2022. Dapat dilihat lebih banyak negeri adalah pendaftaran pencari kerja adalah melebihi daripada kekosongan jawatan yang tersedia. Keadaan ini berlaku apabila bilangan graduan dalam bidang tertentu jauh melebihi peluang pekerjaan yang tersedia, memaksa mereka untuk mencari pekerjaan di luar bidang pengajian mereka.



Rajah 5. Peratusan kesepadanan mengikut program secara tahunan

Selain itu, ramai individu cenderung mencari pekerjaan yang sesuai dengan kemahiran dan minat mereka. Namun, perubahan ekonomi yang pesat sering kali mencetuskan keperluan bagi kemahiran baharu yang belum dimiliki. Dalam jangka pendek, pendorong utama ketidaksepadanan ini adalah kekurangan peluang pekerjaan di banyak negara, terutamanya ekonomi maju, yang memaksa ramai individu menerima pekerjaan yang tidak sesuai dengan kemahiran mereka dan berkualiti rendah (Davos-Klosters, 2014). Untuk mengatasi cabaran ini juga, diperlukan pendekatan yang menyeluruh dan transformasi struktur dalam pasaran buruh, termasuk kaedah pengambilan pekerja yang lebih inklusif dan langkah-langkah lain yang menyokong kesesuaian antara kemahiran graduan dengan keperluan pasaran (Abu Rahim & Yi, 2024). Dasar yang bukan sahaja menumpukan pada penawaran pekerjaan semata-mata, tetapi juga memberi ruang kepada pembangunan kendiri, kemahiran insaniah, dan kebolehsuaian sepanjang hayat adalah penting bagi memastikan graduan bukan sahaja bekerja, tetapi juga berkembang dalam bidang yang sesuai dengan potensi mereka.



Rajah 6. Kekosongan Jawatan dan pendaftaran pencari kerja aktif mengikut negeri
(Sumber: Kementerian Sumber Manusia, 2022)

Sebahagian ketidaksepadanan kelayakan juga berpunca daripada pilihan peribadi dan/atau keadaan individu. Oleh itu, dapat dilihat bahawa ketidaksepadanan pekerjaan berkait rapat dengan ciri-ciri dan kemahiran yang dimiliki oleh graduan itu sendiri, pendidikan yang relevan, dan pengalaman kerja. Ada juga ketidaksepadanan yang bersifat sementara kerana individu berpindah ke pekerjaan baru. Namun begitu dikatakan oleh Abdul Kadir et al.,2020, kebiasaan graduan menerima pekerjaan yang aktiviti teras berbeza daripada kelayakan akan menyebabkan

kesukaran semasa bekerja. Sebagai contoh, graduan bidang kejuruteraan yang memasuki syarikat kewangan memerlukan masa lebih lama untuk mahir dalam pekerjaan tersebut, dan Ketidaksepadanan ini mengganggu keupayaan graduan berkenaan untuk terus berfungsi dengan baik dalam peranan tersebut. Oleh itu, graduan adalah dinasihati untuk tidak memulakan kerjaya dalam pekerjaan yang terlalu berbeza dengan kelayakan, sebaliknya memilih risiko yang berpadanan serta bersesuaian sahaja untuk diambil.

Impak kepada ketidaksepadanan ini boleh menyebabkan kesan kepada individu iaitu graduan, ekonomi dan juga kepada PTSB itu sendiri. Daripada segi graduan, ketidaksepadanan ini akan membuatkan kesukaran penyesuaian diri dengan tufas baharu yang tidak sama dengan pengetahuan dan kemahiran yang ada. Dan perkara ini boleh mengurangkan motivasi, mendapat tekanan psikologi serta menjejaskan perkembangan kerjaya dalam jangka masa panjang. Dikatakan oleh Wicaksono, Theresia dan Al aufa (2023), graduan berisiko tinggi mengalami ketidakpuasan kerja dan kadar bertukar kerja yang tinggi bilamana graduan memulakan kerjaya dalam bidang yang tidak mereka minati dan tidak bersedia. Selain itu, ini juga boleh merencatkan keyakinan diri dan menimbulkan perasaan tidak dihargai dalam dunia pekerjaan (Velciu, 2017). Impak terhadap ekomoni pula, adalah apabila perkara ini menyumbangkan kepada pembaziran modal insan apabila kepakaran dan potensi sebenar graduan tidak digunakan sepenuhnya dalam sektor pekerjaan. Perkara ini menjadi punca kepada pulangan pelaburan dalam Pendidikan tinggi menjadi rendah dan menjejaskan kecekapan pasaran buruh dan produktiviti negara secara keseluruhan (Abu Rahim & Yi, 2024). Selain itu, ianya juga boleh menyumbang kepada pertumbuhan ekonomi yang perlahan dan peningkatan kos sosial. Manakala impak kepada institusi iaitu PTSB pula, kadar ini menunjukkan bahawa terdapat jurang antara hasil pembelajaran dan keperluan sebenar pasaran kerja. Perkara ini menuntut institusi untuk menyemak dan menyesuaikan semula kurikulum agar lebih dinamik dan berkadaran terhadap perubahan industri (Abdullah & Abd Majid, 2022). Selain itu kata Chen et al., (2018), peningkatan kerjasama antara industri dan institusi amat penting, bagi memastikan graduan memperoleh pendedahan sebenar dan bersedia daripada segi kemahiran teknikal serta kemahiran insaniah. Selain itu, kerjasama antara agensi yang berkaitan perlu ditingkatkan bagi mengelakkan pertindihan tugas dan pembaziran sumber (Ibrahim @ Ahyat et.al, 2017)

Oleh itu, graduan perlu meningkatkan kebolehsuaian mereka dengan memperoleh kemahiran yang relevan bagi memastikan graduan kekal kompetitif dalam pasaran pekerjaan yang semakin dinamik. Dinyatakan dalam kajian, graduan yang menerima pekerjaan di luar bidang pengajian adalah bersifat sementara, hakikatnya mereka tidak berminat untuk bekerja diluar bidang (Abd Rashid et al., 2023). Graduan perlu sentiasa melengkapkan diri dengan pelbagai kemahiran serta mempunyai sikap bersedia untuk belajar sesuatu yang baharu bagi memantapkan dan menyesuaikan diri dengan kerja yang ada (Othman & Hussin, 2019). Namun begitu, ketidaksepadanan ini memberikan penyesuaian kemahiran pekerja secara berterusan terhadap perubahan permintaan kerja membolehkan peluang untuk belajar di tempat kerja serta menerima latihan berterusan. Oleh itu, pembangunan dan ketidaksepadanan kemahiran harus dilihat dalam konteks keseluruhan kitaran hidup seseorang yang bekerja itu, di mana bermula dengan pembentukan kemahiran asas di pusat pengajian, diikuti oleh pengumpulan kemahiran praktikal dan umum yang berkaitan dengan pekerjaan, serta disokong dengan latihan semula dan mendapat kemahiran baharu selaras dengan perkembangan teknologi. Tambahan lagi graduan TVET sebenarnya adalah merupakan satu laluan yang jelas untuk pekerja mahir dan membolehkan perkerjaan teknikal diperolehi dan graduan inilah yang menyokong dalam pertumbuhan ekonomi negara. Dari perspektif majikan, mereka memerlukan graduan baru yang berkeyakinan diri dengan memiliki kebolehan dan kemahiran holistik serta personaliti bersopan santun. Secara keseluruhan, graduan baru memiliki pengetahuan asas yang mencukupi di bidang pengkhususan masing-masing, tetapi majikan mengutamakan graduan yang mudah dilatih dan

mampu mengadaptasi diri dengan pekerjaan mereka (Awang et al., 2012) Selain itu, cabaran pekerjaan graduan masa kini turut dinilai melalui penguasaan kemahiran insaniah. Pada masa kini, kebanyakan industri bukan sahaja menekankan kemahiran teknikal, tetapi juga memerlukan graduan yang memiliki kemahiran insaniah yang baik. Aspek kemahiran ini meliputi komunikasi, pemikiran kritis, membuat keputusan yang tepat, penyelesaian masalah, kepemimpinan, kerja berpasukan, serta pengurusan masa yang berkesan. Oleh itu, Mohd Ismail, (2024) menyarankan agar graduan untuk mempersiapkan diri dengan mengasah kemahiran insaniah sepanjang tempoh pengajian, agar dapat menguasai kemahiran-kemahiran ini secara tidak formal dan meningkatkan kebolehpasaran dalam pasaran kerja apabila tamat belajar nanti.

5. Kesimpulan

Secara keseluruhan, isu ketidaksepadanan pekerjaan dalam kalangan graduan, terutamanya lepasan institusi TVET seperti PTSB, kekal sebagai cabaran utama dalam usaha meningkatkan kebolehpasaran dan pengagihan modal insan secara efektif di Malaysia. Walaupun data menunjukkan kadar kebolehpasaran graduan berada pada tahap tinggi, iaitu dapat dilihat peningkatan daripada 89.8% pada tahun 2020 kepada 98.1% pada tahun 2025. Namun kadar kesepadanan masih kekal sederhana, dengan hampir separuh graduan masih bekerja dalam bidang yang tidak seiring dengan pengajian mereka. Kajian yang dijalankan melalui kaedah tinjauan terhadap graduan PTSB dari tahun 2020 hingga 2024 mengesahkan bahawa hanya sebahagian daripada graduan berjaya memperoleh pekerjaan yang benar-benar selari dengan bidang pengajian yang dipelajari. Daripada 3,666 responden yang menjawab soalan berkaitan kesepadanan, hanya 52.5% mengakui bekerja dalam bidang yang dipelajari, manakala 47.5% menyatakan sebaliknya iaitu tidak sepadan. Analisis berdasarkan jantina pula menunjukkan graduan perempuan secara konsisten mencatat kadar ketidaksepadanan yang lebih tinggi berbanding graduan lelaki, dengan jurang yang sedikit mengecil menjelang tahun 2024. Namun, faktor struktur seperti dominasi jantina dalam bidang teknikal, tanggungjawab sosial seperti penjagaan keluarga, kekangan mobiliti, serta persepsi terhadap persekitaran kerja turut memberi kesan ketara terhadap pemilihan kerjaya dalam kalangan graduan wanita. Ini mencerminkan keperluan mendesak untuk menyemak semula hala tuju kurikulum, memperkukuh kerjasama industri–institusi, dan memperluas inisiatif pembangunan kemahiran merentas bidang.

Institusi pendidikan harus berperanan aktif dalam mengurangkan ketidaksepadanan dengan menawarkan kandungan pembelajaran yang selaras dengan kehendak industri serta memberikan pendedahan tentang dunia pekerjaan kepada para pelajar. Pendekatan responsif ini penting dalam memastikan graduan dapat beradaptasi dengan perubahan dalam pasaran buruh, sekaligus membantu graduan mendapatkan pekerjaan yang sesuai dengan kemahiran dan kelayakan mereka. Selain daripada kerjasama industri, langkah-langkah lain perlu diambil sama ada di peringkat pembuat dasar atau pelaksana. Data dan maklumat yang tepat adalah penting untuk membantu dalam pembuatan keputusan berkaitan dasar pendidikan dan latihan. Institusi pendidikan pula harus mempersiapkan pelajar dengan kemahiran belajar yang baik, membolehkan graduan bertahan dalam persekitaran kerja yang berubah-ubah. Selain itu, penting untuk industri menerima graduan dari pelbagai bidang dan memastikan program pendidikan menghasilkan graduan yang seimbang dengan kemahiran yang diperlukan. Lebih penting lagi, pendekatan yang bersifat manusiawi dan inklusif perlu diberi perhatian. Di sebalik statistik dan peratusan ini, wujudnya individu atau graduan yang berusaha menyesuaikan diri dalam dunia kerja yang mencabar dan sering tidak menentu. Polisi perlu memberi tumpuan kepada pembangunan kemampuan pelajar untuk belajar, memandangkan masa depan dunia kerja sukar diramalkan. Peranan kerajaan lebih berfokus kepada menyediakan sokongan dan sumber bagi memudahkan penyelarasan antara graduan dan peluang pekerjaan yang ada. Melalui sokongan

yang tepat, seperti pameran kerjaya dan kaunseling, kerajaan dapat memainkan peranan yang signifikan dalam mengurangkan jurang antara graduan dan keperluan industri. Melalui inisiatif Pengukuhan kemahiran merentas bidang, bukan sahaja membantu mengurangkan impak negatif ketidaksepadanan pekerjaan, malah membina daya tahan kerjaya dan menjadikan graduan lebih bersedia dalam menghadapi masa depan pekerjaan yang kompleks. Ia bukan pilihan, tetapi satu keperluan strategik dalam membangunkan tenaga kerja yang mampan dan kompetitif. Sebagaimana penekanan Pertubuhan seperti World Economic Forum (WEF) dalam keperluan kemahiran abad ke-21 yang merentas semua sektor. Ini termasuk kemahiran digital, komunikasi, pemikiran analitis, dan empati sebagai pelengkap kepada pembangunan modal insan (World Economy Forum, 2020).

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KAJIAN TAHAP TUMPUAN PEMANDU TERHADAP KEHADIRAN PAPAN IKLAN DIGITAL DI JALAN RAYA

Saedah@Saedatulfirdaus binti Saárani

Civil Engineering Department, Sultan Azlan Shah Polytechnic, 35950 Behrang Stesen, Perak, Malaysia.

*Corresponding author e-mail address: saedatulfirdaus@psas.edu.my

Abstrak

Kajian ini bertujuan untuk menganalisis tahap gangguan visual yang berpunca daripada papan iklan digital terhadap tumpuan pemandu di jalan raya, khususnya di kawasan Lembah Klang. Dengan penggunaan papan iklan digital yang semakin meningkat di sepanjang jalan utama dan lebuh raya, isu keselamatan jalan raya menjadi semakin kritikal. Objektif utama kajian ini adalah untuk mengenal pasti tahap gangguan visual yang dialami oleh pemandu, menganalisis hubungan antara pendedahan kepada papan iklan digital dan perubahan tingkah laku pemanduan, serta mencadangkan langkah kawalan yang sesuai bagi mengurangkan risiko kemalangan. Kajian ini menggunakan kaedah kuantitatif melalui soal selidik yang diedarkan kepada 150 orang pemandu aktif. Data dianalisis menggunakan perisian Microsoft Excel bagi mendapatkan nilai min, sisihan piawai dan analisis korelasi Pearson. Dapatan menunjukkan bahawa nilai min bagi beberapa item melebihi 4.0, sekali gus menunjukkan tahap gangguan visual yang tinggi. Terdapat hubungan korelasi positif yang signifikan antara kecerahan papan iklan dan perubahan tingkah laku seperti menoleh dari jalan dan memperlahankan kenderaan. Selain itu, hasil kajian menunjukkan bahawa 80% responden bersetuju agar had kecerahan ditetapkan manakala 70% mencadangkan penjarakan iklan dari persimpangan jalan. Hasil analisis juga membuktikan bahawa kebanyakan responden memandu melalui kawasan iklan digital hampir setiap hari, menjadikan isu ini relevan dan mendesak. Kesimpulannya, kehadiran papan iklan digital mempunyai impak langsung terhadap konsentrasi pemanduan dan meningkatkan risiko gangguan keselamatan jalan raya. Kajian ini menyarankan agar garis panduan khusus berkaitan kecerahan, lokasi dan kandungan papan iklan digital digubal oleh pihak berwajib demi menjamin keselamatan pengguna jalan raya secara menyeluruh.
Kata kunci: Papan Iklan Digital; Gangguan Visual, Tumpuan Pemandu.

1. Pengenalan

Pengiklanan luar kini berkembang ke arah dimensi baharu yang lebih moden dan dinamik, sejajar dengan kemajuan teknologi paparan digital. Salah satu bentuk pengiklanan yang semakin dominan di kawasan bandar utama seperti Lembah Klang ialah papan iklan digital, yang dipasang di sepanjang lebuh raya, jalan utama dan persimpangan trafik yang sibuk. Berbanding papan iklan konvensional, iklan digital memaparkan kandungan yang terang, bergerak, dan kerap berubah kandungannya menjadikannya alat komunikasi visual yang amat berkesan dalam menarik perhatian orang ramai, terutamanya pemandu yang sedang menggunakan jalan raya. Kandungan yang dipaparkan boleh dikawal dari jarak jauh dan disesuaikan mengikut masa, lokasi, atau sasaran khalayak. Oleh itu, papan iklan digital menjadi pilihan utama dalam strategi pemasaran korporat dan komersial masa kini. Namun begitu, penggunaan meluas media iklan ini menimbulkan kebimbangan berkaitan keselamatan jalan raya, khususnya apabila tahap kecerahan melampau atau kandungan visual yang berubah secara pantas berpotensi mengganggu fokus pemanduan. Kemalangan jalan raya di Malaysia menunjukkan angka yang

yang semakin membimbangkan. Menurut statistik dari Institut Penyelidikan Keselamatan Jalan Raya Malaysia (MIROS, 2023), pemandu sering terdedah kepada gangguan visual semasa memandu, sama ada disebabkan oleh telefon bimbit, persekitaran, atau unsur-unsur lain yang merangsang perhatian mereka. Salah satu faktor lain yang semakin jelas kini adalah papan iklan digital yang memancarkan cahaya terang dan bergerak, yang berpotensi mengganggu tumpuan pemandu, terutamanya di kawasan jalan raya utama yang sibuk juga di persimpangan.

Pemandu memerlukan perhatian penuh terhadap suasana sekeliling termasuk kenderaan lain, papan tanda keselamatan dan pergerakan pejalan kaki. Kehadiran papan iklan digital yang terlalu terang, berkelip atau terlalu dekat dengan simpang jalan boleh menarik perhatian pemandu dan menyebabkan mereka menoleh keluar daripada tumpuan pemanduan mereka. Gangguan seperti ini mungkin hanya beberapa saat, namun cukup untuk meningkatkan risiko kemalangan, terutamanya dalam situasi lalu lintas padat atau semasa hujan dan waktu malam. Berdasarkan keperluan untuk menyeimbangkan antara keperluan pengiklanan dan keselamatan pengguna jalan raya, kajian ini dijalankan dengan tiga objektif utama. Pertama ialah untuk mengenal pasti tahap gangguan visual yang disebabkan oleh papan iklan digital terhadap pemandu, khususnya dalam konteks visual yang terang dan kandungan yang kerap berubah. Kedua ialah untuk menganalisis hubungan antara tahap pendedahan kepada papan iklan digital dengan perubahan dalam kelakuan pemanduan, seperti memperlahankan kenderaan, hilang fokus atau menoleh dari jalan. Ketiga adalah untuk mencadangkan langkah kawalan atau penambahbaikan terhadap pemasangan papan iklan digital, seperti dari aspek lokasi, masa operasi, dan had kecerahan, demi meningkatkan tahap keselamatan di jalan raya.



Rajah 1. Papan Iklan Digital di Jalan Semangat (PJ33), Petaling Jaya

Kajian ini memberi tumpuan khusus kepada pemandu yang kerap menggunakan jalan raya di kawasan Lembah Klang dan dijalankan menggunakan pendekatan kuantitatif melalui edaran soal selidik. Dapatan kajian ini diharapkan dapat menjadi rujukan penting kepada pihak berkuasa tempatan, perancang bandar dan industri pengiklanan dalam usaha menggubal dasar dan garis panduan yang mengimbangi antara keberkesanan promosi dan keutamaan keselamatan awam.

Wickens (2008) mencadangkan bahawa manusia menggunakan sumber berbeza untuk memproses maklumat visual, audio dan manual. Apabila papan iklan digital bersaing untuk perhatian visual pemandu, ia mengganggu sumber visual utama yang sepatutnya digunakan untuk memantau jalan raya. Manakala Teori Beban Kognitif oleh Sweller (1988) menyatakan bahawa manusia mempunyai kapasiti terhad dalam memproses maklumat. Apabila pemandu terdedah kepada maklumat visual yang berlebihan, seperti papan iklan digital yang terang dan bergerak, beban kognitif meningkat, mengakibatkan penurunan fokus terhadap tugas utama iaitu pemanduan.

Menurut MIROS (2023), gangguan visual daripada papan iklan digital di lebuh raya utama seperti Lebuhraya Damansara-Puchong (LDP) dikaitkan dengan peningkatan kadar kemalangan kecil, terutamanya di kawasan susur keluar dan persimpangan. Laporan Jabatan Kerajaan Tempatan (2018) turut menyatakan bahawa terdapat keperluan mendesak untuk mengawal aspek kecerahan dan kandungan visual papan iklan digital di kawasan berisiko tinggi.

Antara isu utama yang dikenal pasti adalah ketiadaan standard nasional yang seragam untuk kecerahan dan kadar perubahan paparan papan iklan digital. Persaingan komersial menyebabkan iklan menjadi semakin menarik secara berlebihan, sekali gus meningkatkan potensi gangguan visual. Penguatkuasaan terhad oleh pihak berkuasa tempatan terhadap syarat pemasangan papan iklan digital.

2. Metodologi

Kajian ini menggunakan kaedah pengumpulan data, instrumen kajian, prosedur kajian, dan kaedah analisis data. Kajian ini dijalankan bagi menilai tahap gangguan visual terhadap pemandu akibat papan iklan digital dan hubungannya dengan perubahan kelakuan pemanduan. Kajian ini juga bertujuan untuk mencadangkan langkah-langkah kawalan terhadap pemasangan papan iklan digital demi keselamatan pengguna jalan raya. Populasi kajian terdiri daripada pemandu kenderaan berlesen yang menggunakan jalan raya dan lebuhraya Lembah Klang. Sampel melibatkan 150 orang responden yang aktif menggunakan laluan tersebut sekurang-kurangnya dua kali seminggu.

Instrumen kajian ialah soal selidik yang dibina berdasarkan tiga objektif kajian. Item pertama adalah menilai persepsi tahap gangguan visual seperti kecerahan berlebihan, animasi bergerak, dan saiz papan iklan. Item kedua adalah berkaitan kelakuan pemanduan seperti memperlahankan kenderaan, menoleh dari jalan, mengedipkan mata berulang kerana silau (waktu malam) atau hilang fokus. Item ketiga adalah cadangan kawalan, seperti penetapan had kecerahan dan larangan di kawasan tertentu.



Rajah 2. Lokasi kajian 1, Jalan Semangat (PJ33), Petaling Jaya



Rajah 3. Lokasi kajian 2, Seksyen 13, Shah Alam



Rajah 4. Lokasi kajian 3, Lebuhraya SPRINT



Rajah 5. Lokasi kajian 4, Lebuhraya Persekutuan, Kuala Lumpur



Rajah 6. Lokasi kajian 5, Jalan Pudu, Kuala Lumpur

Semua item diukur menggunakan skala Likert lima mata (1 = Sangat Tidak Setuju hingga 5 = Sangat Setuju), kecuali bahagian cadangan yang memerlukan responden memberi maklum balas cadangan. Data dikumpulkan melalui edaran soal selidik secara dalam talian (Google Forms) dan secara fizikal di kawasan parkir dan stesen minyak di Lembah Klang. Setiap responden diberikan masa sekitar 10 minit untuk melengkapkan soal selidik. Kerahsiaan dan persetujuan dimaklumkan kepada semua responden sebelum soal selidik diedarkan.

Kaedah Analisis Data adalah menggunakan Excel. Item menganalisis Tahap Gangguan Visual adalah menggunakan Fungsi =AVERAGE() dan =STDEV.S(). Ianya untuk mendapatkan nilai min dan sisihan piawai bagi item berkaitan gangguan visual. Item menganalisis Hubungan Pendedahan dan kelakuan pemanduan adalah menggunakan Fungsi =CORREL(range1, range2). Ianya digunakan untuk mengukur kekuatan hubungan antara dua pemboleh ubah. Nilai signifikan (p-value) dikira menggunakan formula t dan =TDIST(). Item menganalisis Langkah Kawalan adalah data dianalisis secara deskriptif untuk melihat kekerapan cadangan serta tema utama dalam jawapan terbuka. Analisis deskriptif dilakukan terhadap item cadangan dengan =COUNTIF() dan =COUNT() dalam Excel.

3. Keputusan dan Perbincangan

Hasil analisis data yang diperolehi melalui soal selidik yang diedarkan kepada 150 orang pemandu berlesen di kawasan Lembah Klang. Analisis ini dibahagikan kepada tiga bahagian iaitu profil demografi responden, kekerapan pendedahan kepada papan iklan digital dan hubungan antara papan iklan digital dengan tahap gangguan tumpuan semasa memandu.

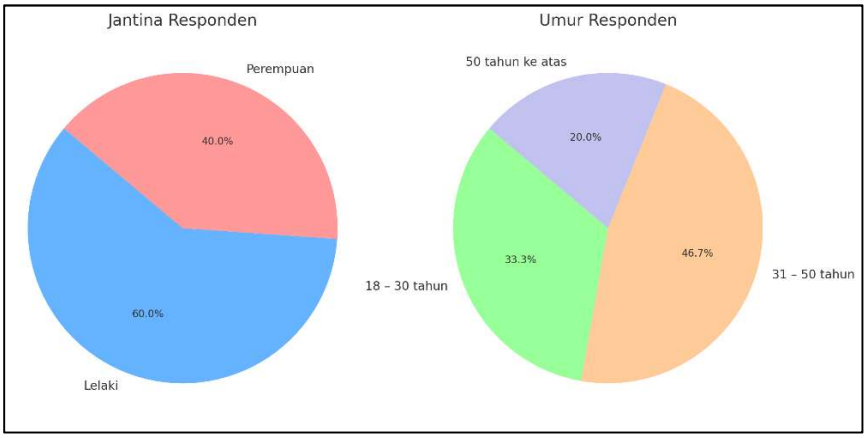
3.1 Profil Responden

Analisis profil responden dilakukan menggunakan fungsi COUNTIF() dan =COUNTA() dalam Excel untuk menghasilkan bilangan dan peratusan setiap kategori demografi.

Jadual 1. Profil Demograf Responden

Jantina	Bilangan (n)	Peratusan (%)
Lelaki	90	60%
Perempuan	60	40%
Umur	**Bilangan (n)**	**Peratusan (%)**
18 – 30 tahun	50	33.3%

31 – 50 tahun	70	46.7%
50 tahun ke atas	30	20.0%



Rajah 7. Profil Demograf Responden

Analisis menunjukkan bahawa majoriti responden dalam kajian ini terdiri daripada golongan lelaki, iaitu sebanyak 90 orang (60%), manakala selebihnya ialah perempuan seramai 60 orang (40%). Keputusan ini memberi gambaran bahawa pandangan lelaki dalam aspek gangguan visual akibat papan iklan digital lebih dominan dalam dapatan kajian ini. Justeru, sebarang interpretasi berkaitan tingkah laku dan tumpuan pemanduan perlu mempertimbangkan dominasi responden lelaki dalam sampel ini. Dari aspek umur pula, kumpulan umur 31 hingga 50 tahun merupakan majoriti, merangkumi 70 orang (46.7%). Ini diikuti oleh kumpulan umur 18 hingga 30 tahun seramai 50 orang (33.3%), dan 50 tahun ke atas seramai 30 orang (20%). Keputusan ini menunjukkan bahawa responden yang berada dalam lingkungan umur bekerja aktif (dewasa pertengahan) merupakan penyumbang utama data, yang logiknya lebih kerap berada di jalan raya dan terdedah kepada pengaruh visual iklan digital. Hal ini penting kerana kumpulan umur ini biasanya mempunyai tanggungjawab mobiliti harian yang tinggi dan lebih berpengalaman dalam konteks pemanduan.

3.2 Lokasi Kajian dan Kekerapan Pemanduan Melalui Kawasan Papan Iklan Digital

Kajian ini dilaksanakan di lima kawasan strategik di Lembah Klang yang terkenal dengan kepadatan trafik serta kehadiran papan iklan digital yang terang dan bersifat dinamik. Lokasi-lokasi ini dipilih bagi mewakili pelbagai situasi lalu lintas di kawasan bandar utama, yang memberi kesan langsung terhadap pengalaman visual pemandu.

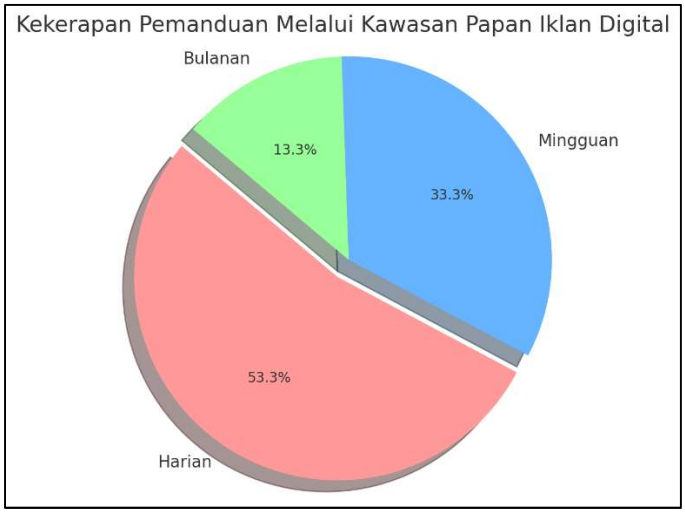
Jadual 2. Lokasi Kajian

Lokasi Kajian	Nama Jalan	Justifikasi Pemilihan
1	Jalan Semangat(PJ33), Petaling Jaya	Laluan komersial utama yang sentiasa sibuk dengan aliran trafik yang padat.
2	Seksyen 13, Shah Alam	Kawasan perindustrian dan rekreasi dengan trafik pelbagai jenis kenderaan.
3	Lebuhraya SPRINT	Lebuh raya utama yang menghubungkan kawasan Damansara ke pusat bandar.
4	Lebuhraya Persekutuan, Kuala Lumpur	Laluan utama penghubung antara Kuala Lumpur dan Petaling Jaya
5	Jalan Pudu, Kuala Lumpur	Kawasan pusat bandar dan sentiasa sibuk dengan aliran trafik pelbagai.

Lima lokasi kajian dijalankan di sekitar Lembah Klang yang mewakili kawasan dengan aliran trafik tinggi dan kepadatan papan iklan digital. Jalan Semangat (PJ33), Petaling Jaya dipilih kerana merupakan laluan komersial utama yang sentiasa sibuk. Seksyen 13, Shah Alam pula merangkumi kawasan perindustrian dan rekreasi dengan pelbagai jenis kenderaan melaluinya. Lebuhraya SPRINT berfungsi sebagai penghubung utama antara Damansara dan pusat bandar, manakala Lebuhraya Persekutuan merupakan laluan penting yang menghubungkan Kuala Lumpur dan Petaling Jaya dengan trafik yang sangat padat. Jalan Pudu, terletak di tengah pusat bandar Kuala Lumpur, sering mengalami kesesakan lalu lintas pelbagai jenis kenderaan. Kesemua lokasi ini dipilih kerana berpotensi tinggi untuk memberi kesan terhadap tumpuan pemandu akibat kehadiran papan iklan digital.

Jadual 3. Kekerapan Pemanduan Melalui Kawasan Papan Iklan Digital

Kekerapan	Bilangan (n)	Peratusan (%)
Harian	80	53.3%
Mingguan	50	33.3%
Bulanan	20	13.3%



Rajah 8. Kekerapan Pemanduan Melalui Kawasan Papan Iklan Digital

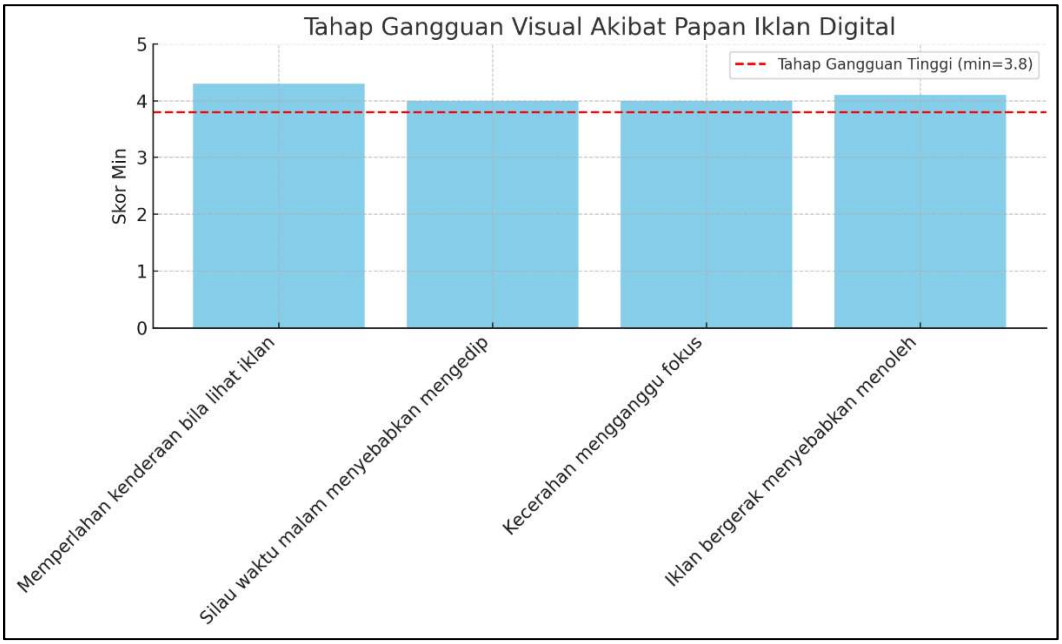
Hasil dapatan menunjukkan bahawa majoriti responden memandu melalui kawasan yang mempunyai papan iklan digital secara harian, iaitu seramai 80 orang (53.3%). Ini diikuti oleh responden yang memandu mingguan sebanyak 50 orang (33.3%), manakala hanya 20 orang (13.3%) yang memandu secara bulanan melalui kawasan tersebut. Keputusan ini menunjukkan bahawa lebih separuh daripada responden terdedah secara kerap kepada papan iklan digital di jalan raya. Justeru, pengalaman mereka terhadap potensi gangguan visual adalah lebih relevan dan signifikan dalam menilai kesan sebenar terhadap tumpuan semasa memandu. Hal ini sekaligus memperkukuh justifikasi kajian ini bahawa gangguan visual daripada iklan digital merupakan isu yang wajar ditangani segera, terutamanya bagi pemandu tetap di kawasan bandar seperti Lembah Klang.

3.3 Analisis Tahap Gangguan Visual Akibat Papan Iklan Digital

Tahap Gangguan Visual Min dan sisihan piawai dikira menggunakan = AVERAGE(range) dan =STDEV.S(range) dalam Excel.

Jadual 4. Tahap Gangguan Visual Akibat Papan Iklan Digital

Item Pernyataan	Min	Sisihan Piawai
Saya akan memperlahankan kenderaan ketika melihat papan iklan digital.	4.3	0.65
Papan iklan digital di waktu malam menyilaukan mata menyebabkan saya mengedipkan mata berulang	4.0	0.74
Kecerahan yang tinggi mengganggu fokus pemanduan saya.	4.0	0.74
Iklan bergerak menyebabkan saya menoleh dari tumpuan pemanduan	4.1	0.72



Rajah 9. Profil Tahap Gangguan Visual Akibat Papan Iklan Digital

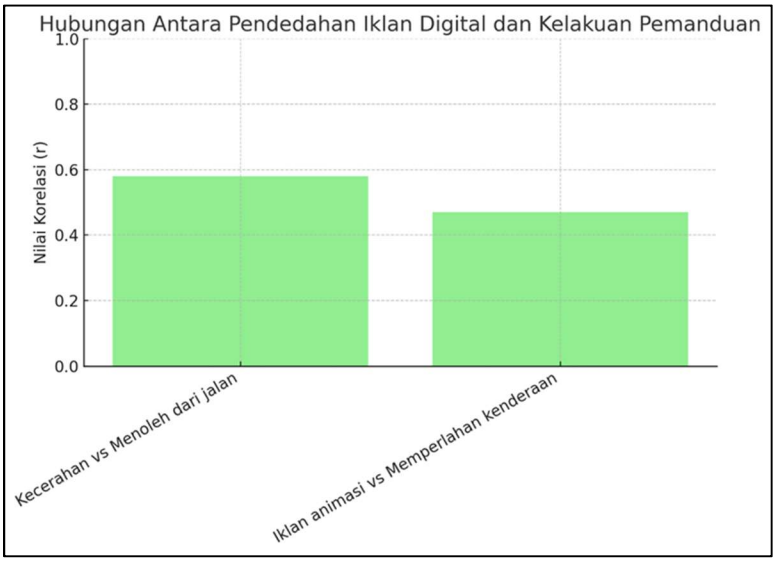
Dapatan kajian menunjukkan bahawa tahap gangguan visual akibat papan iklan digital berada pada tahap yang tinggi berdasarkan nilai min bagi keempat-empat pernyataan yang melebihi 4.0. Item pertama, "Saya akan memperlahankan kenderaan ketika melihat papan iklan digital", mencatatkan nilai min tertinggi iaitu 4.3 dengan sisihan piawai 0.65, menunjukkan bahawa sebahagian besar responden secara konsisten terkesan hingga memperlahankan kenderaan mereka apabila melalui kawasan dengan papan iklan digital. Pernyataan kedua dan ketiga, yang masing-masing menyentuh tentang kecerahan iklan digital yang menyilaukan pada waktu malam dan gangguan terhadap fokus pemanduan, mencatatkan nilai min yang sama iaitu 4.0, dengan sisihan piawai 0.74. Ini memperlihatkan bahawa elemen pencahayaan memainkan peranan besar dalam mengganggu tumpuan pemandu. Sementara itu, pernyataan "Iklan bergerak menyebabkan saya menoleh dari tumpuan pemanduan" pula mencatatkan nilai min 4.1, membuktikan bahawa pergerakan animasi dalam paparan digital sememangnya menarik perhatian pemandu daripada jalan raya. Kesemua dapatan ini menegaskan bahawa papan iklan digital berupaya mengalihkan perhatian pemandu secara signifikan, sekali gus meningkatkan risiko terhadap keselamatan jalan raya.

3.4 Analisis Hubungan antara Pendedahan dan Kelakuan Pemanduan

Hubungan antara Pendedahan dan Kelakuan Pemanduan Korelasi Pearson dikira menggunakan =CORREL(range1, range2) dalam Excel, melibatkan item kecerahan dan kelakuan pemanduan. Formula t dan p-value dikira secara manual menggunakan rumus statistic.

Jadual 5. Hubungan antara Pendedahan dan Kelakuan Pemanduan

Pembolehubah	Korelasi (r)	t	Pembolehubah	Korelasi (r)
Kecerahan papan iklan vs Menoleh dari tumpuan pemanduan	0.58	8.13	150	<0.001
Iklan animasi vs Memperlahan kenderaan	0.47	6.24	150	<0.001



Rajah 10. Profil Hubungan antara Pendedahan dan Kelakuan Pemanduan

Keputusan pembolehubah yang pertama terdapat hubungan positif yang sederhana kuat dan signifikan antara tahap kecerahan papan iklan digital dan kecenderungan pemandu untuk menoleh dari tumpuan jalan. Ini bermaksud, semakin cerah papan iklan, semakin tinggi kemungkinan pemandu terganggu dan menoleh dari fokus utama semasa memandu. Hasil analisis pembolehubah yang kedua menunjukkan terdapat hubungan positif yang signifikan antara kehadiran animasi pada papan iklan digital dengan kelakuan pemandu memperlahankan kenderaan. Ini mencadangkan bahawa pergerakan atau perubahan visual dalam iklan memberi kesan langsung kepada tingkah laku pemanduan.

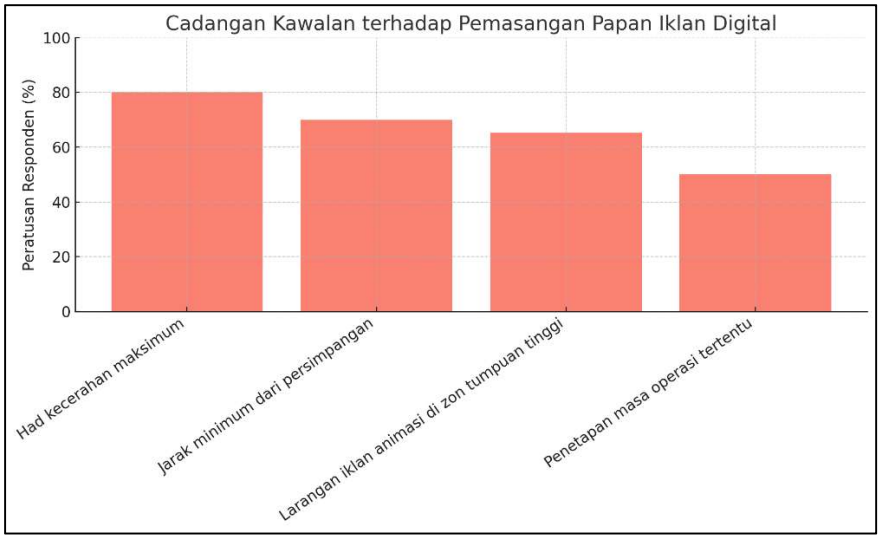
3.5 Cadangan Langkah Kawalan

Analisis deskriptif dilakukan terhadap item cadangan dengan =COUNTIF() dan =COUNT() dalam Excel.

Jadual 6. Cadangan Langkah Kawalan

Cadangan Langkah Kawalan	Bilangan Responden	Peratus (%)
Had kecerahan maksimum ditetapkan	120	80%
Jarak minimum iklan dari persimpangan	105	70%
Larangan iklan animasi di zon tumpuan tinggi	98	65%
Penetapan masa operasi tertentu	75	50%

Berdasarkan dapatan kajian terhadap 150 responden, beberapa langkah kawalan telah dicadangkan oleh pemandu bagi mengurangkan gangguan visual yang berpunca daripada papan iklan digital di jalan raya. Pemandu boleh mencadangkan tiga atau sekurang-kurangnya satu cadangan.



Rajah 11. Cadangan Kawalan Terhadap Pemasangan Papan Iklan Digital

Analisis deskriptif menunjukkan empat cadangan utama yang telah dikenalpasti. Sebanyak 80% responden bersetuju bahawa papan iklan digital perlu dikawal dari segi tahap kecerahan. Ini menunjukkan keprihatinan tinggi dalam kalangan pemandu terhadap silau yang dihasilkan oleh cahaya terlalu terang, terutamanya pada waktu malam. Cadangan ini juga sejajar dengan kajian lepas yang menyatakan bahawa kecerahan yang berlebihan boleh menyebabkan gangguan tumpuan secara langsung. Sebanyak 70% responden mencadangkan agar papan iklan tidak diletakkan terlalu hampir dengan persimpangan jalan. Pemandu perlu memberi tumpuan penuh kepada isyarat trafik dan perubahan laluan di persimpangan, dan kehadiran papan iklan berhampiran lokasi ini boleh menyebabkan gangguan fokus dan meningkatkan risiko pelanggaran atau kemalangan. Sebanyak 65.3% responden menyarankan supaya iklan animasi dihadkan atau dialihkan dari kawasan tumpuan tinggi seperti simpang empat, sekolah, hospital, dan kawasan padat. Kandungan yang bergerak atau berubah-ubah secara pantas berpotensi menarik perhatian pemandu secara tidak sengaja dan mengalihkan tumpuan daripada jalan. Sebanyak responden 50%, mencadangkan agar operasi papan iklan digital hanya dibenarkan pada waktu tertentu sahaja, contohnya tidak melebihi jam 10 malam. Ini bagi mengelakkan gangguan pada waktu malam ketika penglihatan pemandu adalah terhad dan keletihan memandu lebih tinggi.

4. Kesimpulan

Dapatan ini menggambarkan kesedaran tinggi dalam kalangan pemandu terhadap potensi gangguan visual papan iklan digital dan pentingnya kawalan yang lebih ketat. Cadangan yang dikemukakan ini boleh dijadikan asas oleh pihak berkuasa tempatan, MIROS, dan Kementerian Pengangkutan dalam menggubal dasar pemasangan papan iklan digital secara lebih selamat, strategik dan mesra pengguna jalan raya.

Kajian ini telah berjaya menganalisis tahap gangguan visual yang disebabkan oleh papan iklan digital terhadap tumpuan pemandu di kawasan Lembah Klang, dengan tumpuan khusus kepada aspek kekerapan pendedahan, reaksi tingkah laku pemandu, dan cadangan kawalan bagi menjamin keselamatan jalan raya. Dapatan kajian menunjukkan bahawa majoriti responden (60%) terdiri daripada pemandu lelaki, dan kebanyakan mereka berada dalam lingkungan umur 31 hingga 50 tahun (46.7%), iaitu kumpulan yang aktif memandu dalam persekitaran bandar dan lebuh raya. Tambahan pula, lebih separuh responden (53.3%) memandu secara harian melalui

kawasan papan iklan digital, memberikan petunjuk bahawa gangguan visual daripada iklan ini merupakan satu pendedahan yang konsisten dan berulang.

Analisis terhadap tahap gangguan visual menunjukkan bahawa nilai min bagi semua item melebihi 4.0, yang mencerminkan bahawa gangguan visual adalah pada tahap tinggi. Responden melaporkan bahawa kecerahan, animasi bergerak dan perubahan kandungan iklan telah memberi kesan seperti menoleh dari jalan, memperlahankan kenderaan, dan mengedipkan mata kerana silau, terutamanya pada waktu malam. Ini menjelaskan bagaimana maklumat visual berlebihan boleh mengganggu fokus pemandu. Analisis korelasi pula membuktikan adanya hubungan signifikan yang positif antara elemen visual papan iklan digital dengan perubahan tingkah laku pemanduan. Contohnya, terdapat korelasi sederhana ke tinggi ($r = 0.58$) antara kecerahan papan iklan dan kecenderungan pemandu untuk menoleh dari tumpuan jalan, serta korelasi $r = 0.47$ antara iklan animasi dan kelakuan memperlahankan kenderaan. Nilai signifikan $p < 0.001$ dalam kedua-dua kes menyokong hipotesis bahawa gangguan visual dari papan iklan digital benar-benar mempengaruhi kelakuan pemanduan. Tambahan lagi, responden memberikan cadangan kawalan yang jelas dan praktikal, termasuklah penetapan had kecerahan maksimum (80%), penjarakan iklan dari persimpangan (70%), larangan animasi di zon tumpuan tinggi (65.3%), dan masa operasi tertentu (50%). Cadangan ini mencerminkan kesedaran masyarakat terhadap isu keselamatan yang mungkin timbul dan keperluan untuk peraturan yang lebih jelas dalam pemasangan papan iklan digital. Kajian ini turut melibatkan lima lokasi strategik yang mewakili pelbagai jenis persekitaran lalu lintas iaitu dari laluan komersial, lebuh raya utama hingga ke kawasan pusat bandar. Ini memberikan validiti kontekstual yang tinggi dalam menilai kesan sebenar papan iklan digital terhadap pelbagai jenis pengguna jalan raya.

Secara keseluruhannya, kajian ini mengesahkan bahawa papan iklan digital memberi impak yang signifikan terhadap tumpuan pemandu, terutamanya dari segi gangguan visual akibat elemen-elemen paparan yang terang, bergerak dan berubah-ubah. Kesan ini terbukti melalui nilai min yang tinggi, korelasi yang signifikan, dan cadangan konkrit daripada responden. Penemuan ini memberi implikasi penting kepada penggubal dasar, pihak berkuasa tempatan, dan syarikat pengiklanan untuk menilai semula garis panduan pemasangan papan iklan digital. Langkah kawalan seperti penetapan kecerahan maksimum, lokasi strategik, dan pengawalan masa paparan perlu diambil kira untuk menjamin keselamatan pengguna jalan raya secara menyeluruh.

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HUBUNGAN ANTARA KEFAHAMAN DAN PENGAMALAN NILAI MURNI PELAJAR KURSUS PENGHAYATAN ETIKA DAN PERADABAN DI POLITEKNIK IBRAHIM SULTAN

Adilah Hafizah binti Abd Halim

Jabatan Pengajian Am, Politeknik Ibrahim Sultan, 81700 Pasir Gudang, Johor, Malaysia

*Corresponding author e-mail address: adilah@pis.edu.my

Abstrak

Nilai murni merupakan asas penting dalam pembentukan akhlak mulia dan perlu diterapkan secara menyeluruh dalam diri setiap individu, khususnya pelajar institusi pendidikan tinggi. Kajian ini dijalankan untuk menilai hubungan antara tahap kefahaman dan pengamalan nilai murni dalam kalangan pelajar yang mengikuti kursus Penghayatan Etika dan Peradaban (PEP) di Politeknik Ibrahim Sultan. Kajian ini dilaksanakan secara kuantitatif melalui reka bentuk tinjauan menggunakan instrumen soal selidik yang dikongsikan secara dalam talian melalui platform *Google Form*. Seramai 144 orang pelajar daripada tiga jabatan utama telah dipilih secara rawak sebagai responden kajian. Data yang dikumpul dianalisis menggunakan perisian Statistical Package for the Social Sciences (SPSS) versi 27. Dapatan kajian menunjukkan bahawa tahap kefahaman nilai murni (min = 4.59) dan pengamalan nilai murni (min = 4.51) dalam kalangan pelajar berada pada tahap tinggi. Analisis korelasi Pearson mendapati wujud hubungan positif yang signifikan antara kefahaman dan pengamalan nilai murni ($r = 0.686$, $p < 0.01$). Hasil kajian ini membuktikan bahawa kefahaman yang tinggi terhadap nilai murni melalui kursus Penghayatan Etika dan Peradaban dapat mendorong pengamalan nilai tersebut dalam kehidupan pelajar. Kajian lanjutan dengan skop sampel yang lebih luas disarankan agar dapatan dapat digeneralisasikan dan dijadikan asas penambahbaikan kurikulum di Institusi Pengajian Tinggi pada masa hadapan.
Kata Kunci: Hubungan; Nilai murni; Penghayatan Etika; Peradaban.

1. Pendahuluan

Pendidikan dan latihan teknikal dan vokasional (TVET) bukan sekadar menekankan penguasaan kemahiran teknikal semata-mata, malah turut memberi penekanan kepada pembentukan sahsiah, etika dan nilai murni yang kukuh. Dalam konteks ini, pembangunan insan yang holistik merupakan antara objektif utama politeknik sebagai institusi TVET yang berperanan melahirkan graduan yang bukan sahaja kompeten dalam bidang masing-masing, malah memiliki keperibadian yang berintegriti dan beretika tinggi.
Teras strategik Jabatan Pendidikan Politeknik dan Kolej Komuniti (JPPKK) merujuk kepada teras utama yang menjadi panduan dalam mencapai visi dan misi JPPKK sebagai peneraju utama dalam pendidikan TVET. Teras strategik ini menjadi asas kepada perancangan dan pelaksanaan program serta aktiviti JPPKK, selaras dengan Pelan Strategik Politeknik dan Kolej Komuniti.

Justeru, selaras dengan Teras Strategik Pertama JPPKK, iaitu Menghasilkan Graduan TVET yang Berkualiti, aspek nilai murni dan penghayatannya dalam kalangan pelajar perlu diberikan perhatian sewajarnya. Kualiti graduan TVET yang berkualiti bukan sahaja dilihat dari segi kelayakan teknikal, tetapi juga daripada keperibadian mereka melalui ciri-ciri peribadi seperti integriti, tanggungjawab, amanah, hormat-menghormati dan kerjasama. Nilai-nilai ini amat

penting dalam membina budaya kerja profesional yang menjadi keperluan utama industri masa kini.

Kursus PEP merupakan kursus wajib yang ditawarkan di politeknik merupakan salah satu langkah untuk menyokong pelaksanaan teras strategik ini. Kursus ini bertujuan memperkukuhkan kefahaman pelajar terhadap konsep nilai murni dan menggalakkan pengamalannya dalam kehidupan seharian dan alam pekerjaan. Namun begitu, aras kefahaman dan pengamalan nilai murni dalam kalangan pelajar masih perlu dikaji untuk menilai keberkesanan kursus ini dan kesediaan pelajar untuk menjadi graduan TVET yang holistik dari segi intelek mahupun sahsiah.

Justeru, kajian ini bermatlamatkan untuk menilai hubungan antara tahap kefahaman dan pengamalan nilai murni dalam kalangan pelajar Politeknik Ibrahim Sultan melalui pelaksanaan kursus PEP. Dapatan kajian ini diharap dapat menawarkan input bermakna kepada pensyarah dan pihak pengurusan dalam merancang pendekatan pengajaran yang lebih berfokus dan menyeluruh, seterusnya menyumbang ke arah penghasilan graduan TVET yang benar-benar berkualiti seperti yang digariskan dalam pelan strategik JPPKK.

1.1 Objektif Kajian

Kajian ini secara umumnya mempunyai dua (2) objektif utama iaitu:

a. Menilai tahap kefahaman serta penghayatan nilai murni dalam kalangan pelajar melalui pelaksanaan kursus PEP.
b. Mengenal pasti hubungan antara tahap kefahaman dan pengamalan nilai murni dalam kalangan pelajar yang mengikuti kursus PEP.

1.2 Kajian Literatur

Nilai murni memainkan peranan penting dalam pembinaan sahsiah pelajar di institusi pendidikan tinggi. Menurut Othman (2014), integrasi nilai murni dalam pengajaran Bahasa Melayu mampu memberi impak positif terhadap penghayatan nilai dalam kalangan pelajar, membuktikan kepentingan pendidikan nilai perlu disepadukan secara berkesan dalam kurikulum. Hal ini disokong dan diperkuat oleh kajian Sabilan et al. (2018) yang menekankan kepentingan penerapan dan penghayatan nilai murni berdasarkan Falsafah Pendidikan Kebangsaan (FPK) sebagai asas pembangunan insan yang holistik merangkumi aspek intelek, emosi, rohani dan jasmani.

Kajian oleh Jaafar dan Tahir (2017) mendapati kursus Tamadun Islam dan Tamadun Asia (TITAS) mampu memupuk pengamalan nilai murni serta membentuk sahsiah pelajar politeknik ke arah lebih beretika dan bekeperibadian mulia. Dapatan ini seiring dengan kajian oleh Rosli, Mahadi dan Mohamad (2023) yang menunjukkan bahawa pemahaman nilai murni menerusi kursus PEP mendorong pelajar untuk mengamalkan nilai-nilai tersebut dalam kehidupan seharian.

Melalui kajian oleh Saad (2021) pula meninjau pandangan pelajar terhadap pelaksanaan kursus PEP di Politeknik Sultan Abdul Halim Muadzam Shah (POLIMAS), menunjukkan tahap penerimaan yang baik dan kesedaran tinggi tentang kepentingan nilai murni dalam pembentukan sahsiah. Tambahan pula, Talib, Abd Halim dan Shafie (2018) menegaskan bahawa kefahaman agama Islam dan penghayatan akhlak memainkan peranan penting dalam membina nilai diri pelajar baharu di politeknik, sekali gus memperkukuh peranan nilai murni sebagai asas pendidikan.

Selain itu, Hassan et al. (2020) dalam sorotan literatur mereka pula turut merumuskan bahawa tahap kefahaman penuntut institusi pengajian tinggi terhadap nilai etika dan moral secara keseluruhannya berada pada tahap sederhana hingga tinggi. Namun dapatan kajian menyarankan agar penambahbaikan berterusan dilaksanakan supaya pelajar benar-benar menghayati nilai tersebut dalam tindakan dan tingkah laku mereka.

Secara keseluruhan, sorotan literatur ini mengukuhkan pandangan bahawa kefahaman nilai murni yang mendalam, khususnya melalui kursus yang berteraskan etika dan peradaban, mampu meningkatkan tahap pengamalan nilai dalam kalangan pelajar politeknik. Justeru, kajian ini dibangunkan untuk menilai hubungan antara kefahaman dan pengamalan nilai murni dalam kalangan pelajar Politeknik Ibrahim Sultan sebagai usaha memperkasa pembangunan sahsiah dan melahirkan graduan TVET yang seimbang dan berkualiti.

2. Metodologi

Kajian ini menggunakan pendekatan kuantitatif dengan reka bentuk kajian tinjauan dan data dikumpul melalui borang soal selidik yang disebarkan menggunakan platform *Google Form.* Kajian ini melibatkan pelajar yang mengikuti kursus Penghayatan Etika dan Peradaban (PEP) di Politeknik Ibrahim Sultan merangkumi tiga jabatan pengajian iaitu Jabatan Kejuruteraan Mekanikal (JKM), Jabatan Pelancongan dan Hospitaliti (JPH) dan Jabatan Rekabentuk dan Komunikasi Visual (JRKV). Kaedah persampelan rawak digunakan bagi menentukan sampel kajian yang terdiri daripada 144 responden kajian. Penetapan saiz sampel kajian ini ditetapkan berpandukan kepada kerangka panduan penentuan saiz sampel yang dicadangkan oleh Krejcie dan Morgan (1970).

Instrumen soal selidik yang digunakan dalam kajian ini diadaptasi daripada kajian yang dijalankan oleh Rosli, Mahadi dan Mohamad (2023). Instrumen kajian terdiri daripada dua konstruk iaitu (a) konstruk kefahaman nilai murni yang mengandungi 8 item dan (b) konstruk pengamalan nilai murni yang mengandungi 9 item. Setiap item yang dibina dinilai menggunakan persetujuan lima skala Likert berdasarkan skala sangat tidak setuju (STS), tidak setuju (TS), tidak pasti (TP), setuju (S) dan sangat setuju (SS).

Maklumat profil responden seperti jantina, umur dan jabatan pengajian turut ditanya dalam soal selidik. Data hasil soal selidik dianalisis dan diproses menggunakan sistem perisian Statistical Package for the Social Science (SPSS) versi 27. Bagi menilai paras kefahaman dan pengamalan nilai murni pelajar, penghuraian dilakukan berdasarkan skala penentuan julat skor yang dibangunkan oleh Bahman dan Turiman (1999), serta dirumuskan mengikut saranan Nunally (1978) seperti yang ditunjukkan dalam Jadual 1.

Jadual 1. Interpretasi Skala Min

Skala Min	Interpretasi
1.00 hingga 2.00	Rendah
2.01 hingga 3.00	Sederhana
3.01 hingga 4.00	Tinggi
4.01 hingga 5.00	Sangat Tinggi

Selain itu, analisis korelasi Pearson diaplikasikan bagi mengukur kekuatan dan arah hubungan antara kefahaman dan pengamalan nilai murni pelajar. Interpretasi data serta analisis korelasi adalah berpandukan kepada cadangan Cohen (1988) seperti yang ditunjukkan dalam Jadual 2.

Jadual 2. Interpretasi Kekuatan Hubungan (Cohen 1988)

Nilai Korelasi (r)	Interpretasi
0.10 – 0.29	Lemah
0.30 – 0.49	Sederhana
0.50 – 1.00	Kuat

Jadual 2 memaparkan tafsiran tahap kekuatan hubungan yang digunakan untuk menganalisis dapatan kajian ini. Berdasarkan Cohen (1988), nilai korelasi dalam julat 0.10 hingga 0.29 dianggap lemah, manakala nilai korelasi antara 0.30 hingga 0.49 dianggap sederhana. Sementara itu, nilai korelasi dalam julat 0.50 hingga 1.00 adalah ditafsirkan sebagai kuat.

3. **Dapatan dan Perbincangan**

3.1 Demografi Responden Kajian

Kajian ini melibatkan seramai 147 orang pelajar daripada pelbagai jabatan dan peringkat umur. Jadual 3 menunjukan perincian profil responden kajian.

Jadual 3. Profil Responden Kajian

Perkara	Klasifikasi	Kekerapan	Peratus (%)
Jantina	Lelaki	93	64.6%
	Perempuan	51	35.4%
Umur	Bawah 20 tahun	134	93.1%
	21 hingga 23 tahun	7	4.9%
	24 tahun ke atas	3	2%
Jabatan	Jabatan Kejuruteraan Mekanikal	71	49.3%
	Jabatan Pelancongan dan Hospitaliti	59	41%
	Jabatan Rekabentuk dan Komunikasi Visual	14	9.7%

Melalui aspek jantina, majoriti responden merupakan pelajar lelaki iaitu seramai 93 orang (64.6%), manakala pelajar perempuan berjumlah 51 orang (35.4%). Berdasarkan kategori umur, sebahagian besar responden berada dalam kategori bawah 20 tahun iaitu seramai 134 orang (93.1%), diikuti oleh 7 orang (4.9%) dalam lingkungan umur 21 hingga 23 tahun, dan 3 orang (2%) berumur 24 tahun ke atas.

Merujuk kepada jabatan pengajian, kajian ini melibatkan pelajar dari tiga jabatan utama iaitu Jabatan Kejuruteraan Mekanikal seramai 71 orang (49.3%), Jabatan Pelancongan dan Hospitaliti seramai 59 orang (41.0%), dan Jabatan Rekabentuk dan Komunikasi Visual seramai 14 orang (9.7%).

Secara keseluruhannya, profil responden kajian ini menunjukkan kepelbagaian latar belakang dari aspek jantina, umur, dan jabatan pengajian. Hal ini memberikan gambaran yang holisitik terhadap populasi pelajar yang mengikuti kursus Penghayatan Etika dan Peradaban di Politeknik Ibrahim Sultan sekali gus memperkukuh kesahan dapatan kajian.

3.2 Tahap Kefahaman Nilai Murni Melalui Kursus Penghayatan Etika dan Peradaban

Jadual 4 memperincikan skor min dan sisihan piawai (SP) bagi setiap item yang berkaitan dengan tahap kefahaman pelajar terhadap nilai murni hasil daripada kursus Penghayatan Etika dan Peradaban. Secara keseluruhan, semua item menunjukkan tahap kefahaman yang tinggi, dengan nilai min berada dalam julat antara 4.42 hingga 4.79.

Jadual 4. Tahap Kefahaman Nilai Murni Melalui Kursus Penghayatan Etika dan Peradaban dalam Kalangan Pelajar Politeknik Ibrahim Sultan

Bil.	Item	Min	SP	Interpetasi
B1	Semua ajaran agama menyeru penganut untuk melakukan kebaikan.	4.64	0.67	Tinggi
B2	Sikap hormat-menghormati antara rakyat Malaysia pelbagai kaum boleh mengekalkan keharmonian.	4.79	0.62	Tinggi
B3	Pengamalan nilai ikhlas boleh melahirkan bangsa Malaysia bertamadun tinggi.	4.65	0.60	Tinggi
B4	Pembentukan sahsiah yang mantap boleh menangani fenomena-fenomena negatif yang banyak menular dalam masyarakat Malaysia.	4.42	0.95	Tinggi
B5	Pembelajaran mengenai tamadun dan peradaban mampu membentuk nilai silaturahin para pelajar.	4.51	0.75	Tinggi
B6	Amalan toleransi boleh mengekalkan perpaduan antara kaum.	4.66	0.62	Tinggi
B7	Dialog berterusan antara manusia dalam pelbagai budaya dan tamadun boleh mengekalkan Masyarakat yang berakhlak dan bermoral.	4.49	0.77	Tinggi
B8	Pemahaman terhadap kesedaran kesejagatan dalam tanggungjawab sosial dalam setiap ajaran agama boleh membentuk jiwa yang harmoni.	4.63	0.68	Tinggi

Hasil analisi Jadual 4 menunjukkan bahawa secara keseluruhan tahap kefahaman nilai murni pelajar Politeknik Ibrahim Sultan adalah tinggi, dengan min bagi semua item berada dalam julat 4.42 hingga 4.79.

Item B2, iaitu “Sikap hormat-menghormati antara rakyat Malaysia pelbagai kaum boleh mengekalkan keharmonian” merekodkan skor min tertinggi sebanyak 4.79 (SP = 0.62). Hal ini menunjukkan bahawa pelajar sangat memahami kepentingan nilai saling menghormati dalam konteks masyarakat berbilang kaum di Malaysia. Nilai ini amat relevan dengan usaha mengekalkan keharmonian dan perpaduan, selari dengan objektif kursus Penghayatan Etika dan Peradaban.

Item B3 “Pengamalan nilai ikhlas boleh melahirkan bangsa Malaysia bertamadun tinggi” dan B6 “Amalan toleransi boleh mengekalkan perpaduan antara kaum” masing-masing memperoleh skor min yang tinggi 4.65 dan 4.66, mencerminkan tahap kefahaman mendalam pelajar terhadap nilai-nilai murni yang menyokong pembinaan negara bangsa.

Sementara itu, item B4, “Pembentukan sahsiah yang mantap boleh menangani fenomena negatif yang banyak menular dalam masyarakat Malaysia”, mencatatkan skor min paling rendah dalam kalangan semua item iaitu 4.42 (SP = 0.95), namun masih berada pada tahap tinggi. Nilai sisihan piawai yang lebih besar (0.95) menunjukkan wujudnya sedikit perbezaan pendapat atau pengalaman dalam kalangan pelajar berkaitan impak pembentukan sahsiah terhadap gejala sosial, mungkin disebabkan oleh latar belakang atau persepsi individu yang berbeza. Item B1 dan B8 pula, yang masing-masing berkaitan nilai agama dan tanggungjawab sosial, menunjukkan min tinggi (4.64 dan 4.63).

Hal ini mencerminkan kefahaman pelajar tentang nilai-nilai murni yang merentas budaya dan agama sebagai asas membina masyarakat harmoni dan bertanggungjawab. Secara ringkasnya,

dapatan ini memperkukuhkan bahawa pelajar memiliki tahap kefahaman yang kukuh terhadap nilai murni yang ditekankan dalam kursus ini. Kefahaman ini berpotensi menjadi asas penting untuk diterjemahkan dalam bentuk pengamalan.

3.3 Tahap Pengamalan Nilai Murni Melalui Kursus Penghayatan Etika dan Peradaban

Jadual 5 di bawah memperlihatkan skor min dan sisihan piawai (SP) bagi setiap item berkaitan pengamalan nilai murni dalam kalangan pelajar. Semua item menunjukkan tahap pengamalan yang tinggi, dengan nilai min antara 4.59 hingga 4.76.

Jadual 5. Tahap Pengamalan Nilai Murni Melalui Kursus Penghayatan Etika dan Peradaban dalam Kalangan Pelajar Politeknik Ibrahim Sultan

Bil.	Item	Min	SP	Interpetasi
C1	Saya berusaha mengelakkan diri daripada melakukan perkara-perkara buruk.	4.68	0.58	Tinggi
C2	Saya mengamalkan sikap hormat-menghormati antara rakyat Malaysia pelbagai kaum.	4.72	0.52	Tinggi
C3	Saya melakukan kerja dengan penuh keikhlasan.	4.66	0.59	Tinggi
C4	Saya berusaha ke arah membentuk jati diri yang mantap.	4.66	0.57	Tinggi
C5	Saya menjaga hubungan silaturahim sesama manusia.	4.71	0.51	Tinggi
C6	Saya mengamalkan sikap toleransi dalam mengekalkan perpaduan antara kaum.	4.72	0.60	Tinggi
C7	Saya mengajak rakan-rakan untuk melakukan kerja amal.	4.59	0.60	Tinggi
C8	Saya menghindari percakapan yang menyakitkan hati rakan.	4.63	0.58	Tinggi
C9	Saya suka berkawan dan berinteraksi dengan orang yang dapat membimbing saya ke arah kebaikan.	4.76	0.53	Tinggi

Secara keseluruhan, dapatan kajian menunjukkan bahawa pelajar Politeknik Ibrahim Sultan mengamalkan nilai-nilai murni pada tahap yang tinggi, dengan skor min bagi semua item berada dalam julat 4.59 hingga 4.76.

Item C9, iaitu “Saya suka berkawan dan berinteraksi dengan orang yang dapat membimbing saya ke arah kebaikan”, mencatat skor min tertinggi iaitu 4.76 (SP = 0.53). Dapatan ini mencerminkan kecenderungan pelajar untuk memilih persekitaran sosial yang positif dan bersosial dengan individu yang mampu mempengaruhi mereka ke arah kebaikan. Keputusan ini memberi gambaran bahawa faktor sokongan rakan sebaya memainkan peranan penting dalam membina amalan nilai murni dalam kalangan pelajar.

Item C2 “Saya mengamalkan sikap hormat-menghormati antara rakyat Malaysia pelbagai kaum” dan C6 “Saya mengamalkan sikap toleransi dalam mengekalkan perpaduan antara kaum” turut mencatat skor min tinggi masing-masing 4.72, memperlihatkan kemampuan pelajar untuk mempraktikkan nilai harmoni dan toleransi yang relevan dalam konteks kehidupan masyarakat majmuk di Malaysia.

Selain itu, item C1 “Saya berusaha mengelakkan diri daripada melakukan perkara-perkara buruk” dengan min 4.68, dan C5 “Saya menjaga hubungan silaturahim sesama manusia” dengan min 4.71, menunjukkan bahawa pelajar memberi perhatian terhadap nilai pengawalan diri serta berusaha untuk menjaga hubungan baik sesama manusia.

Item C7, “Saya mengajak rakan-rakan untuk melakukan kerja amal”, mencatat min paling rendah iaitu 4.59 (SP = 0.60), namun masih dalam kategori tinggi. Nilai ini mungkin mencerminkan

kecenderungan pelajar untuk menumpukan kepada pengamalan nilai secara individu berbanding inisiatif mengajak orang lain secara aktif untuk turut serta dalam aktiviti amal atau kebajikan.

Secara keseluruhannya, dapatan skor min yang tinggi bagi semua item menegaskan bahawa pelajar bukan sahaja memahami nilai murni yang diajar dalam kursus Penghayatan Etika dan Peradaban, tetapi juga mengaplikasikannya dalam tingkah laku harian mereka. Hasil ini menggambarkan keberkesanan kursus dalam membentuk sahsiah pelajar selaras dengan matlamat Falsafah Pendidikan Kebangsaan serta kehendak industri TVET dalam melahirkan graduan beretika dan berkualiti.

Kedua-dua bahagian menunjukkan bahawa pelajar bukan sahaja memahami nilai murni, tetapi juga mengamalkannya dalam kehidupan seharian. Item B2 dan C9 memperoleh min tertinggi dalam aspek kefahaman dan pengamalan, yang menekankan fokus pelajar terhadap hubungan sosial yang harmoni dan pergaulan yang memberi pengaruh positif. Sebaliknya, skor paling rendah bagi item C7 memberi indikasi bahawa aspek kepimpinan nilai atau inisiatif untuk mengajak orang lain melakukan kebaikan masih boleh dipertingkatkan.

3.4 Analisis Hubungan antara Kefahaman dan Pengamalan Nilai Murni

Analisis korelasi Pearson telah dijalankan bagi menentukan hubungan antara kefahaman nilai murni dan pengamalan nilai murni dalam kalangan pelajar. Hasil analisis menunjukkan nilai pekali korelasi sebanyak r = 0.686 dengan nilai signifikan p = 0.000 pada aras signifikan 0.01 (2-hala).

Jadual 6. Analisis Korelasi antara Tahap Kefahaman Nilai Murni dengan Tahap Pengamalan Nilai Murni

Faktor Pemboleh Ubah	Korelasi (r)	Tahap Signifikan
Kefahaman Nilai Murni dan Pengamalan Nilai Murni	0.686**	0.000

Nota. **Signifikan pada aras p < 0.01

Dapatan ini menunjukkan bahawa terdapat hubungan positif yang signifikan antara tahap kefahaman dan pengamalan nilai murni. Ini bermakna, semakin tinggi kefahaman pelajar terhadap nilai murni, semakin tinggi juga kecenderungan mereka untuk mengamalkannya dalam kehidupan harian.

Berdasarkan kategori kekuatan hubungan oleh Cohen (1988), nilai korelasi 0.686 tergolong dalam kategori hubungan kuat. Keputusan ini membuktikan bahawa kursus Penghayatan Etika dan Peradaban berjaya menyampaikan pengetahuan tentang nilai murni secara berkesan, sekali gus mendorong pelajar untuk mengaplikasikan nilai-nilai tersebut dalam tingkah laku dan interaksi sosial mereka.

Secara keseluruhan, analisis ini menyokong andaian bahawa kefahaman yang mantap terhadap nilai murni memainkan peranan penting dalam mempengaruhi tahap pengamalan dalam kalangan pelajar politeknik. Dapatan ini memberi justifikasi kepada keperluan untuk mengekalkan dan menambah baik pendekatan pengajaran nilai murni dalam kursus berteraskan etika dan peradaban di institusi TVET.

4. Kesimpulan

Secara keseluruhan, kajian ini berjaya mencapai kedua-dua objektif yang telah ditetapkan. Pertama, tahap kefahaman pelajar terhadap nilai murni melalui kursus Penghayatan Etika dan Peradaban (PEP) didapati berada pada tahap tinggi (min = 4.59), menunjukkan bahawa pelajar

mempunyai pengetahuan yang baik tentang konsep nilai-nilai seperti hormat-menghormati, keikhlasan, toleransi, silaturahim dan tanggungjawab sosial. Kedua, tahap pengamalan nilai murni juga berada pada tahap tinggi (min = 4.51), yang membuktikan bahawa nilai-nilai yang difahami turut diterjemahkan dalam tindakan harian pelajar.

Melalui analisis korelasi Pearson, kajian ini turut mendapati hubungan positif yang signifikan antara kefahaman dan pengamalan nilai murni ($r = 0.686$, $p < 0.01$), sekaligus menyokong hipotesis bahawa peningkatan kefahaman terhadap nilai murni dapat mendorong pelajar untuk lebih mengamalkannya. Dapatan ini menunjukkan bahawa kursus PEP berfungsi secara efektif dalam menyampaikan nilai-nilai murni secara holistik, merangkumi aspek intelek, emosi, sosial dan spiritual pelajar.

Impak utama kajian ini adalah memperkukuh peranan kursus PEP sebagai komponen penting dalam pembentukan sahsiah dan karakter pelajar TVET yang seimbang dan berintegriti. Kajian ini juga memberikan justifikasi kukuh agar pendekatan pengajaran nilai murni di politeknik disampaikan secara lebih kontekstual, interaktif dan berasaskan situasi dunia sebenar, selari dengan keperluan industri dan masyarakat masa kini.

Sebagai cadangan, kajian lanjutan boleh dilakukan dengan skop sampel yang lebih luas melibatkan pelbagai institusi, bagi memperkukuh generalisasi dapatan dan menyumbang kepada penambahbaikan kurikulum di Institusi Pendidikan Tinggi seluruh negara.

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PENGGUNAAN HAMPAS SOYA DALAM PENGHASILAN SERUNDING SEBAGAI INTI POPIA SIMPUL: KAJIAN PENILAIAN SENSORI DAN PENERIMAAN PENGGUNA

Nur Syamimi binti Ramlan*, Suriati binti Ali

Jabatan Teknologi Pemprosesan Makanan, Kolej Komuniti Sabak Bernam, 45200 Sabak Bernam, Selangor Darul Ehsan, Malaysia

*Corresponding author e-mail address: syamimi@staf.kksbs.edu.my

Abstrak

Hampas soya selalunya dibuang setelah diproses masih mengandungi nilai nutrisi tinggi seperti serat, lemak, protein dan vitamin. Kajian ini bertujuan untuk membangunkan produk popia simpul menggunakan hampas soya sebagai bahan utama dalam formulasi serunding. Empat formulasi telah dihasilkan dengan peratusan hampas soya sebanyak 30%, 50%, 70%, dan 100% dan sampel kawalan menggunakan serunding ikan. Objektif kajian adalah untuk menilai penerimaan pengguna terhadap pelbagai formulasi serunding hampas soya dalam popia simpul melalui penilaian sensori. Metodologi kajian melibatkan ujian penilaian sensori menggunakan skala hedonik tujuh titik yang menilai atribut rupa, bau, warna, rasa, tekstur dan penerimaan keseluruhan. Seramai 50 orang panel tak terlatih telah mengambil bahagian dalam ujian ini. Analisis statistik dilakukan menggunakan perisian SPSS dengan ujian duncan multiple range untuk menentukan perbezaan signifikan antara formulasi. Keputusan menunjukkan bahawa formulasi dengan 100% hampas soya mendapat skor tertinggi dalam semua atribut sensori dan hampir menyamai sampel kawalan, menunjukkan penerimaan yang baik oleh panelis. Formulasi ini juga menunjukkan potensi dalam mengurangkan pembaziran makanan dengan memanfaatkan sisa hampas soya. Cadangan penambahbaikan adalah melaksanakan kajian mengenai jangka hayat produk. Kesimpulannya, penggunaan hampas soya dalam penghasilan serunding popia simpul berpotensi sebagai alternatif makanan yang berkhasiat dan mesra alam.
Kata kunci: Hampas Soya, Popia Simpul, Penilaian Sensori.

1. Pengenalan

Okara (berasal daripada bahasa Jepun) atau hampas kacang soya merupakan sisa pepejal tidak larut yang terhasil daripada proses penghasilan produk berasaskan soya. (Mansor *et al.*, 2022). Di Asia (Watanebe, 1997) dan Malaysia, produk hasilan soya digemari pelbagai kaum terutamanya Kaum Melayu dan Cina seperti air soya dan taufufa (Maizura *et al.*, 2014). Selepas penghasilan produk hasilan soya, okara yang terhasil adalah banyak iaitu 1.1 sehingga 1.2kg okara (berat basah) dihasilkan daripada 1 kg kacang soya yang telah diproses untuk dijadikan susu soya atau tauhu (Azlina *et al*., 2023 & Khare *et al.*, 1995). Hampas kacang soya mengandungi kandungan kelembapan yang sangat tinggi iaitu (70-80%) menyebabkan ia susah diuruskan kerana mudah rosak dan menjadi busuk. (Azlina *et al*., 2023) Justeru, hampas soya tersebut seringkali akan dibuang begitu sahaja di tempat pelupusan sampah atau dibakar (Azlina *et al.*, 2023), dijadikan makanan haiwan ternakan ataupun baja oleh petani (Aisyah *et al*., 2022) dan ini menyumbang kepada peningkatan pencemaran alam sekitar. Walaupun sering dianggap sebagai sisa buangan, okara kaya dengan nutrisi seperti kandungan serat yang tinggi (~50%), protein (~25%), asid lemak tak tepu (~25%), monosakarida, oligosakarida, vitamin, mineral dan isoflavon (Li *et al*., 2012).

Popia simpul merupakan sejenis makanan ringan tradisional yang popular di Malaysia, yang dimakan pada bila-bila masa dan lebih banyak dinikmati oleh pengguna terutama ketika musim perayaan seperti Hari Raya Aidilfitri. Ia diperbuat daripada inti serunding seperti ikan dan daging yang dibungkus menggunakan kulit popia. Popia ini disimpul atau digulung dan digoreng sehingga bewarna keperangan dan mempunyai tekstur yang rangup. Popia simpul menjadi kegemaran pelbagai peringkat usia termasuk golongan kanak-kanak hingga dewasa kerana rasanya yang manis, pedas dan mempunyai tekstur yang rangup. Pembuatan popia simpul kebanyakannya dihasilkan oleh pengusaha industri makanan kecil dan sederhana (IKS). Popia simpul ini juga dijual secara meluas secara tradisional malahan telah berjaya mempelopori pasaran tempatan mahupun dijual laris secara atas talian. Meskipun mendapat tempat dalam kalangan pengguna, kos pengeluaran popia simpul ini mahal. Ini kerana kos bahan mentah yang mahal dan mudah rosak seperti serunding daging dan ikan menyebabkan perlunya mencari alternatif bahan mentah lain untuk mengurangkan kos pengeluaran. Justeru penggunaan hampas soya boleh dijadikan sebagai sumber utama bagi menggantikan inti tradisional yang diperbuat dari serunding ikan atau daging. Penggunaan hampas soya ini bukan sahaja mengurangkan kos pengeluaran, malah menyumbang kepada usaha kelestarian melalui pengurangan pembuangan sisa makanan (Azlina et al., 2023).

Hampas soya mempunyai kandungan nutrisi yang tinggi dan mempunyai kebaikan kepada kesihatan. Justeru, banyak kajian telah dijalankan bagi penggunaan hampas soya dalam penghasilan pelbagai produk dalam industri perubatan dan industri pemprosesan produk makanan seperti produk bakeri, snek makanan ringan dan bahan penstabil semula jadi (Josephine & Rubiyah, 2018). Terdapat pelbagai kajian telah menunjukkan hampas soya berpotensi digunakan untuk penghasilan makanan ringan. Sebagai contoh, kajian oleh (Norzaleha *et al*., 2022) mendapati bahawa penambahan okara dalam kerepek ubi kayu meningkatkan kandungan protein dan serat pemakanan, walaupun terdapat sedikit penurunan dalam skor organoleptik. Selain itu, kajian penggunaan hampas soya dalam sebagai ramuan yang mampan dan lebih sihat dalam penyediaan roti oleh (Siti Saleha *et al.*, 2022) juga menunjukkan diterima baik oleh pengguna dalam skor penilaian sensori. Kajian diwujudkan untuk mengetahui penerimaan masyarakat terhadap inovasi makanan ini. Produk makanan dan minuman boleh dinilai menggunakan skala hedonik (Lawless & Heymann, 1999). Menurut Anna (1998) dan Aminah (2004), skala hedonik digunakan untuk mengenalpasti penerimaan pengguna terhadap produk berkaitan industri makanan. Namun, berdasarkan kajian yang lepas masih belum ada kajian yang menggunakan hampas soya untuk menghasilkan popia simpul ini. Maka, objektif kajian ini dijalankan bagi menilai potensi penggunaan hampas soya sebagai serunding dalam penghasilan inti popia simpul dari penilaian sensori dan penerimaan pengguna.

2. Metodologi

Bahan yang digunakan dalam penghasilan popia simpul adalah kacang soya, kulit popia segera, bawang merah, bawang putih, halia, serai, santan, cili kering, asam keping, gula, garam, perisa dan minyak masak. Semua bahan diperoleh di kedai sekitar Sabak Bernam, Selangor. Ikan selayang dibeli di Pasar Basah Sabak Bernam, Selangor.

2.1 Penyediaan hampas kacang soya

Kacang soya dibeli di kedai runcit di Sabak Bernam, Selangor. Kacang soya telah digunakan dalam proses pembuatan air kacang soya. Selepas dikisar dan diperah, hampas kacang soya dikumpulkan dan disimpan dalam bekas kedap udara dan disimpan dalam peti sejuk beku bersuhu -18°C (Berjaya, BJY-CFSD100A-R6). Hampas kacang soya tersebut kemudian

dinyahbeku semalaman dalam peti sejuk dua pintu bersuhu 4◦C (Berjaya, 2D/DC-BBH-1) sebelum digunakan untuk dibuat serunding.

2.2 Penyediaan isi ikan

Ikan selayang disiang dan dicuci bersih. Ikan direbus bersama asam keping sehingga masak. Setelah sejuk, isi ikan diasingkan daripada tulang menggunakan tangan. Kemudian isi ikan dikisar menggunakan mesin pemproses makanan bagi mendapatkan tekstur yang lebih halus.

2.3 Penyediaan popia simpul

Kaedah pemprosesan serunding hampas soya popia simpul adalah sama seperti kaedah tradisional penghasilan popia simpul menggunakan serunding ikan atau daging. Penghasilan serunding ikan menggunakan kaedah Ealangov *et al*., (2023). Pengubahsuaian yang dilakukan adalah serunding hampas soya dikeringkan dalam mesin pengering *Food Dehydrator* supaya serunding menjadi lebih kering dan dikisar halus menggunakan mesin pengisar (Panasonic). Serunding kemudian dijadikan inti dalam popia simpul.

Sebanyak 5 formulasi popia simpul telah dihasilkan di mana terdapat perbezaan kuantiti serunding hampas soya yang digunakan. Sampel kawalan yang digunakan adalah serunding ikan. Kesemua sampel termasuk sampel kawalan akan menjalani ujian sensori. Rajah 1 menunjukkan proses penghasilan popia simpul menggunakan serunding hampas soya.



Rajah 1. Serunding okara yang telah dikeringkan dalam mesin *food dehydrator* dan kemudiannya serunding okara selepas dikisar halus dalam mesin pengisar dan popia simpul yang telah siap digoreng sehingga berwarna keperangan



Rajah 2. (a) *Mesin Food Dehydrator* yang digunakan bagi mengeringkan serunding okara, (b) mesin *Food Processor* yang digunakan untuk mengisar bahan mentah dan (c) mesin pengisar untuk menghaluskan tekstur serunding okara

2.4 Rekabentuk Kajian

Rekabentuk kajian yang digunakan ialah rekabentuk rawak lengkap dengan blok dan dilakukan replikasi sebanyak 3 kali bagi menambah ketepatan dan kebolehpercayaan. Rawatan yang dilakukan terhadap sampel adalah penggunaan hampas soya dan empat formulasi popia simpul yang berbeza akan dihasilkan dan satu formulasi popia simpul menggunakan serunding ikan tanpa okara sebagai kawalan. Jadual 1 menunjukkan formulasi bagi popia simpul.

Jadual 1. Formulasi Popia Simpul

Formulasi	F0	F1	F2	F3	F4
Isi ikan (g)	1000	700	500	300	0
Hampas Soya (g)	0	300	500	700	1000
Bawang merah (g)	200	200	200	200	200
Bawang Putih (g)	50	50	50	50	50
Halia (g)	30	30	30	30	30
Serai (g)	100	100	100	100	100
Santan (g)	200	200	200	200	200
Cili kering (g)	50	50	50	50	50
Gula (g)	60	60	60	60	60
Garam (g)	5	5	5	5	5
Perisa (g)	4	4	4	4	4
Minyak masak (ml)	100	100	100	100	100

2.5 Penilaian Sensori Makanan

Penentuan sensori sampel popia simpul menggunakan teknik ujian hedonik untuk mengetahui sampel yang lebih digemari oleh panel penilai sebagai pengguna. Seramai 50 orang telah diambil sebagai panel penilai yang terdiri daripada kalangan pelajar dan staf Kolej Komuniti Sabak Bernam (lelaki dan perempuan dalam lingkungan umur 18 hingga 46 tahun yang tidak mempunyai pengetahuan khusus tentang popia simpul. Tiada kriteria tertentu yang diperlukan pada penilai dan mereka bersedia untuk menilai sampel yang dibentangkan. Popia simpul tersebut telah disediakan beberapa hari lebih awal dan disimpan pada suhu bilik.

Panel diberikan lima sampel popia simpul yang terdiri daripada popia simpul tanpa hampas soya (kawalan), popia simpul yang mengandungi peratusan yang berbeza (F1, F2, F3 dan F4) bagi melihat perbandingan antara lima jenis popia simpul beserta borang penilaian. Sampel dilabelkan dengan kod rawak iaitu popia simpul tanpa hampas soya (kawalan) 615, popia simpul (F1) 229, popia simpul (F2) 173, popia simpul (F3) 345 dan popia simpul (F4) 573 bagi mengelakkan bias daripada responden.

Penilaian sensori dijalankan dengan menilai 6 ciri attribut mengikut turutan berikut - rupa, bau, warna, rasa, tekstur serta penerimaan keseluruhan. Penilaian ini menggunakan 7 unit skor dari nilai 1 (paling tidak suka) hingga 7 (paling suka) (Norzaleha *et al*., 2013). Skor yang rendah bagi sesuatu atribut menunjukkan sampel yang dinilai mempunyai pencirian yang negatif dan begitu juga sebaliknya.

Panel penilai menguji popia simpul di Makmal Sensori Kolej Komuniti Sabak Bernam, Selangor. Keadaan persekitaran bilik sensori adalah dikawal pencahayaannya serta suhunya antara 27-30°C dan bebas daripada sebarang pencemaran bau.

Panel penilai telah diberi penerangan awal tentang cara menilai sampel mengikut setiap atribut secara satu persatu dan cara mengisi borang penilaian dengan tepat. Panel penilai diminta untuk menilai 6 atribut iaitu rupabentuk, bau, warna, tekstur, rasa serta penerimaan keseluruhan bagi

lima sampel popia simpul yang telah diletakkan khas di dalam dulang. Air suam diberikan bagi mengkumur mulut di antara setiap sampel yang dirasa (Aminah, 2000).

2.6 Analisis Statistik

Data yang diperolehi dari penilaian sensori makanan dianalisis menggunakan perisian *Statistical Packages for Social Science* (SPSS) versi 23.0 untuk ujian Duncan Multiple Range bagi menentukan terdapat perbezaan yang bererti atau tidak dalam sampel popia simpul bagi atribut-atribut yang dikaji.

3. Keputusan dan Perbincangan

Ujian penilaian sensori telah dilakukan kepada 50 orang penilai tak terlatih bagi membuat penilaian terhadap sensori popia simpul menggunakan formulasi yang berbeza (F1 sehingga F4). Ujian hedonik dijalankan kerana ingin mengkaji penerimaan pengguna terhadap empat sampel popia simpul. 50 orang penilai dianggap bersesuaian dengan ujian hedonik menurut (Aminah, 2004). Data penilaian diperolehi daripada borang penilaian yang diberikan kepada panel penilai yang merupakan penilaian terhadap enam atribut iaitu rupa bentuk, bau, warna, tekstur, rasa serta penerimaan keseluruhan. Penerimaan keseluruhan panel penilai terhadap popia simpul diperolehi dan data dapat dibincangkan.

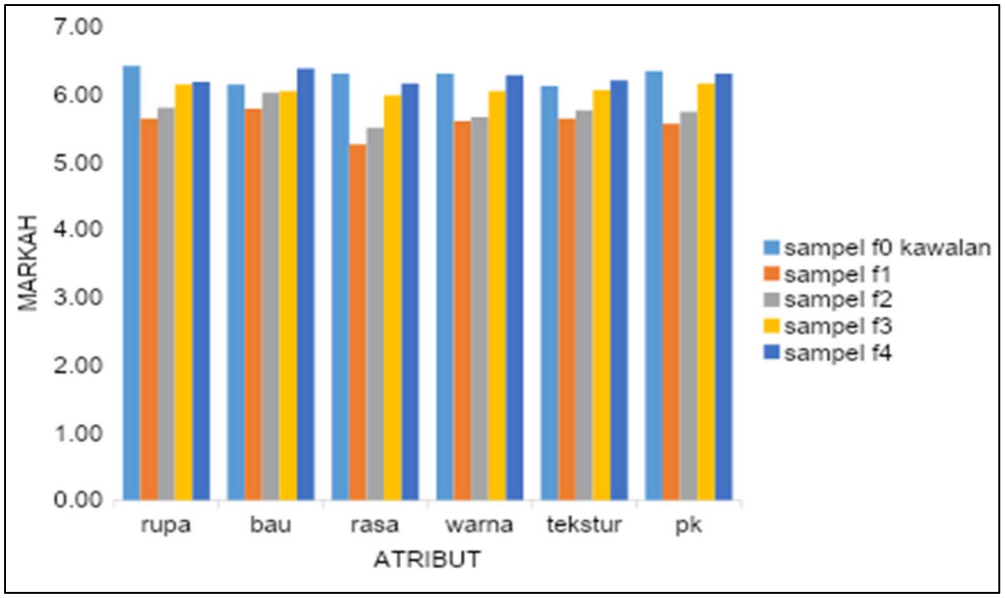
Jadual 2. Min skor atribut (*n = 50*) bagi popia simpul okara

Atribut	Rupabentuk	Bau	Warna	Tekstur	Rasa	Penerimaan Keseluruhan
F0(kawalan)	6.42 ±0.64^{a}	6.42 ±0.70^{ab}	6.12 ±0.94^{a}	6.12 ±0.80^{a}	6.3 ±0.84^{a}	6.34 ±0.77^{a}
F1	5.64 ±0.72^{b}	5.78 ±0.76^{c}	5.6 ±0.67^{b}	5.64 ±0.90^{c}	5.26 ±1.16^{b}	5.56 ±0.84^{b}
F2	5.80 ±0.83^{b}	6.02 ±0.84^{bc}	5.66 ±0.80^{b}	5.76 ±0.92^{bc}	5.50 ±1.28^{b}	5.74 ±0.96^{b}
F3	6.14 ±0.64^{a}	6.04 ±0.78^{bc}	6.04 ±0.57^{a}	6.06 ±0.79^{ab}	5.98 ±0.91^{a}	6.16 ±0.61^{a}
F4	6.18 ±0.77^{a}	6.18 ±0.53^{a}	6.28 ±0.61^{a}	6.20 ±0.61^{a}	6.14 ±0.68^{a}	6.30±0.54^{a}

Data dinyatakan sebagai min ± sisihan piawai, simbol $^{a-c}$ yang berbeza dalam lajur yang sama menunjukkan terdapat perbezaan bererti ($p< 0.05$).
Nota:
F0 (Kawalan) Popia simpul inti serunding ikan
F1 Popia inti serunding hampas soya 30%, serunding ikan 70%
F2 Popia inti serunding hampas soya 50%, serunding ikan 50%
F3 Popia inti serunding hampas soya 70%, serunding ikan 30%
F4 Popia inti serunding hampas soya 100%

Berdasarkan Jadual 2, nilai min yang tinggi menunjukkan lebih tinggi kesukaan pengguna. Sampel kawalan F0 menggunakan serunding ikan dijadikan rujukan bagi atribut yang dinilai. Dari segi rupabentuk, skor yang tertinggi diperolehi F3 (6.14 ± 0.64) dan F4 (6.18 ± 0.77), yang menunjukkan tahap visual paling disukai oleh penilai manakala F1 (5.64 ± 0.72) dan F2 (5.80 ± 0.83) mendapat skor lebih rendah, menunjukkan formulasi ini kurang menarik dari segi rupabentuk. Skor atribut bau tertinggi dicatatkan oleh F4 (6.18 ± 0.53) yang menunjukkan aroma yang lebih disukai pengguna manakala F1 menunjukkan nilai paling rendah dalam aspek ini iaitu (5.78 ± 0.76). F2 (6.02 ± 0.84) dan F3 (6.04 ± 0.78) pula berada di tahap sederhana bagi atribut bau. Ini kerana okara menghasilkan bau yang lebih digemari pengguna dan tidak berbau seperti

kekacang mentah (Hamid *et al*., 2023). Bagi atribut warna, F4 (6.28 ± 0.61) dan F3 (6.04 ± 0.57) menunjukkan warna yang paling menarik dan disukai pengguna. F1 (5.60 ± 0.67) dan F2 (5.66 ± 0.80) pula menunjukkan nilai yang rendah secara signifikan. Ini kerana kandungan protein yang tinggi menyebabkan warna perang keemasan yang lebih ketara disebabkan oleh tindak balas pencoklatan (Hamid *et al*., 2023). Ini menunjukkan pengguna lebih menyukai warna popia simpul yang berwarna lebih gelap. Menurut (Taghdir *et al*., 2017) warna gelap yang dihasilkan oleh okara kepada makanan boleh disebabkan oleh pigmen warna kuning yang ada dalam tepung okara dan tindakan Millard semasa pemprosesan. Bagi atribut tekstur, F4 dan F3 (masing-masing 6.20 ± 0.61 dan 6.06 ± 0.79) mencatat keputusan tekstur yang baik manakala F1 (5.64 ± 0.90) dan F2 (5.76 ± 0.92) menunjukkan kelemahan dari segi tekstur produk. Penggunaan okara yang tinggi menghasilkan tekstur yang lebih keras berbanding penggunaan okara yang sedikit. (Hamid *et al*., 2023). Penilaian dari segi rasa menunjukkan F4 (6.14 ± 0.68) mendapat skor tertinggi menggambarkan rasa yang lebih memuaskan pengguna. F1 (5.26 ± 1.16) dan F2 (5.50 ± 1.28) pula kurang disukai, manakala F3 (5.98 ± 0.91) menunjukkan kualiti rasa yang sederhana. Bagi atribut penerimaan keseluruhan menunjukkan Formulasi F4 (6.30 ± 0.54) dan F3 (6.16 ± 0.62) mencatatkan keputusan penerimaan keseluruhan yang terbaik di mana kesemuanya melebihi purata manakala F1 (5.56 ± 0.84) dan F2 (5.74 ± 0.96) mencatat penerimaan pengguna yang lebih rendah.



Rajah 2. Nilai atribut bagi penilaian sensori Popia Simpul

Berdasarkan rajah 2, ujian menunjukkan perbezaan yang signifikan dalam semua atribut yang ditunjukkan oleh sample popia simpul F0, F1, F2, F3 dan F4. Formulasi F3 dan F4 didapati mendapat skor lebih tinggi dari segi rupabentuk, rasa, warna dan penerimaan keseluruhan berbanding F1 dan F2. Terutamanya F4 memperoleh skor tertinggi bagi rupabentuk (6.18±0.77), rasa (6.14 ± 0.68), bau (6.18 ± 0.53), warna (6.28 ± 0.61), tekstur (6.20±0.61) dan penerimaan keseluruhan (6.30 ± 0.54), menunjukkan bahawa formulasi ini paling menyeluruh dan diterima oleh penilai hampir menyamai keputusan sampel kawalan (F0). Sebaliknya, F1 dan F2 menunjukkan nilai yang rendah pada hampir kesemua atribut sensori. F1 mencatat skor rendah dalam rupa (5.64±0.72), rasa (5.26 ± 1.16), bau (5.78 ± 0.76), warna (5.60±0.67) dan tekstur (5.64 ± 0.90), menggambarkan kekurangan dari segi penerimaan produk oleh pengguna. F2 menunjukkan nilai yang lebih baik sedikit berbanding F1, tetapi masih di bawah median dalam kebanyakan atribut. Secara keseluruhan, F4 muncul sebagai formulasi pilihan pengguna

berdasarkan ujian sensori ini, diikuti rapat oleh F3. Keputusan ini menunjukkan bahawa kombinasi bahan F4 menarik perhatian pengguna untuk menerima produk. Bagi penghasilan secara komersil produk popia simpul, F4 seharusnya dipertimbangkan untuk dilaksanakan kajian lanjutan bagi perkembangan potensi produk dan diuji dalam kalangan panel sensori terlatih. Analisis data menunjukkan bahawa F4 mendapat keputusan skor tinggi yang konsisten dan hampir menyamai sampel kawalan dalam keseluruhan atribut. Ini menunjukkan pengguna menerima keseluruhan atribut penilaian sensori bagi F4 sebagai popia simpul yang benar-benar diterima oleh citarasa pengguna.

4. Penutup

Kesimpulannya, hasil penilaian sensori terhadap popia simpul yang menggunakan 4 formulasi okara yang berbeza (F1:30%, F2:50%, F3:70% dan F4:100%) telah menunjukkan bahawa dengan penggunaan 100% serunding hampas kacang soya menunjukkan tiada perbezaan dengan popia simpul menggunakan serunding ikan. Analisis ini diperkukuhkan dengan mendapati penggunaan F4 iaitu 100% okara, respon panel penilai dapat diterima oleh pengguna dari segi rupabentuk, bau, warna, tekstur, rasa dan penerimaan keseluruhan. Justeru, penggunaan okara sebagai inti popia simpul dapat diterima pengguna sekaligus membuktikan bahawa okara sesuai dijadikan serunding bagi produk makanan snek berasaskan okara.

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HUBUNGAN ANTARA JANTINA DAN PENCAPAIAN AKADEMIK DALAM KURSUS MIKROEKONOMI DAN MAKROEKONOMI DI KALANGAN PELAJAR POLITEKNIK

Hanani binti Abdul Ghani*, Faizan Maisarah binti Abu Bakar

Jabatan Perdagangan, Politeknik Tuanku Sultanah Bahiyah, Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: hanani@ptsb.edu.my

Abstrak

Kajian ini dijalankan bagi mengenal pasti hubungan antara jantina dan pencapaian pelajar dalam kursus Mikroekonomi dan Makroekonomi, serta menilai sumbangan pencapaian dalam kursus Mikroekonomi sebagai peramal kepada pencapaian dalam kursus Makroekonomi. Seramai 137 orang pelajar dari sebuah politeknik awam telah dipilih sebagai responden. Data dianalisis menggunakan kaedah statistik deskriptif, analisis korelasi Pearson dan regresi mudah serta berganda. Hasil analisis menunjukkan bahawa terdapat hubungan yang signifikan dan positif antara jantina dan pencapaian dalam kursus Mikroekonomi ($r = 0.222$, $p = 0.009$), namun tiada hubungan signifikan antara jantina dan pencapaian dalam kursus Makroekonomi ($r = 0.113$, $p = 0.189$). Selain itu, pencapaian dalam Mikroekonomi didapati mempunyai hubungan yang sangat kuat dan signifikan dengan pencapaian dalam Makroekonomi ($r = 0.615$, $p < 0.001$). Melalui analisis regresi, didapati bahawa pencapaian Mikroekonomi adalah peramal yang signifikan terhadap pencapaian dalam Makroekonomi ($\beta = 0.622$, $p < 0.001$). Penemuan ini menunjukkan bahawa penguasaan awal dalam kursus asas seperti Mikroekonomi memainkan peranan penting dalam meramalkan kejayaan pelajar dalam kursus lanjutan seperti Makroekonomi. Kajian ini memberikan implikasi kepada pensyarah dan pembuat dasar kurikulum agar menekankan pembelajaran berstruktur dalam kursus asas ekonomi, serta menggalakkan pendekatan pengajaran yang menyokong gaya pembelajaran pelajar yang pelbagai, termasuk berdasarkan jantina.

Kata kunci: Jantina; Mikroekonomi; Makroekonomi.

1. Pengenalan

Jabatan Perdagangan merupakan salah satu jabatan yang terdapat di Politeknik Tuanku Sultanah Bahiyah (PTSB). Jabatan Perdagangan di politeknik ini menawarkan tiga program iaitu Diploma Akauntansi (DAT/DAC), Diploma Pengajian Perniagaan (DPM) dan Diploma Pemasaran (DPR). Pelajar-pelajar dari ketiga-tiga program ini terlibat dengan kursus teras mikroekonomi pada semester satu dan kursus makroekonomi pada semester dua. Sukatan kursus ini telah mendapat pengiktirafan dari *Malaysian Qualification Accredition* (MQA) sebelum digunapakai di seluruh politeknik di Malaysia. Mikroekonomi adalah berkaitan dengan permintaan dan penawaran; keseimbangan pasaran; konsep keanjalan; konsep pengeluaran dan kos pengeluaran dan struktur pasaran manakala makroeokonomi pula berkaitan pendapatan negara; keseimbangan pendapatan negara; peranan dan polisi kerajaan; masalah pengangguran dan inflasi; wang dan perbankan dan perdagangan antarabangsa.

Kursus mikroekonomi adalah berkonsepkan skop yang lebih kecil atau individu dan pelajar perlu lulus terlebih dahulu pada semester satu untuk mengambil kursus makroekonomi pada semester dua. Kursus makroekonomi pula adalah berkonsepkan skop yang lebih besar iaitu ekonomi secara aggregat. Namun terdapat persoalan yang timbul sejauh mana pelajar mampu mencapai

kecemerlangan dalam kursus mikroekonomi dan makroekonomi ini. Pelajar perlu lulus kursus mikroekonomi ini pada semester satu baru boleh mengikuti kursus makroekonomi pada semester 2.

Pencapaian pelajar yang rendah dalam kursus mikroekonomi memberikan masalah kepada pelajar yang mengambil kursus makroekonomi. Namun terdapat juga masalah pelajar cemerlang dengan mikroekonomi tetapi tidak dalam makroekonomi; dan ada juga pelajar yang tidak cemerlang dalam mikroekonomi tetapi cemerlang dalam makroekonomi. Pembelajaran ekonomi ini seringkali dianggap sebagai sesuatu yang sukar dan membosankan bagi sesetengah pelajar kerana dikatakan sangat tidak berkaitan dengan Diploma Perakaunan, Diploma Pengajian Perniagaan dan Diploma Pemasaran. Ini memberikan kesan yang buruk terhadap bidang berkaitan dengan kehidupan seharian.

Objektif utama kajian adalah bagi mengkaji hubungan antara pencapaian pelajar-pelajar Diploma Akauntansi Jabatan Perdagangan pada Sesi 1 2024/2025 dan Sesi 2 2024/2025 untuk kursus Mikroekonomi dan kursus Makroekonomi.

H_{01}: Jantina pelajar mempengaruhi pencapaian pelajar di dalam kursus Mikroekonomi.

H_{02}: Jantina pelajar mempengaruhi pencapaian pelajar di dalam kursus Makroekonomi.
H_{03}: Pencapaian pelajar di dalam Mikroekonomi mempengaruhi pencapaian pelajar di dalam Makroekonomi

2. Pernyataan masalah

Politeknik Malaysia untuk Diploma Akauntansi hanya mewajibkan kepujian dalam matematik moden sahaja di peringkat SPM. Berdasarkan portal pengambilan pelajar politeknik, syarat kemasukan program diploma ini di politeknik Malaysia adalah warganegara Malaysia, lulus Bahasa Melayu, lulus Sejarah, lulus Bahasa Inggeris dan mendapat tiga kepujian dalam mata pelajaran lain. Pelajar Diploma Akauntansi ini perlu mengambil kursus ekonomi iaitu Mikroekonomi dan Makroekonomi di mana pelajar-pelajar perlu mengambil kursus Mikroekonomi pada semester 1 dan Makroekonomi pada semester 2. Pelajar-pelajar perlu lulus kursus Mikroekonomi dahulu kerana ia merupakan pra-syarat untuk kursus Makroekonomi.
Daripada pemerhatian yang dilakukan oleh pensyarah, didapati pelajar dari program akauntansi ini agak sukar untuk menguasai kursus makroekonomi berbanding mikroeokonomi. Topik-topik dalam kursus makroekonomi ini agak susah kerana melibatkan banyak teori seperti peranan kerajaan dalam merangka belanjawan, perbelanjaan kerajaan, hasil kerajaan dan dasar-dasar kerajaan. Topik yang melibatkan pengiraan hanya dua topik iaitu pendapatan negara dan keseimbangan pendapatan negara. Namun, pencapaian yang baik dalam mikroekonomi adalah kerana kursus ini banyak melibatkan pengiraan seperti fungsi permintaan, fungsi penawaran, keseimbangan pasaran, keanjalan dan tahap pengeluaran.

Terdapat segelintir pelajar yang gagal dalam kursus mikroekonomi. Kegagalan mereka ini menyebabkan mereka perlu mengulang kursus ini pada semester berikutnya sehingga mendatangkan kesan-kesan yang negatif terhadap pelajar. Implikasi daripada masalah ini ialah pelajar akan mengalami gangguan dalam penyusunan jadual program asal mereka. Antara masalah yang sering berlaku ialah pertindihan jadual waktu antara kursus yang di ulang dengan kursus yang wajib di ambil dalam semester berikutnya. Akibatnya wujud pelajar yang terpaksa menamatkan pengajian melebihi tempoh masa yang ditetapkan.

Mungkin terdapat pelbagai faktor kegagalan pelajar tersebut, namun wujud tanggapan bahawa pelajar yang gagal atau mendapat keputusan yang kurang cemerlang dalam Makroekonomi mungkin disebabkan oleh prestasi yang kurang baik dalam kursus yang berkonsepkan kepada

bidang atau kursus yang memberi penekanan utama kepada pemahaman konsep, prinsip, dan asas pengetahuan yang diasaskan kepada teori-teori tertentu, berbanding dengan aplikasi praktikal atau amali. Oleh itu, kajian ini dilaksanakan untuk melihat hubungan signifikan pencapaian mikroekonomi dan makroekonomi di kalangan pelajar.

3. Literatur Kajian

Pengajaran subjek Ekonomi menjadi lebih bermakna apabila guru berjaya menarik minat serta keyakinan pelajar terhadap mata pelajaran ini. Oleh itu, guru perlu bersikap kreatif dan inovatif dalam merancang dan melaksanakan proses pengajaran dan pembelajaran (PdP), khususnya bagi membantu pelajar menjawab soalan esei dengan tepat dan berkesan (Tun Sulung et al., 2023) Tahap kemahiran pedagogi guru turut mencerminkan kecekapan kepimpinan mereka, lebih-lebih lagi apabila guru berusaha memastikan kejayaan pelajar, membina persekitaran positif, serta bersikap terbuka dalam berkongsi ilmu (Musa & Seng, 2017). Pendekatan PdP yang menarik dan tidak rutin amat penting dalam membentuk pengetahuan, sikap dan tingkah laku positif dalam kalangan pelajar, dan guru harus sentiasa berusaha melakukan penambahbaikan secara berterusan (Jusoh et al., 2017).

Selain itu, elemen pengetahuan, sikap dan pendekatan pembelajaran dalam subjek Ekonomi perlu diberi perhatian serius oleh pihak berkaitan untuk meningkatkan prestasi pelajar, lebih-lebih lagi dalam era persaingan akademik yang semakin mencabar, yang mencerminkan kualiti sesebuah institusi pendidikan (Salam et al., 2022)

Peningkatan sikap positif dan penerimaan pelajar terhadap pembelajaran berasaskan komputer menjadikan mereka lebih yakin dan berkesan dalam pembelajaran meskipun teknologi menjadi semakin kompleks. Menurut Puteh & Salam (2011) penggunaan teknologi maklumay dan komunikasi (ICT) sebagai strategi pendidikan menyeluruh mampu meningkatkan pencapaian pelajar. Guru pula perlu lebih kreatif dan inovatif dalam mencari pendekatan baharu bagi meningkatkan motivasi dan minat pelajar. ICT bukan sahaja menyokong keberkesanan PdP, malah turut mempertingkatkan produktiviti serta keberkesanan pengurusan. Dalam pembelajaran Makroekonomi, penggunaan ICT secara interaktif didapati meningkatkan keyakinan pelajar, terutamanya apabila bahan elektronik (softcopy) digunakan dalam e-pembelajaran yang lebih menarik berbanding bahan bercetak. Hal ini mendorong penglibatan aktif pelajar dalam kuliah dan mewujudkan keperluan untuk terus meneroka kaedah interaktif yang menyeronokkan (Zakaria, 2024).

Kajian Mujianto (2019) pula menunjukkan bahawa pelajar menganggap YouTube sebagai media pengajaran yang berkesan untuk mendapatkan maklumat, hiburan, dan perkongsian video. Rakaman video boleh dimuat naik ke YouTube dan diapresiasi oleh pengguna lain, manakala penggunaan aplikasi seperti Kahoot terbukti membantu pemahaman dan pencapaian pelajar berbanding kaedah konvensional (Mohd Nordin & Hasan, 2018). Aplikasi ini memperkenalkan elemen pertandingan secara langsung dan membolehkan pensyarah mendapatkan analisis jawapan pelajar secara individu, sekali gus memudahkan pelaksanaan aktiviti pemulihan. Kaedah ini bukan sahaja interaktif dan inovatif, malah berfungsi sebagai alat penilaian pantas dan tepat terhadap penguasaan pelajar.

Sementara itu, Chooi Yi (2017) menyatakan bahawa pengajaran topik-topik ekonomi membantu pelajar memahami isu berkaitan sumber terhad serta membuat keputusan yang rasional. Pemahaman terhadap konsep-konsep seperti permintaan dan penawaran, keseimbangan pasaran, keanjalan dan campur tangan kerajaan membolehkan pelajar berperanan sebagai pengguna dan pengeluar yang bertanggungjawab. Dalam konteks makroekonomi, pelajar dapat memahami isu ekonomi Malaysia, serta konsep ekonomi terbuka dan tertutup. Kaedah tutor sebaya dengan bantuan rakaman audio-video pensyarah didapati berkesan dalam meningkatkan

prestasi pelajar, mendorong pembelajaran aktif, memupuk kemahiran komunikasi dan pemikiran kritikal, serta mewujudkan suasana pembelajaran yang kondusif.

Dalam kursus Mikroekonomi, kemahiran analitikal dan visualisasi sangat penting. Pelajar perlu mampu menyelesaikan masalah ekonomi melalui kemahiran mengira, melakar dan mentafsir keluk serta data. Namun begitu, kesukaran dalam visualisasi sering menghalang kefahaman mereka. Pengajaran berasaskan hafalan pula tidak menyokong perkembangan kognitif dan kreativiti pelajar (Ali et al., 2024). Kelemahan dalam kemahiran asas statistik, matematik dan interpretasi graf turut menyukarkan pemahaman ekonomi. Oleh itu, pembangunan kemahiran visualisasi sangat penting bukan sahaja untuk memahami konsep ekonomi, malah juga dalam membina kreativiti dan keupayaan sintesis yang diperlukan dalam dunia pekerjaan.

Akhir sekali, kajian Jelas et al. (2005) menunjukkan bahawa pelajar perempuan mempunyai kemahiran dan strategi pembelajaran yang lebih baik berbanding pelajar lelaki. Mereka juga lebih jelas tentang cita-cita dan matlamat pendidikan. Oleh itu, guru perlu membantu pelajar lelaki meningkatkan kemahiran belajar serta membina wawasan pendidikan yang lebih mantap. Ketidaksamaan kadar kematangan antara jantina menuntut guru agar mengaplikasikan pendekatan pengajaran yang pelbagai dari segi kaedah, teknik, aktiviti dan bahan supaya dapat memenuhi keperluan dan kepelbagaian pelajar.

4. Metodologi

Kajian ini telah dijalankan dengan menggunakan pendekatan kuantitatif berbentuk deskriptif, yang bertujuan untuk menganalisis dan menghuraikan data secara sistematik berdasarkan pemerhatian terhadap pola-pola tertentu dalam keputusan peperiksaan pelajar. Semua maklumat yang digunakan dalam kajian ini diperoleh secara rasmi daripada Sistem Pengurusan Maklumat Politeknik (SPMP) melalui platform i-Exam yang digunakan oleh institusi untuk pengurusan data peperiksaan.

Data utama dalam kajian ini terdiri daripada keputusan peperiksaan akhir bagi dua kursus teras dalam bidang ekonomi, iaitu kursus DPB10033 – Mikroekonomi bagi Sesi 1 Tahun Akademik 2024/2025 dan kursus DPB20033 – Makroekonomi bagi Sesi 2 Tahun Akademik 2024/2025. Kedua-dua kursus ini merupakan sebahagian daripada sukatan pelajaran bagi program Diploma Akauntansi yang ditawarkan oleh Jabatan Perdagangan di politeknik terlibat.

Populasi kajian ini merangkumi keseluruhan pelajar Diploma Akauntansi yang mengambil kedua-dua kursus tersebut, yang terdiri daripada empat kelas iaitu DAT A, DAT B, DAT C dan DAT D. Jumlah keseluruhan pelajar yang terlibat sebagai sampel dalam kajian ini adalah seramai 137 orang. Sampel ini dipilih berdasarkan ketersediaan dan kesempurnaan data yang diperoleh daripada sistem. Perincian kategori pelajar mengikut pembahagian kelas dapat dirujuk dalam Jadual 1, yang menunjukkan bilangan responden dari setiap kelas yang terlibat dalam kajian ini.

Jadual 1. Kekerapan dan Peratus Pelajar Diploma Akauntansi Semester 2 Jabatan Perdagangan Mengikut Jantina dan Kelas

		Bilangan	Peratus
Jantina	Lelaki	34	24.6
	Perempuan	103	74.6
Kelas	DAT 2A	33	24.1
	DAT 2B	36	26.3
	DAT 2C	36	26.3
	DAT 2D	32	23.4
Jumlah		137	

Untuk mencapai objektif kajian, data yang dikumpul akan dianalisis secara komprehensif menggunakan perisian Statistical Package for the Social Sciences (SPSS).

5. Keputusan dan Perbincangan

Hasil keputusan dan perbincangan akan diolah mengikut objektif yang telah dinyatakan pada awal penyelidikan

H_{01}: Jantina pelajar mempengaruhi pencapaian pelajar di dalam kursus Mikroekonomi.

Berdasarkan analisis korelasi Pearson yang telah dijalankan ke atas data seramai 137 orang responden, dapatan kajian menunjukkan bahawa terdapat hubungan yang signifikan dan positif antara pemboleh ubah jantina dengan pencapaian pelajar dalam kursus Mikroekonomi. Hasil analisis menunjukkan nilai pekali korelasi Pearson r=0.222 dengan nilai signifikan p=0.009. Oleh kerana nilai ini adalah lebih kecil daripada aras signifikan 0.01 (dua-hala), maka dapat disimpulkan bahawa hubungan antara jantina dan pencapaian pelajar adalah signifikan secara statistik, walaupun kekuatannya berada pada tahap rendah.

Penemuan ini memberikan gambaran bahawa perbezaan jantina mempunyai kesan tertentu, meskipun kecil, terhadap prestasi akademik pelajar dalam kursus Mikroekonomi. Secara purata, salah satu kumpulan jantina, sama ada lelaki atau perempuan, telah menunjukkan pencapaian yang lebih tinggi dalam kursus ini, bergantung kepada pengekodan data. Hubungan ini berkemungkinan dipengaruhi oleh pelbagai faktor, termasuk gaya pembelajaran, tahap minat terhadap mata pelajaran yang berasaskan kuantitatif, serta tahap keyakinan pelajar dalam menyelesaikan masalah berasaskan logik dan pengiraan.

Jadual 2. Jadual Korelasi antara Jantina dan Pencapaian Mikroekonomi Pelajar Diploma Akauntansi Semester 2 Jabatan Perdagangan

		Mikroekonomi
Jantina	Pearson Correlation	.222**
	Sig. (2-tailed)	.009
	N	137

Bagi menguji kekuatan hubungan antara Jantina dan pencapaian pelajar di dalam Mikroekonomi, analisis regresi berganda telah dilaksanakan. Jadual 3 menunjukkan hasil Keputusan analisis regresi berganda dengan meletakkan pencapaian pelajar di dalam Mikroekonomi sebagai pemboleh ubah bersandar.

Jadual 3. Hasil Keputusan Analisis Regresi Bagi Pencapaian Pelajar di dalam Mikroekonomi dan Jantina

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
1 (Constant)	70.871	4.547		15.585	.000
Jantina	4.948	2.118	.189	2.336	.021

Nota. a. Dependent Variable: Mikroekonomi

Bagi model pertama, di mana pencapaian pelajar di dalam Mikroekonomi ditetapkan sebagai pemboleh ubah bersandar, keputusan daripada analisis regresi menunjukkan bahawa pemboleh ubah jantina memberikan sumbangan yang signifikan secara statistik terhadap pencapaian pelajar dalam kursus tersebut. Nilai koefisien tidak piawai (unstandardized coefficient) yang diperoleh bagi pemboleh ubah jantina ialah β=4.948, dengan nilai statistik t=2.336 dan nilai signifikan p=0.021. Oleh kerana nilai p ini adalah lebih kecil daripada aras signifikan konvensional iaitu 0.05, maka dapat disimpulkan bahawa jantina adalah peramal yang signifikan dalam model

regresi ini dan mempunyai kesan yang bermakna terhadap skor pelajar dalam kursus Mikroekonomi.

Penemuan ini menunjukkan bahawa terdapat perbezaan purata skor Mikroekonomi yang signifikan secara statistik antara kategori jantina pelajar. Secara lebih spesifik, satu kategori jantina mencatatkan skor pencapaian Mikroekonomi yang lebih tinggi sebanyak 4.948-unit secara purata berbanding kategori jantina yang lain. Ini menggambarkan bahawa jantina pelajar memberi kesan yang nyata terhadap pencapaian akademik dalam kursus yang bersifat kuantitatif ini.
Penemuan ini turut selaras dengan hasil analisis korelasi Pearson yang dijalankan sebelum ini, yang turut menunjukkan kewujudan hubungan positif dan signifikan antara jantina dan pencapaian dalam Mikroekonomi ($r = 0.222$, $p = 0.009$). Konsistensi antara kedua-dua hasil analisis ini memberikan keyakinan terhadap kesahihan dapatan serta menguatkan andaian bahawa jantina bukan sahaja berkorelasi dengan prestasi, malah turut memainkan peranan sebagai peramal kepada variasi pencapaian pelajar dalam subjek tersebut.

Penemuan ini penting kerana ia membuka ruang kepada pemahaman yang lebih mendalam tentang peranan faktor demografik seperti jantina dalam pencapaian akademik pelajar, khususnya dalam subjek Mikroekonomi yang menekankan kepada pemikiran logik, pengiraan kuantitatif dan pemahaman konsep ekonomi asas. Perbezaan ini mungkin disumbangkan oleh pelbagai faktor termasuk gaya pembelajaran yang berbeza antara pelajar lelaki dan perempuan, tahap keyakinan diri dalam menyelesaikan masalah kuantitatif, perbezaan minat terhadap topik ekonomi, atau perbezaan dalam pendekatan terhadap tugasan dan peperiksaan.

Penemuan ini selari dengan dapatan kajian lepas oleh Pargulski & Reynolds (2017) yang mendapati bahawa pelajar lelaki cenderung menunjukkan prestasi lebih baik dalam subjek ekonomi yang menekankan aspek kuantitatif, disebabkan oleh tahap keyakinan yang lebih tinggi terhadap kemahiran matematik. Ini selaras dengan kajian yang telah dibuat oleh Del Río & Strasser (2013) dan Parker et al. (2018) melaporkan bahawa kanak-kanak perempuan melaporkan bahawa matematik adalah sukar bagi mereka dan sering menunjukkan pencapaian yang lemah dalam subjek matematik berbanding dengan kanak-kanak lelaki. Namun begitu, kajian oleh Kocsis & Molnár (2025) pula menekankan bahawa beza jantina dalam prestasi akademik tidak hanya bergantung kepada kemampuan semata-mata, sebaliknya juga dipengaruhi oleh faktor motivasi intrinsik, strategi pembelajaran yang dikawal sendiri (*self-regulated learning strategies*), *self-efficacy*, dan pendidikan terdahulu.

Tambahan pula, Andini & Prastiyowati (2021) mendapati bahawa strategi pembelajaran berbeza antara pelajar lelaki dan perempuan turut menyumbang kepada perbezaan pencapaian dalam ssesuatu subjek. Ini menunjukkan bahawa faktor jantina, meskipun bukan penentu tunggal, boleh memainkan peranan penting dalam membentuk prestasi pelajar dalam bidang pengajian yang kompleks seperti Mikroekonomi.
Secara keseluruhannya, dapatan ini menyokong keperluan untuk pendidik memahami dinamika jantina dalam bilik kuliah, dan seterusnya membangunkan pendekatan pengajaran yang inklusif dan adaptif, agar potensi setiap pelajar dapat dimaksimumkan tanpa mengira latar belakang jantina mereka.
H_{02}: Jantina pelajar mempengaruhi pencapaian pelajar di dalam kursus Makroekonomi.

Berdasarkan analisis korelasi Pearson yang telah dijalankan ke atas data seramai 137 orang responden, hasil analisis menunjukkan bahawa tiada hubungan yang signifikan antara pemboleh ubah jantina dengan pencapaian pelajar dalam kursus Makroekonomi. Nilai pekali korelasi yang diperoleh adalah $r=0.113$ dengan nilai signifikan $p=0.189$. Oleh kerana nilai p ini adalah lebih besar daripada aras signifikan yang ditetapkan, iaitu 0.01 (dua-hala), maka dapatan ini secara

statistik menunjukkan bahawa perbezaan jantina tidak memberi kesan yang signifikan terhadap pencapaian pelajar dalam kursus Makroekonomi.
Dengan kata lain, keputusan ini memberikan gambaran bahawa jantina bukanlah faktor utama atau peramal penting yang mempengaruhi prestasi pelajar dalam subjek ini. Sama ada pelajar itu lelaki mahupun perempuan, skor pencapaian mereka dalam Makroekonomi tidak menunjukkan perbezaan yang signifikan secara statistik, sekaligus mencadangkan bahawa faktor lain mungkin lebih relevan dalam menjelaskan variasi pencapaian pelajar bagi kursus ini.

Secara keseluruhannya, hasil analisis ini menunjukkan bahawa faktor jantina tidak memainkan peranan utama dalam menentukan pencapaian akademik dalam Makroekonomi, dan sebarang intervensi atau penambahbaikan pengajaran dalam subjek ini mungkin lebih sesuai difokuskan kepada gaya pembelajaran, tahap penguasaan awal pelajar, atau keberkesanan pendekatan pengajaran yang digunakan oleh pensyarah berbanding kepada perbezaan jantina semata-mata.

Jadual 4. Jadual Korelasi antara Jantina dan Pencapaian Makroekonomi Pelajar Diploma Akauntansi Semester 2 Jabatan Perdagangan

		Makroekonomi
Jantina	Pearson Correlation	.113
	Sig. (2-tailed)	.189
	N	137

Bagi menguji kekuatan hubungan antara Jantina dan pencapaian pelajar di dalam Makroekonomi, analisis regresi berganda telah dilaksanakan. Jadual 5 menunjukkan hasil Keputusan analisis regresi berganda dengan meletakkan pencapaian pelajar di dalam Makroekonomi sebagai pemboleh ubah bersandar.

Jadual 5. Hasil Keputusan Analisis Regresi Bagi Pencapaian Pelajar di dalam Makroekonomi dan Jantina

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
1 (Constant)	63.787	4.906		13.002	.000
Jantina	2.845	2.285	.107	1.245	.215

Nota. a. Dependent Variable: Makroekonomi

Bagi model kedua, di mana pencapaian pelajar di dalam Makroekonomi ditetapkan sebagai pemboleh ubah bersandar, hasil analisis regresi menunjukkan bahawa jantina tidak memberikan sumbangan yang signifikan secara statistik terhadap pencapaian pelajar dalam kursus Makroekonomi. Nilai koefisien yang diperoleh ialah β=2.845, dengan nilai statistik t=1.245 dan nilai signifikan p=0.215, iaitu melebihi aras signifikan 0.05. Ini menandakan bahawa jantina bukanlah indikator yang signifikan dalam model ini dan tidak mempunyai impak statistik yang ketara terhadap pencapaian pelajar dalam subjek Makroekonomi.

Penemuan ini selaras dengan analisis korelasi Pearson terdahulu, yang turut menunjukkan tiada hubungan yang signifikan antara jantina dan pencapaian pelajar di dalam Makroekonomi. Ini mencadangkan bahawa prestasi pelajar dalam Makroekonomi tidak dipengaruhi oleh faktor jantina secara langsung. Sebaliknya, mungkin terdapat pemboleh ubah lain yang tidak dimasukkan dalam model ini yang berpotensi memberikan kesan yang lebih besar terhadap pencapaian pelajar dalam subjek tersebut, seperti tahap literasi ekonomi, minat terhadap isu ekonomi semasa, atau keberkesanan kaedah pengajaran.

Penemuan ini juga tidak selaras dengan dapatan yang diperoleh bagi subjek Mikroekonomi, di mana jantina didapati mempunyai hubungan signifikan terhadap pencapaian pelajar. Ketidakkonsistenan ini berkemungkinan besar disebabkan oleh perbezaan dari segi struktur kandungan kursus, pendekatan pengajaran, tahap aplikasi teori ekonomi, atau tahap penglibatan pelajar dalam kelas. Berbanding Mikroekonomi yang sering melibatkan pengiraan dan model matematik, kursus Makroekonomi mungkin lebih menekankan kepada pemahaman konsep makro seperti inflasi, pengangguran, dasar fiskal dan monetari, yang mungkin tidak dipengaruhi secara langsung oleh faktor jantina.

Selain itu, kajian terdahulu seperti yang dibincangkan oleh Stopol & Bedard (2018) turut mendapati bahawa perbezaan jantina dalam prestasi kursus ekonomi adalah lebih ketara dalam subjek kuantitatif, manakala dalam subjek yang lebih konseptual seperti Makroekonomi, perbezaan jantina cenderung untuk menjadi tidak signifikan. Hal ini menyokong dapatan dalam kajian ini, dan mencadangkan bahawa pendidik perlu lebih menumpukan perhatian kepada faktor-faktor lain seperti tahap literasi ekonomi pelajar, motivasi dalaman, strategi belajar kendiri, serta pengalaman terdahulu pelajar dalam mata pelajaran yang berkaitan.

Secara keseluruhannya, hasil analisis ini menunjukkan bahawa faktor jantina tidak memainkan peranan utama dalam menentukan pencapaian akademik dalam Makroekonomi, dan sebarang intervensi atau penambahbaikan pengajaran dalam subjek ini mungkin lebih sesuai difokuskan kepada gaya pembelajaran, tahap penguasaan awal pelajar, atau keberkesanan pendekatan pengajaran yang digunakan oleh pensyarah berbanding kepada perbezaan jantina semata-mata. Tambahan lagi, penemuan ini juga memberi isyarat bahawa hubungan antara jantina dan prestasi akademik dalam kursus Makroekonomi mungkin lebih kompleks dan tidak semestinya bersifat linear. Oleh itu, kajian lanjutan boleh dijalankan dengan memasukkan pemboleh ubah moderator atau mediator untuk meneroka kemungkinan hubungan tidak langsung atau interaksi yang lebih kompleks antara pemboleh ubah-pemboleh ubah yang terlibat.
H_{03}: Pencapaian pelajar di dalam Mikroekonomi mempengaruhi pencapaian pelajar di dalam Makroekonomi

Berdasarkan analisis korelasi Pearson yang telah dijalankan ke atas data seramai 137 orang responden (seperti yang terdapat pada Jadual 6), dapatan kajian mendapati bahawa terdapat hubungan yang sangat signifikan dan positif antara pencapaian pelajar dalam kursus Mikroekonomi dan Makroekonomi. Nilai pekali korelasi yang diperoleh adalah tinggi, iaitu r=0.615, dengan nilai signifikan p=0.000. Oleh kerana nilai p ini adalah jauh lebih kecil daripada aras signifikan yang ditetapkan (0.01), maka hubungan ini boleh dianggap sangat signifikan dari sudut statistik, dan menunjukkan hubungan linear yang kukuh antara pencapaian pelajar dalam kedua-dua subjek berkenaan.

Penemuan ini memberikan gambaran yang jelas bahawa pelajar yang menunjukkan prestasi cemerlang dalam kursus Mikroekonomi berkemungkinan besar akan turut mencapai keputusan yang baik dalam kursus Makroekonomi. Hubungan yang kuat ini mencadangkan bahawa kejayaan dalam satu kursus mempunyai perkaitan rapat dengan kejayaan dalam kursus yang lain, mungkin kerana wujud elemen kemahiran asas yang saling berkait, seperti pemikiran analitik, kefahaman terhadap konsep ekonomi asas, keupayaan menyelesaikan masalah, dan kemahiran interpretasi data ekonomi.

Selain itu, kemungkinan besar struktur pengajaran, kaedah penilaian, serta pendekatan pembelajaran yang digunakan dalam kedua-dua kursus tersebut adalah relatif serupa, yang menyumbang kepada kekuatan hubungan antara pencapaian pelajar dalam kedua-dua subjek.

Sebagai contoh, sekiranya kursus Mikroekonomi menekankan pemahaman terhadap permintaan dan penawaran, elastisiti, serta tingkah laku firma dan pengguna, dan Makroekonomi pula memperluas konsep-konsep ini kepada tahap agregat seperti pertumbuhan ekonomi, inflasi dan dasar kerajaan, maka pelajar yang telah menguasai asas dalam Mikroekonomi akan lebih bersedia untuk memahami kandungan Makroekonomi yang lebih luas dan kompleks.
Penemuan ini juga selari dengan kajian lepas seperti yang dilaporkan oleh Anderson et al. (1994), yang mendapati bahawa prestasi dalam kursus pengantar ekonomi mikro adalah peramal yang baik bagi pencapaian dalam kursus ekonomi lanjutan, termasuk Makroekonomi. Hal ini menunjukkan bahawa penguasaan awal terhadap konsep mikro berfungsi sebagai asas yang kukuh bagi memahami kerangka makro. Dalam konteks ini, kejayaan pelajar dalam kedua-dua subjek mungkin juga dipengaruhi oleh faktor-faktor intrinsik seperti tahap motivasi, disiplin belajar, serta minat terhadap subjek ekonomi secara umum.

Secara keseluruhannya, dapatan ini memberikan implikasi penting kepada pihak pengajar dan penyedia kurikulum. Ia menunjukkan bahawa usaha untuk meningkatkan pencapaian pelajar dalam kursus Mikroekonomi mungkin akan memberi kesan positif secara tidak langsung terhadap pencapaian mereka dalam kursus Makroekonomi. Oleh itu, pelaksanaan program pengukuhan awal dalam Mikroekonomi seperti bimbingan tambahan, tutorial bertumpu, atau aktiviti pengayaan boleh menjadi antara strategi yang berkesan dalam memperkukuhkan prestasi pelajar secara menyeluruh dalam bidang ekonomi.

Jadual 6. Jadual Korelasi antara Pencapaian Mikroekonomi dan Pencapaian Makroekonomi Pelajar Diploma Akauntansi Semester 2 Jabatan Perdagangan

		Makroekonomi
Mikroekonomi	Pearson Correlation	.615**
	Sig. (2-tailed)	.000
	N	137

Jadual 7. Hasil Keputusan Analisis Regresi Bagi Pencapaian Pelajar di dalam Makroekonomi dan Pencapaian Pelajar di dalam Makroekonomi

	Unstandardized Coefficients		Standardized Coefficients		
Model	B	Std. Error	Beta	t	Sig.
1 (Constant)	22.753	5.007		4.544	< .001
Mikroekonomi	.622	.069	0.615	9.054	<.001

Nota. a. Dependent Variable: Makroekonomi

Jadual 7 membentangkan keputusan daripada analisis regresi yang dijalankan untuk menentukan sumbangan pencapaian dalam kursus Mikroekonomi terhadap pencapaian dalam kursus Makroekonomi, dengan Makroekonomi ditetapkan sebagai pemboleh ubah bersandar dan Mikroekonomi sebagai pemboleh ubah peramal. Objektif utama analisis ini adalah untuk mengenal pasti sama ada prestasi pelajar dalam Mikroekonomi dapat meramalkan prestasi mereka dalam Makroekonomi secara signifikan.

Hasil analisis menunjukkan bahawa pemboleh ubah Mikroekonomi mempunyai kesan positif yang sangat signifikan secara statistik ke atas pencapaian dalam Makroekonomi. Ini ditunjukkan melalui nilai koefisien tidak piawai (unstandardized coefficient) iaitu $\beta = 0.622$, nilai statistik $t = 9.054$, dan nilai signifikan $p < 0.001$. Nilai p yang sangat kecil ini (jauh di bawah aras signifikan konvensional 0.01) memberikan bukti yang kukuh bahawa pencapaian dalam Mikroekonomi merupakan peramal yang sah dan kuat terhadap pencapaian dalam kursus Makroekonomi.

Secara interpretasi, nilai β = 0.622 menunjukkan bahawa setiap peningkatan satu unit dalam pencapaian Mikroekonomi dijangka akan meningkatkan pencapaian Makroekonomi sebanyak 0.622-unit secara purata, dengan syarat semua faktor lain adalah malar. Ini menggambarkan satu hubungan langsung yang kuat antara kedua-dua subjek tersebut.

Selain itu, nilai Beta piawai (standardized coefficient) yang diperoleh adalah β=0.615, yang menunjukkan bahawa Mikroekonomi merupakan peramal yang sangat kuat secara statistik dan praktikal terhadap Makroekonomi dalam model ini. Nilai ini selaras dengan pekali korelasi Pearson antara kedua-dua pemboleh ubah yang juga tinggi (r = 0.615), sekali gus menunjukkan bahawa hubungan tersebut bukan sahaja wujud secara linear, malah dapat diramalkan dengan kebolehpercayaan yang tinggi melalui model regresi ini.

Penemuan ini membawa implikasi penting bahawa kejayaan dalam subjek Mikroekonomi dapat dijadikan indikator awal atau penunjuk aras kepada prestasi pelajar dalam Makroekonomi. Hal ini menyokong teori bahawa kedua-dua kursus ini berkongsi struktur pemikiran ekonomi, kemahiran analitikal, dan pendekatan penyelesaian masalah yang serupa. Oleh itu, pelajar yang menunjukkan penguasaan yang baik dalam konsep-konsep asas Mikroekonomi seperti penawaran dan permintaan, keseimbangan pasaran, serta keanjalan harga, lebih bersedia untuk memahami konsep-konsep Makroekonomi yang lebih kompleks seperti Keluaran Dalam Negara Kasar (KDNK), kadar inflasi, dan dasar kewangan.

Penemuan ini turut konsisten dengan kajian terdahulu oleh (Anderson et al., 1994) dan (Ahlstrom & Switzer, 2024) yang menyatakan bahawa prestasi pelajar dalam kursus pengenalan ekonomi mikro mempunyai nilai ramalan yang tinggi terhadap pencapaian dalam kursus ekonomi makro. Dalam konteks pendidikan politeknik atau institusi pengajian tinggi, dapatan ini memberikan petunjuk berguna kepada pensyarah dan pentadbir kurikulum bahawa intervensi awal dalam pengajaran dan pemahaman Mikroekonomi dapat memberikan kesan berganda terhadap pencapaian pelajar dalam keseluruhan pembelajaran ekonomi.

Secara keseluruhannya, model regresi ini bukan sahaja membuktikan secara statistik bahawa Mikroekonomi adalah peramal signifikan terhadap Makroekonomi, malah turut memberikan asas empirikal kepada strategi pengajaran dan pembangunan kurikulum bersepadu, yang menekankan kesinambungan pengetahuan dan kemahiran antara kursus ekonomi asas dan lanjutan.

6. Kesimpulan dan Cadangan

Secara keseluruhannya, dapatan kajian menunjukkan bahawa terdapat hubungan yang signifikan antara jantina dan pencapaian dalam kursus Mikroekonomi, namun hubungan tersebut tidak wujud dalam kursus Makroekonomi. Ini mencadangkan bahawa jantina memainkan peranan dalam subjek yang bersifat kuantitatif seperti Mikroekonomi, tetapi kurang relevan dalam subjek yang lebih konseptual seperti Makroekonomi. Selain itu, kajian turut mendapati bahawa pencapaian dalam kursus Mikroekonomi mempunyai hubungan yang sangat kuat dan signifikan dengan pencapaian dalam kursus Makroekonomi. Malah, melalui analisis regresi, didapati bahawa Mikroekonomi merupakan peramal yang kukuh terhadap prestasi pelajar dalam Makroekonomi. Dapatan ini menekankan pentingnya penguasaan awal dalam kursus asas ekonomi untuk kejayaan dalam kursus lanjutan.

Berdasarkan hasil kajian, beberapa cadangan boleh dikemukakan. Pertama, pihak pensyarah disarankan memberi penekanan yang lebih mendalam terhadap penguasaan konsep dalam kursus Mikroekonomi kerana prestasi dalam kursus ini terbukti memberi kesan langsung terhadap

pencapaian dalam Makroekonomi. Pelaksanaan aktiviti pengukuhan seperti kelas tambahan atau sesi tutorial berstruktur boleh membantu pelajar yang lemah. Selain itu, kurikulum perlu disusun secara progresif dan saling melengkapi antara kursus asas dan lanjutan agar pelajar dapat membina pemahaman secara berperingkat. Pendekatan pengajaran juga perlu lebih inklusif dan mengambil kira perbezaan gaya pembelajaran mengikut jantina, khususnya bagi subjek seperti Mikroekonomi. Di samping itu, kajian lanjutan disarankan untuk melibatkan pemboleh ubah tambahan seperti tahap minat pelajar, strategi pembelajaran, atau faktor motivasi dalaman bagi memberi gambaran yang lebih menyeluruh terhadap prestasi akademik. Akhir sekali, penggunaan teknologi seperti alat bantu digital dan kecerdasan buatan boleh diteroka bagi meningkatkan pemahaman pelajar terhadap konsep ekonomi yang kompleks dan meningkatkan penglibatan secara aktif dalam proses pembelajaran.

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ENHANCING TEACHING AID TOOL THROUGH THE MAPPING BUDDIES PLATFORM: A CASE STUDY IN TUANKU SULTANAH BAHIYAH POLYTECHNIC

Hasmawazi binti Hamzah, Intan Radina binti Ahmad*, Nurfah Nabilah binti Mohd Fadzil

Commerce Department, Tuanku Sultanah Bahiyah Polytechnic, Kulim Hi-Tech Park, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: intan.radina@ptsb.edu.my

Abstract

A teaching aid tool can benefit both the lecturer and the students in the classroom and add interest to the lesson. In addition, the material can be presented effectively and understood by the students. To achieve that goal, the Mapping Buddies Platform was developed, and this invention can benefit students studying commerce. The teaching aid tool is a mind map approach. Students will complete the mind map after the end of each topic. This innovation all started when students had difficulty memorizing the contents in commerce subjects. Moreover, in order to boost their memorization, they have to practice writing the idea of the subject. Thus, the main objective of this paper is to find out the effectiveness of using the Mapping Buddies Platform and to foster creative thinking among students. Additionally, the goal of this paper is to develop an innovative product that will enhance students' understanding and help them quickly and efficiently memorise the information in the commerce subjects. The analysis's conclusion demonstrates that learning implementation is more successful and can boost students' motivation and academic performance.

Keywords: teaching aid tool, platform, teaching and learning, mind map

1. Introduction

Lecturers implement different approaches during delivering information to students to ensure the successful execution and effectiveness of the educational and learning process. Besides that, lecturers can use a range of techniques to make the lesson more engaging for students and increase the effectiveness of the teaching and learning process. Moreover, lecturers can use teaching aids to capture students' attention and stimulate their interest in the subject matter in addition to enhancing their engaging and successful teaching methods.

With the use of teaching aids, students can become more curious and gain a thorough understanding of each subject. To put it another way, lecturers can make learning engaging and successful (Daud et al., n.d.). Students will be more focused and attentive when using the teaching aids, which will improve their overall understanding of each subject they have studied. Therefore, using educational tools can help lecturers as well as improve student performance. The use of instructional tools that are both safe and capable of enhancing the dynamic nature of the classroom is encouraged. Due to insufficient instructional aids, students may have a lower understanding of the teaching and learning process (Basiron, 2012). According to the results of earlier research, using instructional aids can enhance students' theoretical comprehension and foster their creativity (Falina et al., 2021). Therefore, the purpose of this study is to determine how beneficial the Knowledge Buddies Platform is. Since this innovative product is being used for students in the Commerce Department, the requirement for this teaching aid tool in the teaching and learning process is critical.

A key role in developing future business, management, and commerce experts is played by Politeknik Tuanku Sultanah Bahiyah's (PTSB) Commerce Department. It supports the polytechnic's objective of generating graduates who are competent, diverse, and prepared for the workforce by meeting industry demands as one of the main academic divisions within the institution. Diploma programs in business studies, marketing, and accounting are among those offered by the department. In order to satisfy the ever-changing demands of both domestic and international business contexts, these programs are regularly assessed and created in accordance with the Malaysian Qualifications Framework (MQF). The Commerce Department prioritises student-centered learning strategies such as Collaborative Learning in accordance with the Outcome-Based Education (OBE) framework. These approaches seek to develop the critical thinking, communication, and leadership abilities that graduates need when they enter the corporate world.

Furthermore, a lot of mixed learning environments are supported by digital tools and platforms like Google Classroom, Kahoot, Padlet, and Microsoft Teams, particularly given the post-pandemic change in the way education is delivered. As a result, the Mapping Buddies Platform may help students efficiently learn commerce subjects when used as a teaching aid.

1.1 The Rise of Teaching Aids in Modern Education

Teaching aids are tools that help students study a subject more effectively by making the teaching and learning process easier (Widiyatmoko & Nurmasitah, 2014). Additionally, it enhances the classroom teaching and learning process. In addition, it is considered an essential feature because it can assist students in better comprehending and grasping a subject. Textbooks, reference books, images, films, games, and other resources that are appropriate for the times and technology can all be used as teaching aids.

In order to save money, teaching aids might be developed by students or teachers themselves, utilising a variety of waste items (Widiyatmoko & Nurmasitah, 2014). This is demonstrated by the creation of instructional aids from used boxes and magazine scraps. In addition, teaching tools facilitate learning through a variety of techniques, including speaking, listening, and exchanging ideas with peers (Widiyatmoko & Nurmasitah, 2014).

1.2 The Outline of Mapping Buddies Platform

Mapping Buddies Platform is a digital learning platform developed using Google Sites, aimed at gathering teaching and learning materials across a variety of subjects or courses. This platform offers a well-organized and user-friendly interface where lecturers can easily upload and share notes, interactive activities, and reference links (Roodt & de Villiers, 2012). It enhances collaboration and accessibility between lecturers and students, especially through the integration of Google Workplace tools such as Google Docs, Slides, and Drive (Harsanto, 2022). In addition, its responsive design allows students to access content smoothly across multiple devices, making the learning process both inside and outside the classroom more flexible and inclusive (Gumjudpai & Somrat, 2021).

Mind mapping is a graphic technique based on the concept of *Radiant Thinking*, a form of associative thought process closely related to the natural function of the human mind (Buzan, 1993). It serves as a powerful visual tool that helps individuals unlock and enhance their cognitive potential. According to Ibrahim (2013), four fundamental features of mind maps are as follows: the main theme extends from the centre as branches, each branch contains a keyword or image

printed along a connecting line, the branches form a connected network structure, and the core image forms the subject of attention.

As a two-dimensional graphic organizer, mind mapping is comparable to other visual tools such as flowcharts, timelines, and tables. These tools use intersecting figures, connecting lines, and physical positioning to show links between ideas or processes (John & Olusola, 2006). However, mind mapping offers distinct advantages over concept mapping, particularly in its use of color and free-form structure. According to Davies (2011), the unconstrained nature of mind mapping allows for unlimited idea generation and association, which promotes creative thinking and encourages brainstorming.

Furthermore, mind mapping enhances student engagement by making information delivery more visually appealing and dynamic. It also aids in memory retention and boosts learner motivation. Overall, mind mapping in the classroom fosters the growth of critical and creative thinking abilities in addition to conceptual understanding.

1.3 The Overview of Mapping Buddies Platform

Mapping Buddies Platform is a structured digital learning tool designed to facilitate the use of mind mapping as a technique to support knowledge construction, critical thinking, and collaborative learning. It functions as a repository that compiles mind maps produced by students as part of their academic tasks, along with teaching and learning resources aligned with specific courses or subject areas. This platform is rooted in the pedagogical principle that visualization of knowledge—particularly through mind maps—enhances cognitive processing and long-term memory retention (Buzan, 2006; Biktimirov & Nilson, 2003).

To support the effective creation of mind maps, the platform provides three principal features. The first feature is a collection of over fifteen customizable mind map templates, designed to cater to diverse learning preferences and organizational needs. These templates allow students to select and apply different mapping structures according to the complexity and nature of the subject matter.

The second feature offers structured guidance, including step-by-step instructions for constructing mind maps based on course topics or subtopics. This pedagogical support helps students break down complex content into manageable units while highlighting the hierarchical and relational links among ideas (Rostron, 2002). Through this process, students are better equipped to internalize information and develop higher-order thinking skills.

The third key feature allows users to upload or download completed mind maps. This function not only promotes personalized learning and content archiving but also encourages knowledge sharing among students. By reviewing one another's work, students are exposed to various interpretations and conceptual frameworks, thereby enriching the overall learning experience.

Beyond these three core features, the Mapping Buddies Platform also supports instructional delivery. Educators can upload lecture notes, slides, and instructional videos for student reference. These resources are accessible on demand, allowing students to revisit and revise the material according to their individual pace and schedule. The asynchronous access model supports flexibility and inclusivity, particularly for students with diverse learning contexts.

At the start of each semester, students receive a download link or QR code to install the Mapping Buddies Platform application on their mobile devices. This user-friendly setup allows seamless

integration of the platform into students' academic routines, enabling them to engage with the content anytime and anywhere. The flexibility provided by the platform aligns with the principles of self-regulated and technology-enhanced learning environments (Zimmerman, 2002).

2. Methodology

This study employed a quantitative case study design to evaluate the effectiveness of the Mapping Buddies Platform as a teaching aid among students in the Department of Commerce at Tuanku Sultanah Bahiyah Polytechnic. A total of 60 students who had used the Mapping Buddies Platform during the teaching and learning process were selected as respondents. The research instrument used was a structured questionnaire consisting of items based on a 5-point Likert scale, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The data collected were analysed using the latest version of SPSS software through descriptive statistical methods, namely mean and percentage. The mean scores obtained were interpreted using the range proposed by Rosmawati (2020) to determine the level of platform effectiveness based on students' perceptions.

3. Result and Discussion

To evaluate the effectiveness of the Mapping Buddies Platform, a set of questionnaires was distributed to 60 students from the Commerce Department at Politeknik Tuanku Sultanah Bahiyah's (PTSB) to gather their feedback. According to the study that has been conducted, the demographic information (Section A) that has been analyzed is gender, course, and semester.

Table 1. Respondent information

No.	Demographic characteristics		N	Percentage
1	Gender	Male	18	30%
		Female	42	70%
2	Course	Management	8	13.3%
		Accounting	45	75%
		Marketing	7	11.6%
3	Semester	4	10	16.7%
		5	50	83.3%

The study findings were received by the researcher based on the respondents' feedback on the 3 sections which are platform usability evaluation, interactivity and design evaluation and mind map usage evaluation. The results are analyzed in the form of percentages and mean scores. The scores given for each problem statement are as shown in the table 2 below:

Table 2. Five-point Likert Scale Table

No.	1	2	3	4	5
1	Strongly disagree	Disagree	Neutral	Agree	Strongly agree

The mean value obtained for each section is interpreted according to the scale set as a measurement as shown in Table 3:

Table 3. Interpretation of Mean Score

No.	Mean Score	Interpretation of Mean score
1	1.00 to 2.00	Low
2	2.01 to 3.00	Medium Low
3	3.01 to 4.00	Medium High
4	4.01 to 5.00	High

Section B: Platform Usability Evaluation

Table 4. Overall average for the Usability Evaluation Platform

No.	Item	Mean Score	Interpretation
1	Landing page allows me to view content easily.	4.72	High
2	Students can download documents easily from the platform.	4.80	High
3	Students can upload documents easily to the platform.	4.77	High
4	The navigation menu is easy to use.	4.70	High
5	The links to the homepage and additional pages is easy to use.	4.75	High
	Overall Mean	4.75	High

Based on the table above, the mean for platform usability evaluation is at a high level of 4.75. This shows that students are satisfied with the use of the Mapping Buddies Platform, where they can access the platform easily and at any time. They also felt the links and icons within the Mapping Buddies Platform were easy to use.

Section C: Interactivity and Design Evaluation

Table 5. Overall average for Interactivity and Design Evaluation

No.	Item	Mean Score	Interpretation
1	Elements and icons on the platform are interactive.	4.68	High
2	Menu options function as expected when clicked.	4.72	High
3	Provided links to external platform work properly.	4.72	High
4	Graphics displayed are appropriate and visually appealing.	4.78	High
5	Overall design of the graphics and landing page is suitable and attractive.	4.68	High
6	Navigating from topic to topic within the module is easy.	4.70	High
	Overall Mean	4.71	High

Based on the table above, the mean for interactivity and design evaluation is at a high level of 4.71. This shows that students are satisfied with the features of the Mapping Buddies Platform, which have appropriate and attractive graphics. Students are also satisfied with the overall design of the graphics, and the home page is appropriate and attractive.

Section D: Mind Map Usage Evaluation

Table 6. Overall average for Mind Map Usage Evaluation

No.	Item	Mean Score	Interpretation
1	Mind maps help me in memorizing the terms in a topic or subtopic.	4.73	High
2	Mind maps are able to increase understanding towards contents for each topic or subtopic.	4.75	High
3	I use Mind Maps as a tool to study with my friends.	4.63	High
4	I use Mapping Buddies as a platform to share my Mind Map.	4.63	High
5	Mapping Buddies Platform able to attract students towards subject/course.	4.78	High
6	Mapping Buddies Platform is an interactive way to use.	4.77	High
	Overall Mean	4.73	High

Based on the table above, the mean for mind map usage evaluation is at a high level of 4.73. This indicates that students perceive the use of mind maps as a helpful learning strategy that supports their ability to recall and retain important terms and concepts within topics and subtopics more effectively. In addition, students also feel that using a mind map can help them improve their understanding and interest in the content of each topic and course they are studying.

4. Conclusion and Recommendation

In conclusion, the Mapping Buddies Platform has been a very successful teaching aid in improving the education and learning process for students in Politeknik Tuanku Sultanah Bahiyah's Commerce Department. The results show that users are highly satisfied with the platform's usability, engagement, and mind maps' effectiveness as a teaching tool. The platform was considered by the students to be easy to use, attractive in design, and helpful in enhancing their understanding and recall of the course material. The implementation of digital mind mapping enhanced student participation, creativity, and teamwork in addition to assisting knowledge retention.

In order to support a greater variety of courses and learning methods, it is recommended that the Mapping Buddies Platform be offered to other polytechnic departments. To further improve participation, the platform may also be developed in the future to incorporate interactive tests, real-time collaboration tools, and mobile notification integration. To ensure the best possible use of this modern device for encouraging outcome-based education, teachers should also receive ongoing training on the proper use of mind mapping and digital platforms.

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STREAMERS' IMPACT ON REPEAT PURCHASES IN LIVE COMMERCE

Nurul Fazlena binti Mohd Mohradi*, Sharipah Khadijah binti S. Hashim, Hanani binti Abdul Ghani

Commerce Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim Hi Tech, Kedah, Malaysia

*Corresponding author e-mail address: nurulfazlena@ptsb.edu.my

Abstract

This study highlights inadequate streamer expertise and unsatisfactory delivery experiences as major concerns that undermine consumer trust and decrease the likelihood of repeat purchases on live commerce platforms (Lim, San, & Siang, 2024). This study examines the impact of Streamer Expertise and Online Delivery Experience on Repurchase Intention within live commerce platforms, focusing on diverse L-commerce users in Malaysia across Instagram, Facebook, Shopee, and TikTok. Using convenience sampling, data were collected through a structured survey via Questionnaires were created using Google Forms, and data were analyzed using SPSS through hypothesis testing to determine significant relationships and differences, ensuring efficient and cost-effective insights. The findings indicate that Streamer Expertise plays a crucial role in fostering consumer trust, as skilled and engaging presenters enhance purchase confidence and buyer satisfaction. Additionally, Online Delivery Experience significantly influences repeat purchases by providing seamless shopping experiences, where efficient, reliable, and timely delivery services contribute to positive consumer perceptions. These results highlight the need for L-commerce platforms to invest in professional streamers, improve product presentation strategies, and optimize delivery services to strengthen consumer engagement and retention. Furthermore, integrating emerging technologies, such as AI-driven recommendations and virtual shopping experiences, could enhance personalization and convenience in live commerce transactions. This study offers valuable insights for businesses aiming to boost consumer loyalty and long-term engagement. Future research should explore evolving consumer preferences and the role of digital advancements in shaping live commerce trends. By improving streamer expertise and delivery efficiency, L-commerce businesses can sustain growth and remain competitive in the online retail industry.

Keywords: Live Commerce (L-Commerce); Streamer Expertise; Online Delivery Experience; Repurchase Intention.

1. Introduction

This study explores Live Commerce (L-Commerce), a platform combining live streaming and e-commerce, emphasizing streamer-consumer interactions that drive sales, foster relationships, and shape consumer behavior, particularly in Malaysia. Live Commerce (L-Commerce) blends live video streaming with e-commerce, creating an interactive shopping experience that enhances consumer engagement and drives sales. Unlike traditional e-commerce, L-Commerce allows real-time interaction between streamers and consumers, fostering trust and community. Studies by Yun et al. (2023) and Xu et al. (2020) highlight that streamer expertise significantly impacts consumer behavior, influencing repurchase intentions. Knowledgeable streamers enhance trust, encouraging repeat purchases. Additionally, online delivery experience further strengthens these relationships, making streamers essential to L-Commerce's success. In Malaysia, platforms like Shopee Live demonstrate their impact on sales and growth. Repurchase intention is vital for L-

Commerce success, as engaging streamers with expertise improves consumer trust and encourages repeat purchases (Yun et al., 2023). In Malaysia, streamers like Khairul Aming build stronger consumer connections, boosting repurchase intentions on L-Commerce platforms. Through TikTok Live, Khairul Aming enhances real-time interaction with customers, effectively building trust and encouraging repeat purchases, which account for 76% of his total sales (The Free Library, 2023). Therefore, the integration of live video streaming and e-commerce has transformed the online shopping experience, creating a more dynamic and interactive environment for consumers. Streamers play an essential role in this shift, impacting consumer behavior with their expertise and real-time interactions. Additionally, the online delivery experience plays a vital role in shaping consumer behavior. For L-Commerce platforms aiming to thrive, understanding and optimizing these factors will be crucial for achieving lasting success in this innovative shopping landscape. This study highlights the objectives of identifying the key factors that influence consumer trust and repurchase intention in L-Commerce, with a focus on streamer expertise and delivery experience. It also aims to examine the role of real-time engagement, emotional connection, and perceived convenience in shaping consumer behavior and fostering long-term customer loyalty. Through these objectives, the study seeks to provide valuable insights into how the integration of live video streaming and e-commerce creates a more personalized, interactive, and trust-based online shopping environment.

2. Literature Review

Streamer expertise plays a vital role in live commerce by shaping consumer behavior, satisfaction, and purchasing decisions. Research by Yun et al. (2023) highlights that knowledgeable streamers enhance cognitive engagement and emotional arousal, which can lead to impulsive buying and social interaction. Similarly, Lee and Chen (2021) emphasize that expertise improves viewers' enjoyment, increasing their likelihood of making spontaneous purchases. Anshu, Gaur, and Singh (2022) also stress the impact of streamer expertise on customer attitudes and repeat purchase intentions, particularly in fostering value co-creation. Xu et al. (2020) further support these findings, showing that a streamer’s proficiency enhances cognitive and emotional connections, ultimately boosting customer satisfaction and brand loyalty. Collectively, these studies illustrate the significance of expert streamers in delivering engaging and trustworthy shopping experiences, which contribute to higher consumer retention and business growth in live commerce. Streamer expertise is crucial in live commerce, influencing consumer behavior, trust, and sales. Thus, this study confirms its impact on impulsive buying, loyalty, and platform success, emphasizing the need for skilled streamers.

In live commerce (L-commerce), the online delivery experience is a key factor influencing consumer behavior and purchase decisions. It includes delivery speed, order accuracy, product condition, and overall convenience, all of which contribute to a smooth shopping experience. A reliable and efficient delivery service helps build consumer trust, encourages repeat purchases, and enhances the credibility of L-commerce platforms. Since live commerce relies on real-time interactions, the quality of the delivery process significantly impacts consumer engagement and long-term loyalty. Yun et al. (2023) explored the impact of delivery experience on cognitive and emotional responses in L-commerce, finding that efficient delivery enhances engagement and encourages impulse buying. Lee and Chen (2021) found that a positive delivery experience increases perceived enjoyment, leading to more spontaneous purchases. Anshu, Gaur, and Singh (2022) highlighted that a well-managed delivery process strengthens trust and repurchase intentions in online grocery retail. These studies emphasize the importance of optimizing delivery services to sustain consumer interest, boost sales, and foster long-term loyalty in live commerce platforms. Thus, efficient delivery enhances consumer behavior, making it crucial for platforms to optimize for sustained success in this evolving market.

Repurchase intention in live commerce (L-commerce) refers to a consumer's likelihood of making repeat purchases based on prior shopping experiences and satisfaction levels. Various factors, such as the expertise of streamers, trust, and product presentation, influence consumer behavior in this setting. Streamer expertise, which includes their product knowledge, communication skills, and ability to provide accurate information, plays a significant role in shaping consumer engagement and purchase decisions. According to Lee and Chen (2021), streamers who demonstrate high expertise enhance consumers' trust and shopping enjoyment, leading to stronger repurchase intentions. Similarly, Yun et al. (2023) found that knowledgeable streamers create a more informative and reliable shopping experience, increasing consumer confidence in their purchases. The credibility built through expert streamers fosters long-term customer relationships and loyalty in the L-commerce space. Several studies emphasize the impact of streamer expertise on consumer repurchase behavior. Xu et al. (2020) applied the stimulus-organism-response (S-O-R) framework and discovered that knowledgeable streamers positively influence consumer trust, satisfaction, and repeat purchase decisions. Additionally, Pink and Djohan (2021) found that streamers with strong product expertise improve post-purchase satisfaction, increasing customer retention. These findings highlight the importance of leveraging well-informed and skilled streamers to enhance the shopping experience, as they play a crucial role in shaping consumer perceptions, driving sales, and fostering loyalty in L-commerce. Thus, repurchase intention is a vital component of live commerce that significantly influences consumer behaviour and shopping outcomes.

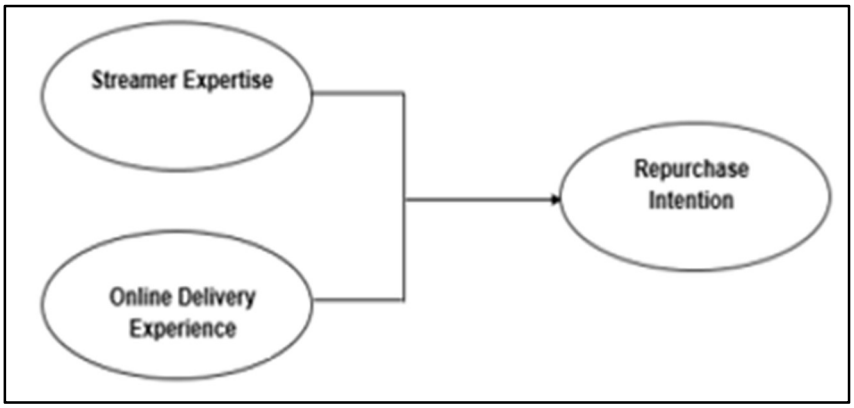


Fig. 1. Proposed Framework

3. Methodology

This study targets a diverse group of L-commerce users on platforms like Instagram, Facebook, Shopee, and TikTok, including young adults, professionals, social media enthusiasts, convenience seekers, and deal hunters in Malaysia. Given the unknown population size of L-commerce users, determining an appropriate sample size is essential. Following Koyuncu and Kılıç (2019), a minimum of 200 respondents is classified as "Good" for quantitative research, ensuring reliable findings. Convenience sampling is adopted for its practicality, selecting participants based on accessibility rather than random selection. This approach is ideal for reaching online shoppers efficiently and cost-effectively. Data collection is conducted through a structured online survey distributed via Google Forms, enabling broad respondent reach. The survey aims to gather quantitative data on the impact of streamer expertise on repurchase intentions, providing valuable insights into consumer behaviour in L-commerce. This method ensures effective data collection aligned with the study’s objectives.

4. Results and Discussion

For this study, data analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 20.0. To evaluate the research objectives, a descriptive mean score analysis was used to examine streamers' impact on repeat purchases in live commerce. The mean interpretation table categorizes consumer responses into three levels: low, moderate, and high, helping to assess the strength of consumer tendencies in L-Commerce.

The analysis of Streamer Expertise, Online Delivery Experience, and Repurchase Intention reveals a high level of agreement among respondents, indicating their strong influence on consumer behaviour in L-Commerce. Streamer Expertise holds an average minimum value of 4.7609, showing that consumers perceive live streamers as skilled, qualified, and experienced. The highest-rated item ("I feel the live streamer is skilled") suggests that well-trained streamers enhance consumer trust and engagement, ultimately affecting purchase decisions. Similarly, Online Delivery Experience, with an average minimum of 4.8366, demonstrates that consumers view L-Commerce delivery services as efficient and convenient. The highest mean score ("Overall, in using online delivery service, L-Commerce shopping or transaction would be easy for me") suggests that seamless delivery services contribute significantly to a positive shopping experience. The construct of Repurchase Intention exhibits the highest average minimum of 5.7233, reflecting strong consumer loyalty toward L-Commerce platforms. The most agreed-upon statements indicate that consumers intend to continue purchasing via L-Commerce and actively seek products through this medium. This high tendency suggests that previous positive experiences, combined with reliable streamers and smooth delivery services, strengthen consumer trust and commitment. Therefore, L-Commerce businesses should focus on enhancing streamer expertise, optimizing delivery efficiency, and ensuring a seamless purchasing process to maintain and expand their customer base. The analysis shows high consumer agreement on streamer expertise (4.7609), online delivery experience (4.8366), and repurchase intention (5.7233), highlighting their strong influence on L-Commerce behaviour in table 1 below.

Table 1. Descriptive Analysis

Construct	Abbr.	Items	Mean	Average Min	Level of Tendency
Streamer Expertise	SE1	I feel the live streamer is experienced.	4.7767	4.7609	High
	SE2	The live streamer listens to what I say.	4.6650		
	SE3	I feel the live streamer is qualified.	4.7524		
	SE4	I feel the live streamer is skilled.	4.8495		
Online Delivery Experience	ODE1	Purchasing L-Commerce products through online delivery services is sensible.	4.7136	4.8366	High
	ODE2	Purchasing L-Commerce products through online delivery services is wise.	4.7573		
	ODE3	Purchasing L-Commerce products through online delivery services is good.	4.8835		
	ODE4	Purchasing L-Commerce products through online delivery services is rewarding.	4.7718		
	ODE5	I feel comfortable using the online delivery services.	4.9272		

	ODE6	Overall, in using online delivery service, L-Commerce shopping or transaction would be easy for me.	4.9660		
Repurchase Intention	RI1	I would consider purchasing products using L-Commerce in the future.	5.7718	5.7233	High
	RI2	I intend to purchase products using L-Commerce.	5.7330		
	RI3	Before buying products, I will look for them in L-Commerce.	5.7718		
	RI4	I consider L-Commerce as my first choice.	5.6165		

5. Conclusion

The analysis highlights a strong influence of Streamer Expertise, Online Delivery Experience, and Repurchase Intention on consumer behavior in L-Commerce, with high levels of agreement among respondents. Repurchase Intention recorded the highest average minimum score (5.7233), indicating strong consumer preference for continued engagement with L-Commerce platforms. Online Delivery Experience (4.8366) was also highly rated, emphasizing the importance of efficient and seamless delivery services in shaping a positive shopping experience. Streamer Expertise (4.7609) further reinforces the role of skilled and qualified streamers in enhancing consumer trust and engagement, ultimately influencing purchasing decisions. The highest-rated items in each category suggest that a smooth delivery process, skilled streamers, and prior positive experiences significantly boost consumer confidence and repeat purchases. To sustain growth, L-Commerce businesses should invest in professional streamer training, optimize delivery services, and ensure a seamless purchasing journey, as these factors have proven to be key drivers of customer retention and satisfaction.

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PEMBANGUNAN APLIKASI REALITI TERIMBUH (AR) BERASASKAN ASET 3 DIMENSI LABU SAYONG BAGI PEMULIHARAAN REKA BENTUK WARISAN TRADISI MELAYU DI KUALA KANGSAR, PERAK

Nur Hazirah binti Zulkifle*[1], Siti Zubaidah binti Ibrahim

Teknologi Seni Permainan, Kolej Komuniti Selayang, 68100 Batu Caves, Selangor Malaysia

*Corresponding author e-mail address: nurhazirahzulkifle@gmail.com

Abstrak

Labu Sayong merupakan kraf tembikar tradisional yang sinonim dengan warisan budaya Melayu dari Kuala Kangsar, Perak, namun minat terhadap kraf ini semakin berkurangan terutama dalam kalangan generasi muda. Projek ini menggunakan metodologi pembangunan aplikasi Realiti Terimbuh (AR) yang merangkumi fasa pra-produksi, produksi, dan pasca-produksi, dengan proses termasuk pemodelan 3Dimensi (3D), penghasilan laman web interaktif, serta integrasi aset dalam platform AR. Hasil kajian menunjukkan bahawa 35 responden memberi maklum balas positif terhadap kefahaman, kesesuaian tema, kualiti model 3D, dan pengalaman menggunakan AR, dengan 100% responden bersetuju untuk mencadangkan laman web ini. Perbincangan dengan pakar mengesahkan keberkesanan projek ini dalam memperkenalkan Labu Sayong secara interaktif, serta mencadangkan penambahbaikan dari segi reka bentuk laman web dan kestabilan teknologi AR. Limitasi projek termasuk kekangan masa dan masalah teknikal dalam pelaksanaan projek Realiti Maya (VR) yang belum dapat direalisasikan sepenuhnya. Rumusan kajian ini menegaskan bahawa penggunaan teknologi AR berpotensi memelihara dan memperkenalkan warisan budaya secara inovatif, dengan cadangan untuk mengembangkan aplikasi VR sebagai langkah lanjut bagi menarik minat generasi muda dalam seni kraf tradisional.
Kata Kunci: Labu Sayong; Realiti Terimbuh (AR); Warisan Tradisi Melayu.

1. Pengenalan

Labu Sayong merupakan kraf tembikar tradisional yang sinonim dengan warisan budaya Melayu, khususnya dari daerah Kuala Kangsar, Perak. Keunikan reka bentuk serta fungsinya sebagai bekas menyimpan air yang sejuk secara semula jadi menjadikan Labu Sayong simbol seni pertukangan Melayu yang halus dan bernilai tinggi. Walaupun popularitinya semakin merosot, Labu Sayong sebagai kraf tradisional perlu dipelihara dan diwariskan agar generasi akan datang dapat menghargai serta meneruskan warisan budaya ini.

Kepupusan warisan tradisional semakin membimbangkan apabila generasi muda kurang mengenali nilai seni budaya tempatan. Industri Labu Sayong yang dahulunya menjadi sumber rezeki utama penduduk kampung kini semakin merosot, dengan kurang daripada 10 pengusaha aktif berbanding lebih 90 peratus tiga puluh tahun lalu (Mohd Pareb Zamari, *Berita Harian*, 2024). Menurut kajian oleh Jamel, Jamal, dan Khan (2021), kurangnya kajian menyeluruh tentang proses pembuatan Labu Sayong menjadi antara punca kelemahannya untuk berkembang. Tambahan pula, masyarakat kini tidak memahami kegunaan serta kebaikan Labu Sayong, menyebabkan ia kurang digunakan dalam kehidupan harian (Khusairi, Abd Razak, & Yunus, 2021).

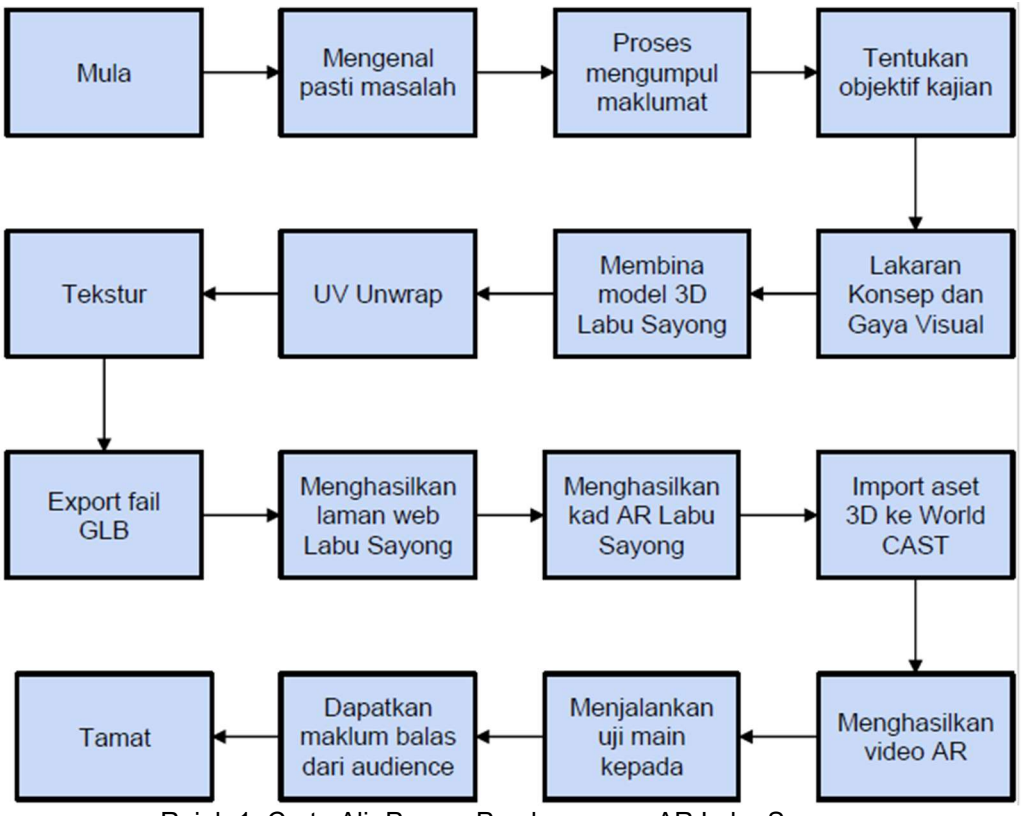
Persoalan kajian ini merangkumi tiga aspek utama berkaitan penghasilan Augmented Reality (AR) mengenai Labu Sayong. Pertama, menilai maklumat sejarah, proses pembuatan dan nilai budaya

dalam laman web berkaitan. Kedua, mengenal pasti cara membangunkan aplikasi AR yang menarik untuk generasi muda. Ketiga, mengkaji keberkesanan dan kebaikan penggunaan AR dalam memperkenalkan Labu Sayong secara digital.

Objektif kajian ini adalah untuk mengenalpasti kandungan maklumat berkaitan Labu Sayong dalam laman web dari aspek sejarah, proses pembuatan dan nilai budaya; seterusnya membangunkan aset 3Dimensi (3D) Labu Sayong secara terperinci dalam bentuk Realiti Terimbuh (AR) bagi menarik minat generasi muda serta menganalisis tahap keberkesanan penggunaan dan kebaikan Labu Sayong melalui penyampaian interaktif menggunakan platform digital berasaskan AR.

2. Metodologi

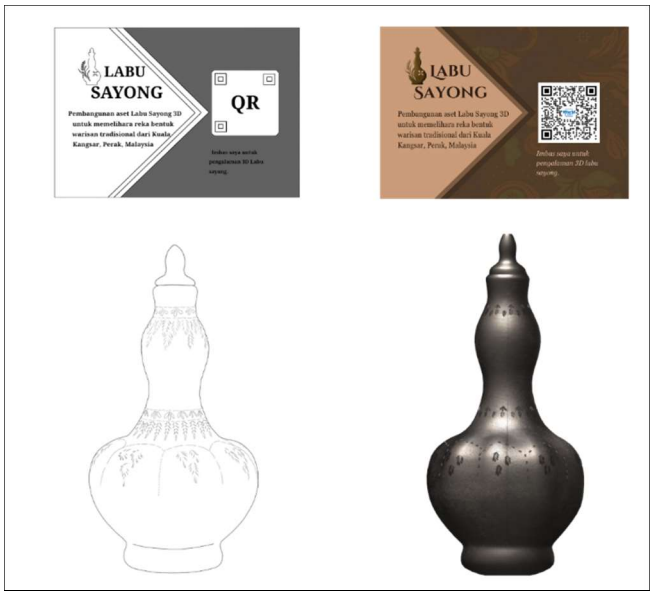
Metodologi pembangunan aplikasi Realiti Terimbuh (AR) bagi projek Labu Sayong merangkumi tiga fasa utama iaitu Pra-Produksi, Produksi dan Pasca-Produksi. Proses ini digambarkan melalui satu carta alir yang menyusun keseluruhan aliran kerja secara sistematik dan berkesan, membantu memastikan hasil akhir menepati objektif serta keperluan pengguna. Bermula dari perancangan kandungan, pembangunan aset dan interaksi, hinggalah kepada pengujian serta penambahbaikan akhir sebelum pelancaran.



Rajah 1. Carta Alir Proses Pembangunan AR Labu Sayong

Carta alir proses pembangunan AR Labu Sayong, seperti yang ditunjukkan dalam Rajah 1, bermula dengan langkah mengenal pasti masalah berkaitan usaha pemeliharaan warisan budaya, diikuti dengan proses pengumpulan maklumat dan penetapan objektif kajian. Seterusnya, lakaran awal konsep dan gaya visual direka bentuk sebagai panduan dalam fasa pembangunan aset. Pembinaan model 3D Labu Sayong dilakukan, disusuli proses UV unwrap dan penambahan

tekstur untuk memberikan perincian visual. Aset 3D yang telah lengkap dieksport dalam format GLB dan digunakan dalam pembangunan laman web serta penciptaan kad AR Labu Sayong. Model tersebut juga diimport ke dalam platform World CAST bagi menghasilkan pengalaman video AR. Proses ini diakhiri dengan pelaksanaan sesi uji main bersama audiens serta pengumpulan maklum balas daripada pengguna dan pakar untuk tujuan penambahbaikan.



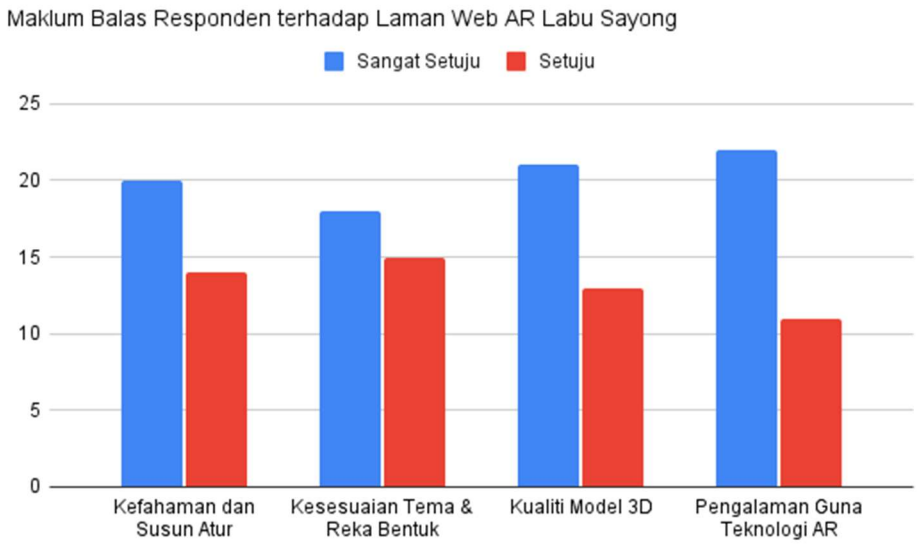
Rajah 2. Lakaran dan hasil aset 3D AR Labu Sayong

Keseluruhan proses bermula dari lakaran sehingga kepada hasil akhir aset 3D yang digunakan dalam pengalaman realiti terimbuh (AR), seperti yang ditunjukkan dalam Rajah 2.

3. Hasil Kajian dan Perbincangan

Hasil kajian menunjukkan bahawa seramai 35 orang responden berumur antara 18 hingga 31 tahun ke atas telah terlibat dalam sesi uji main laman web AR Labu Sayong yang dijalankan secara fizikal dan dalam talian. Analisis demografi mendapati majoriti responden berumur antara 18 hingga 25 tahun (51.4%), diikuti oleh mereka yang berumur 31 tahun ke atas (45.0%), manakala hanya seorang responden berumur antara 15 hingga 17 tahun. Responden lelaki merupakan majoriti dengan peratusan sebanyak 65.7%. Walaupun hanya 8.5% responden pernah melayari laman web Realiti Terimbuh (AR) Labu Sayong sebelum ini, mereka memberikan maklum balas yang signifikan selepas sesi uji main. Secara keseluruhan, laman web ini dilihat mudah diakses, susun atur kandungannya teratur, dan penggunaan elemen AR dianggap jelas serta mudah difahami.

Responden memberikan maklum balas yang positif terhadap laman web AR Labu Sayong, dengan bilangan tertinggi berada pada kategori “Sangat Setuju” bagi semua aspek yang dinilai. Carta Bar 1 menunjukkan aspek Pengalaman Guna Teknologi AR dan Kualiti Model 3D menerima tahap persetujuan tertinggi, diikuti oleh Kefahaman dan Susun Atur serta Kesesuaian Tema dan Reka Bentuk. Hanya sebilangan kecil responden yang tidak bersetuju, menunjukkan penerimaan yang baik secara keseluruhan terhadap laman web ini.



Rajah 3. Carta Bar Maklum Balas Responden Terhadap Laman Web AR Labu Sayong

Dalam sesi perbincangan bersama beberapa individu yang terlibat secara langsung dalam penghasilan dan pemodelan Labu Sayong, pelbagai pandangan telah dikemukakan bagi mempertingkatkan kualiti produk serta penyampaian maklumat melalui teknologi 3D dan AR. Menurut Muhammad Shahril Izuan Ridzuan, seorang pengusaha Labu Sayong di Kedai Win Kraf, apabila ketebalan labu sudah mencukupi, lebihan cecair tanah di tengah perlu dibuang untuk menghasilkan lubang; jika tidak, labu akan menjadi padat. Beliau turut mencadangkan agar rekaan 3D yang dihasilkan diberi penambahan seperti jalur atau lekuk bagi menampakkan kontras yang lebih menarik (komunikasi peribadi, 15 Ogos 2025). Hasmuni Binti Daud, guru sejarah di Sekolah Menengah Kebangsaan Puchong Perdana, pula berpandangan bahawa penerangan mengenai sejarah Labu Sayong adalah lengkap dan memuaskan (komunikasi peribadi, 18 Ogos 2025). Sementara itu, Sakinah Binti Mazuki, pengasas Senikina Studio yang mewakili syarikat Kelembai di Universiti Pendidikan Sultan Idris (UPSI) dan juga alumni Kolej Komuniti Selayang, menyatakan bahawa walaupun rekaan 3D yang dibangunkan sudah baik dari segi reka bentuk, ia masih boleh dipertingkatkan dari segi fungsi seperti keupayaan untuk memutar model, dan beliau berharap agar projek AR ini dapat diteruskan dengan lebih maju (komunikasi peribadi, 18 Ogos 2025).

4. Rumusan

Hasil kajian ini telah membawa kepada penghasilan prototaip aset 3D Labu Sayong dan pembangunan laman web Realiti Terimbuh (AR) yang memaparkan sejarah, proses pembuatan, dan nilai budaya Labu Sayong. Aset 3D yang dibangunkan secara terperinci berjaya menarik minat generasi muda melalui pendekatan interaktif di platform World CAST. Analisis maklum balas menunjukkan penggunaan AR ini memberi impak positif, dengan tahap kepuasan pengguna yang tinggi. Secara umumnya, kajian ini telah menepati objektif iaitu mengenal pasti kandungan maklumat berkaitan Labu Sayong, membangunkan aset 3D dalam bentuk AR, dan menganalisis keberkesanan penggunaannya. Kajian lanjutan dicadangkan untuk membangunkan permainan berasaskan proses pembuatan Labu Sayong menggunakan teknologi Realiti Maya (VR).

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DEVELOPMENT OF AN EDUCATIONAL GAME TO IMPROVE SPELLING SKILLS AMONG PRIMARY SCHOOL STUDENTS

Nur Zarra Syamimi binti Amiruddin*, Ummu Hani binti Yusof

Diploma Teknologi Seni Permainan, Kolej Komuniti Selayang, Persiaran Pegawai, KM16 Jalan Ipoh, 68100 Batu Caves, Selangor, Malaysia.

*Corresponding author e-mail address: zarrasyamimi@gmail.com

Abstract

Literacy and communication skills are vital for students' academic and social development, yet many primary school students still struggle with reading and speaking, particularly in English. These challenges are often due to a lack of engaging, interactive learning environments. To address this issue, this study explores effective teaching methods to improve reading proficiency among Year 1 to Year 6 students and introduces an educational game designed to support speech and spelling development. The game features vibrant 2D visuals and was developed using the Unity platform. Data was gathered through literature reviews and surveys, with gameplay testing sessions conducted to evaluate its effectiveness. Feedback from students was overwhelmingly positive, with most users agreeing or strongly agreeing with the benefits of the game. The appealing 2D design successfully captured students' interest. Future recommendations include incorporating storytelling elements and enhancing certain levels to create a more immersive learning experience.
Keywords: Literacy development; Game-based Learning; Spelling Skills.

1. Introduction

Literacy and speech development are important skills that significantly influence a child's academic performance and overall communication ability. However, many primary school students in Malaysia continue to face difficulties in these foundational areas, particularly those in Year 1, often due to a lack of interest in this issue. The current classroom environment lacks engaging, interactive elements that are essential for motivating young learners, resulting in decreased enthusiasm and slower progress in reading and speaking.

In addition to literacy issues, speech development is another serious concern. Many young learners struggle with pronunciation and fluency because they are not sufficiently motivated to engage in speech practice. According to Salleh (2021), increasing learner motivation through engaging and activity-based learning can significantly improve English proficiency among primary school students. In addition, both educators and parents find it difficult to track a child's speech and literacy development (Siti Jamilah, 2021). Recent research suggests that Game-Based Learning (GBL) may be a game-changer in education since it provides children with a fun, interactive, and multisensory process that aligns with children's learning styles. GBL can solidify sound-letter association and retention while having children engaged in meaningful literacy activities, when supported with 2D assets.

The objectives of this study are to identify the level of spelling mastery among Level 1 primary school students, to develop a digital game that enhances spelling skills through an engaging and interactive learning approach, and to evaluate the effectiveness of the developed digital game in

improving the students' spelling abilities. By integrating engaging visuals, adaptive learning mechanics, and speech recognition technology, the game will provide a personalised and motivating learning environment tailored to each child's pace and needs.

2. Methodology

This study involved a minimum of 30 respondents, who were Malaysian primary school pupils between the ages of seven and nine, participating in this study. The participants came from different age ranges, social backgrounds, and types of learning environments, allowing for a more comprehensive analysis of the difficulties encountered in English language instruction.

The development process of the game-based learning tool began with identifying key problems in literacy and speech, followed by the preparation and distribution of questionnaires to gather user feedback. The results were analysed to understand user needs, which guided the next steps. References related to user interface (UI) design were reviewed, leading to the creation of initial sketches and 2D models.

The game's storyline and overall flow were carefully designed to align with specific educational goals, aiming to create a meaningful and engaging experience for young learners. The development process was executed using Unity to build the core gameplay mechanics, while a progress tracking system based on educational principles was developed using Visual Studio Code to monitor students' learning outcomes and performance. Once completed, the application is tested through a playtest session to assess visuals, content comprehension, and level of interactivity.

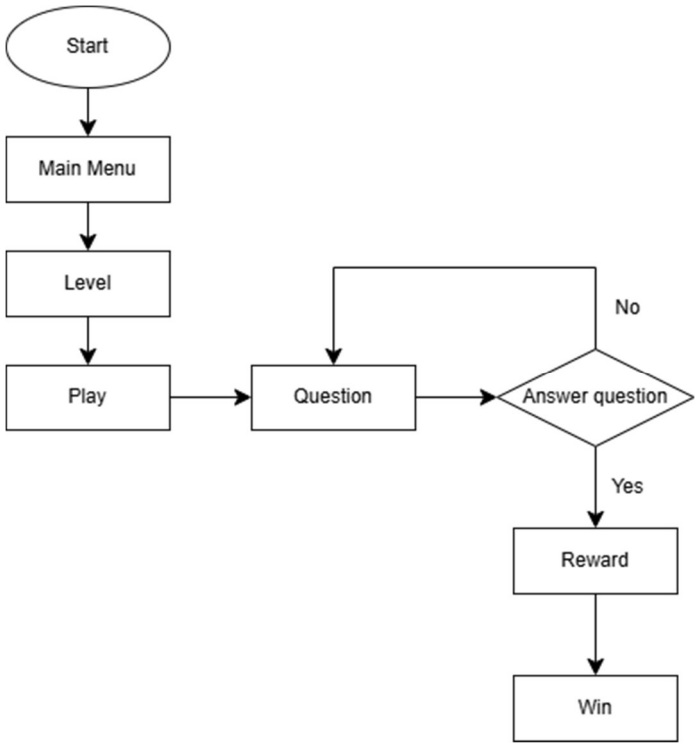


Fig. 1. Echo Letters Game Flowchart

Figure 1 illustrates the overall game flow of Echo Letters, from the main menu to level progression. Upon launching the game, players are presented with the main screen and can begin by selecting the 'Play' button. They are then directed to the level selection interface, where they may choose a desired level to start. To proceed within the game, players must complete an initial task by arranging the given letters correctly into the designated spaces. Completing this task allows them to advance to subsequent levels.

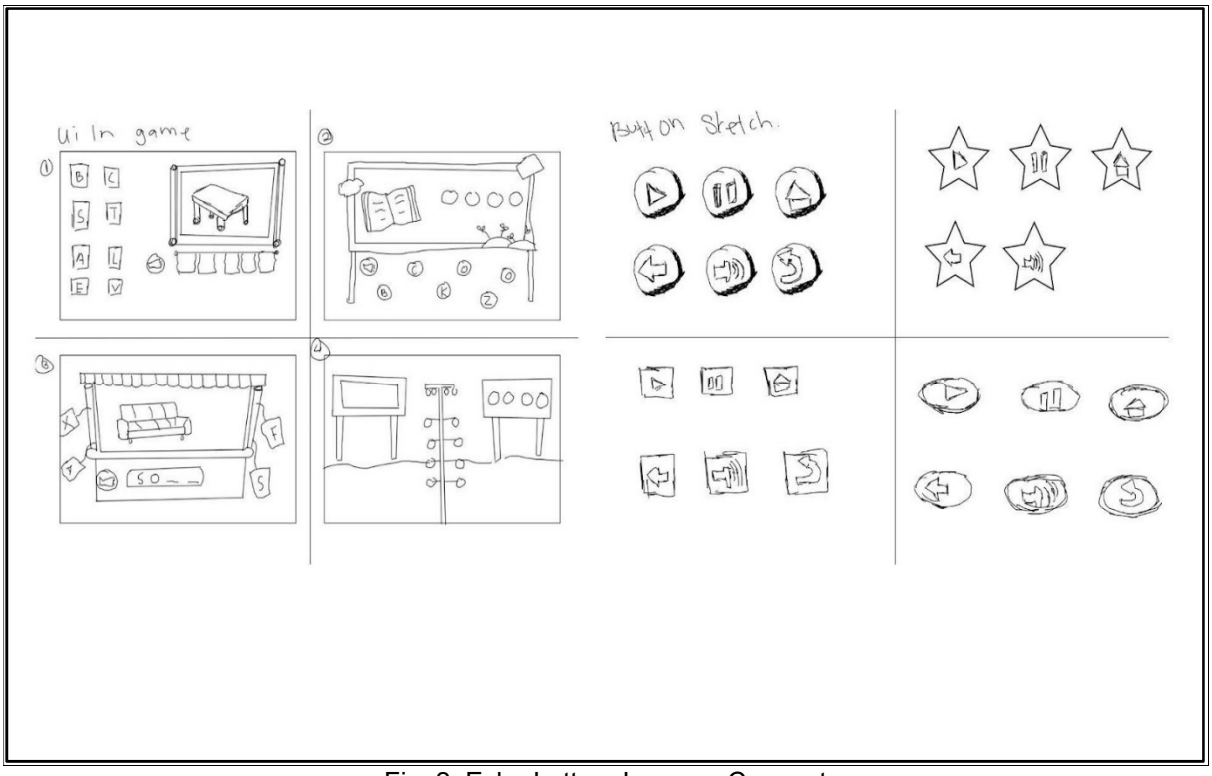


Fig. 2. Echo Letters In-game Concept

Figure 2 illustrates the design development process for the Echo Letters game. The initial sketches focused on outlining the basic layout, determining the placement of the task display, alphabet tiles, and navigation buttons. Subsequent sketches refined the arrangement of these elements to improve usability and ensure a smooth learning experience for young players. The button concepts explored different shapes and icons, such as stars and circles, to identify visuals that are both engaging and easily recognisable. These concept drawings guided the creation of a child-friendly interface that supports intuitive navigation and enhances the overall educational experience.

Figure 3 illustrates the final interface display of the Echo Letters game, developed from the initial concept sketches into a complete digital layout. It features core components such as the main menu, in-game tasks, pause menu, and level completion screen-each designed to provide a seamless and intuitive experience for young users. The interface prioritises clarity and simplicity, incorporating bold icons, legible fonts, and vibrant colours to capture attention, maintain engagement, and encourage independent interaction throughout gameplay.



Fig. 3. Interface Display in Echo Letters Game

Figure 3 illustrates the final interface display of the Echo Letters game, developed from the initial concept sketches into a complete digital layout. It features core components such as the main menu, in-game tasks, pause menu, and level completion screen-each designed to provide a seamless and intuitive experience for young users. The interface prioritises clarity and simplicity, incorporating bold icons, legible fonts, and vibrant colours to capture attention, maintain engagement, and encourage independent interaction throughout gameplay.

3. Results and Discussion

The implementation of the game-based learning tool produced promising results in enhancing students' spelling proficiency and engagement in English learning. A total of 30 primary school students, aged between seven and nine, participated in the study. Pre- and post-assessment results showed that 83% of the students improved their spelling performance after interacting with the game. Many were able to recognise and recall words more accurately, demonstrating stronger sound-letter association and spelling retention. The game's interactive format also encouraged independent learning, with students showing increased confidence in attempting spelling tasks without assistance.

Questionnaire responses provided further insight into the effectiveness of the tool. Most students selected "Agree" or "Strongly Agree" for statements related to enjoyment, clarity, and engagement. They reported feeling more motivated and found the colourful visuals and interactive elements helpful in understanding spelling concepts. Parental feedback echoed similar sentiments, noting improvements in their children's willingness to practise English at home. These findings are supported by earlier research, such as that of Abdul Rabu and Talib (2017), which confirmed the role of digital game-based learning in boosting vocabulary achievement and learner acceptance. Additionally, Siti Jamilah (2021) emphasised the importance of motivation in student learning, which the game successfully addressed through its visual and interactive design.

Despite the positive outcomes, several areas for improvement were identified. Some students expressed a desire for more variation in gameplay, such as new characters, backgrounds, or voice-over features to enhance the learning experience. Moreover, while the progress tracking

system helped monitor learning outcomes, its functionality could be further improved with real-time feedback or reports accessible to parents and teachers. Future development should also consider integrating storytelling elements to create a more immersive learning journey. Overall, the findings demonstrate that game-based learning offers a viable alternative to conventional methods, supporting student-centred learning through interactive, enjoyable, and educationally effective digital environments.

4. Conclusion

The development of this game-based learning tool has shown clear effectiveness in enhancing literacy and speech development among Year 1 primary school students in Malaysia. Through the use of vibrant 2D visuals and a child-friendly interface, the game

successfully captured learners' attention and transformed language learning into a more engaging and enjoyable experience. Feedback from students and educators indicated that the game was well-suited to the learners' level and effectively reinforced key language skills such as spelling and pronunciation.

The positive responses, along with improvements in students' learning outcomes, highlight the potential of game-based learning to complement traditional teaching approaches. By addressing common classroom challenges such as low motivation and limited interactive content, the game offers an innovative solution that aligns with the learning styles of young children.

Future enhancements, such as expanding content, incorporating speech recognition features, and improving mobile accessibility, could further strengthen the tool's educational impact. With continued development, the game holds strong potential to support both classroom instruction and home-based learning, ultimately helping young learners build a more solid foundation in English literacy and communication skills.

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KAJIAN TERHADAP TAHAP EMOSI AKADEMIK PELAJAR DENGAN PENCAPAIAN GRED MATEMATIK DI KALANGAN PELAJAR KEJURUTERAAN DI POLITEKNIK

Zuraini binti Ibrahim[1]*, Noor Hanim binti Ismail[2], Faridah binti Ismail[1]

[1]Mathematics, Science & Computer Department, Tuanku Sultanah Bahiyah Polytechnic, 09000 Kulim, Kedah, Malaysia

[2]Commerce Department, Tuanku Sultanah Bahiyah Polytechnic, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: zuraini@ptsb.edu.my

Abstrak

Emosi akademik merupakan faktor psikologi yang penting dalam dunia pendidikan, terutamanya dalam kalangan pelajar aliran teknikal dan kejuruteraan. Dalam bidang kejuruteraan, subjek Matematik Kejuruteraan sering dianggap mencabar dan boleh menimbulkan emosi negatif seperti kebimbangan dan tekanan, khususnya menjelang peperiksaan akhir. Oleh itu, kajian ini dijalankan bertujuan untuk mengkaji emosi pelajar politeknik dan pencapaian mereka dalam subjek Matematik Kejuruteraan serta membuat perbandingan emosi akademik bagi Jabatan Kejuruteraan Mekanikal (JKM) dan Jabatan Kejuruteraan Elektrik (JKE) di Politeknik Tuanku Sultanah Bahiyah (PTSB). Kajian ini melibatkan seramai 49 orang pelajar JKE dan 42 orang pelajar JKM yang menjadikan jumlah keseluruhan pelajar adalah seramai 91 orang. Instrumen yang digunakan ialah *Achievement Emotions Questionnaire* (AEQ) yang disesuaikan bagi mengukur emosi positif dan negatif pelajar berdasarkan tiga kategori iaitu emosi semasa di kelas (*class-related emotions*), emosi semasa pembelajaran (*learning-related emotions*), dan emosi semasa ujian (*test-related emotions*). Hasil dapatan menunjukkan bahawa pelajar JKE mempamerkan skor emosi positif yang lebih tinggi (min=4.27, sp=0.70) berbanding dengan JKM (min=4.15, sp=0.85). Manakala, untuk skor emosi negatif, pelajar JKM memperolehi skor yang lebih tinggi berbanding JKE iaitu (min=2.02, sp=1.13) dan (min=1.99, sp=1.13) masing-masing. Dari segi pencapaian, sebanyak 55% pelajar JKM dan 51% pelajar JKE mendapat markah yang cemerlang dalam subjek Matematik Kejuruteraan. Secara keseluruhannya, walaupun terdapat perbezaan dalam pengalaman emosi akademik, ianya tidak mempengaruhi keseluruhan prestasi akademik pelajar dalam subjek Matematik Kejuruteraan. Hasil kajian ini diharapkan dapat membantu para pensyarah memahami impak emosi terhadap prestasi pelajar serta dapat merangka strategi pedagogi yang lebih holistik.
Kata Kunci: Emosi akademik; Matematik Kejuruteraan; Pencapaian pelajar.

1. Pengenalan

Pelan Pembangunan Pendidikan Malaysia (PPPM) 2015-2025 (Pendidikan Tinggi) telah dibentuk di bawah bidang pengetahuan dalam atribut Aspirasi Pelajar mengkehendaki pelajar menguasai bidang pilihan, mampu memanfaatkan, menghubungkan, dan mengaplikasikan pengetahuan yang telah dipelajari, serta mampu menghargai kesenian, kebudayaan, serta sains, teknologi kejuruteraan dan matematik (STEM). Ilmu matematik dikenal pasti sebagai bidang penting pada PPPM 2015-2025 kerana ianya memberi kesan dalam kehidupan secara tidak langsung. Kepentingan emosi dalam pembelajaran turut ditekankan, dimana perkembangan emosi pelajar dinyatakan sebagai aspek lain yang kritikal dalam kualiti pendidikan negara. Hal ini jelas menunjukkan bahawa emosi membawa peranan penting dalam sistem pendidikan negara.

Emosi akademik boleh dikelompokkan kepada emosi positif seperti keseronokan, harapan dan kelegaan, serta emosi negatif seperti kebimbangan, marah, malu dan kebosanan (Pekrun, 2006). Emosi memainkan peranan penting, kerana ia bukan sahaja akan mempengaruhi motivasi dan minat pelajar, malah ia turut memberi kesan kepada pencapaian dan penguasaan pelajar dalam setiap mata pelajaran. Oleh itu, adalah penting untuk memahami dan mengambil kira emosi pelajar semasa melalui proses pengajaran dan pembelajaran. Menurut Talib & Amran (2023), emosi yang dialami oleh pelajar terutamanya semasa menjalani sesuatu proses pembelajaran adalah berkait rapat dengan penguasaan dan pencapaian mereka dalam mata pelajaran yang dipelajari. Manakala, David et al., (2021) menerangkan, emosi secara teorinya mempengaruhi pencapaian pelajar secara tidak langsung melalui motivasi dan pemprosesan maklumat.

Emosi akademik, juga disebut sebagai emosi pencapaian, adalah perasaan yang dikaitkan dengan hasil dan aktiviti pencapaian. Emosi pencapaian boleh diklasifikasikan sebagai emosi sifat atau emosi menyatakan yang biasa ditemui dalam suasana pendidikan yang berbeza (Wu & Yu, 2022). Umum mengetahui bahawa persekitaran pembelajaran juga mempengaruhi komponen emosi, motivasi, dan kognitif pembelajaran. Dalam persekitaran akademik, pelajar mungkin merasakan pelbagai emosi berkaitan pencapaian yang dikaitkan dengan aktiviti mereka, termasuk keseronokan, kemarahan, kekecewaan dan kebosanan. Pada masa yang sama, mereka mungkin merasakan banyak perasaan yang berkaitan dengan pencapaian dan hasil, seperti kegembiraan, kesyukuran, harapan, kebimbangan, keputusasaan, kebanggaan, kelegaan, kesedihan, dan rasa malu (Ismail et al., 2024).

Keupayaan untuk belajar dengan berkesan amat dipengaruhi oleh emosi individu sewaktu menjalani sesuatu proses pembelajaran. Dalam konteks pendidikan teknikal dan kejuruteraan, pencapaian akademik pelajar turut dipengaruhi oleh faktor emosi akademik. Emosi seperti seronok, harapan, dan kebimbangan sering timbul semasa pelajar melalui proses pengajaran dan pembelajaran di kelas, semasa pembelajaran kendiri serta semasa menghadapi ujian atau penilaian. Skagerlund et al. (2019) menyatakan bahawa pembelajaran matematik adalah satu usaha yang kompleks secara kognitif dan mencabar emosi. Hal ini kerana pelajar sering kali dilihat menunjukkan sikap tidak selesa, risau dan takut untuk mengikuti pembelajaran khususnya melibatkan subjek Matematik.

Matematik merupakan salah satu cabang ilmu yang mengasah minda seseorang untuk berfikir secara mantik dan bersistem bagi menghuraikan sesuatu masalah serta menentukan keputusan. Memahami konsep asas dalam matematik amat penting khususnya dalam kalangan pelajar yang sedang mengikuti pengajian dalam bidang sains, matematik, dan teknologi sepertimana sama pentingnya dalam bidang perdagangan, ekonomi, dan kemanusiaan (Raman & Ling, 2021). Tahap penguasaan matematik yang baik adalah amat penting untuk membantu para pelajar meningkatkan pencapaian dalam bidang akademik khususnya bidang kejuruteraan. Menurut Mansor & Amran (2023), pelajar yang suka belajar Matematik mampu mempengaruhi perhatian mereka dalam proses pengajaran dan pembelajaran serta dapat memahami isi kandungan sesuatu topik yang diajar sekaligus dapat meningkatkan proses kognitif pelajar terutama memori kerja mereka. Pengetahuan Matematik yang kukuh amat penting kepada pelajar bagi menyakinkan mereka mempelajari subjek Matematik Kejuruteraan. Tanpa pengetahuan asas Matematik yang kukuh, pelajar akan menghadapi masalah mempelajari kursus Matematik Kejuruteraan.

Pendekatan pengajaran oleh pensyarah juga memainkan peranan penting dalam menentukan motivasi dan emosi pelajar terhadap Matematik. Sekiranya pendekatan yang digunakan

membosankan, dan tidak menarik, akan menyebabkan pelajar kurang berminat dengan Matematik dan seterusnya akan timbul emosi negatif dalam diri pelajar. Mereka akan berasa takut dan bimbang setiap kali mengikuti kelas matematik dan tidak mempunyai keberanian untuk bertanyakan soalan sekiranya tidak memahami topik-topik tertentu (Mansor & Imran, 2023). Malah, Amran dan Bakar (2020) pula menyatakan bahawa pelajar yang mempunyai banyak emosi negatif juga akan mengalami kesukaran untuk mengingati perkara baharu yang dipelajari di dalam kelas. Keadaan ini menyebabkan pelajar mengalami kesukaran dalam menghafal teori, rumus, logik dan fakta berkaitan nombor sehingga melahirkan persepsi negatif terhadap pembelajaran matematik.

Dalam sistem Politeknik, Matematik Kejuruteraan merupakan kursus wajib yang perlu diambil terutamanya untuk pelajar-pelajar bidang kejuruteraan. Pelajar perlu lulus ketiga-tiga kursus Matematik iaitu Matematik Kejuruteraan 1 (DBM10013), Matematik Kejuruteraan 2 (DBM20023) dan Matematik Kejuruteraan 3 (DBM30033) bagi memenuhi jam kredit yang telah ditetapkan dan membolehkan pelajar memperolehi Diploma dalam bidang masing-masing. Kurikulum Politeknik yang berbeza dengan sekolah sedikit sebanyak akan mempengaruhi emosi pelajar semasa proses pengajaran dan pembelajaran di dalam kelas, semasa pembelajaran kendiri serta semasa menghadapi ujian atau penilaian. Kajian-kajian lepas menunjukkan bahawa emosi boleh mempengaruhi motivasi, tumpuan, dan prestasi pencapaian pelajar. Namun, terdapat kekurangan kajian yang meneliti tahap emosi akademik pelajar kejuruteraan dan hubungannya dengan prestasi akademik mereka di peringkat politeknik. Oleh itu, kajian ini dijalankan untuk mengenalpasti tahap emosi pelajar, menganalisis pencapaian akademik mereka, dan membandingkan perbezaan antara dua jabatan kejuruteraan bagi mendapatkan gambaran yang lebih jelas tentang keadaan emosi dan prestasi pelajar politeknik terhadap subjek Matematik Kejuruteraan.

Kaedah penilaian di Politeknik Malaysia tertakluk kepada Arahan-arahan Peperiksaan dan Kaedah Penilaian yang dikeluarkan oleh Kementerian Pendidikan Malaysia (KPM). Pencapaian pelajar dinilai daripada Penilaian Berterusan (PB) dan Peperiksaan Akhir (PA) yang mana pemberatan PB adalah 60% sementara PA adalah 40%. Penilaian Berterusan adalah berbentuk formatif yang mana ia dinilai di akhir sesi proses pengajaran dan pembelajaran melalui kuiz, ujian dan tugasan. Manakala, Peperiksaan Akhir pula adalah berbentuk sumatif yang mana ia menguji kesemua topik yang telah dipelajari sepanjang semester.

Jadual 1 menunjukkan Sistem Gred untuk menilai pencapaian markah pelajar Politeknik. Ia digunakan untuk mengukur pencapaian akademik pelajar secara adil dan saksama dan juga memberi gambaran yang jelas tentang prestasi pelajar untuk setiap kursus yang diambil. Selain itu, ia digunakan untuk asas pengiraan Purata Nilai Gred (PNG) dan PNG Kumulatif (PNGK). Gred A+, A dan A- (markah 75 -100) menunjukkan penguasaan pelajar yang sangat tinggi terhadap sesuatu kursus. Manakala, gred B+, B dan B- (markah 60 – 74) menunjukkan pemahaman dan penguasaan yang baik dan stabil terhadap sesuatu kursus. Gred C+, C dan C- (markah 47 – 59) menunjukkan pelajar dapat memenuhi keperluan yang minimum untuk lulus. Gred D+ dan D (markah 40 – 46) menunjukkan status pelajar lulus bersyarat, dimana, pelajar masih dianggap lulus, namun tetap berisiko dan perlu diperbaiki. Pelajar diberi peluang untuk memperbaiki gred dengan mengambil dan menduduki peperiksaan untuk subjek yang sama. Gred E, E- dan F (markah 0 – 39) menunjukkan pelajar gagal kursus dan perlu membuat pengulangan kursus bagi membolehkan pelajar melengkapkan keperluan jam kredit keseluruhan.

Jadual 1. Sistem Gred

Markah	Nilai Mata	Gred	Status
90 - 100	4.00	A+	Sangat Cemerlang
80 - 89	4.00	A	Cemerlang
75 - 79	3.67	A-	Kepujian
70 - 74	3.33	B+	Kepujian
65 - 69	3.00	B	Kepujian
60 - 64	2.67	B-	Lulus
55 - 59	2.33	C+	Lulus
50 - 54	2.00	C	Lulus
47 - 49	1.67	C-	Lulus
44 - 46	1.33	D+	Lulus
40 - 43	1.00	D	Lulus
30 - 39	0.67	E	Gagal
20 - 29	0.33	E-	Gagal
0 - 19	0.00	F	Gagal

Nota. Sumber: Arahan-Arahan Peperiksaan dan Kaedah Penilaian Politeknik & Kolej Komuniti

2. Metodologi Kajian

Kajian ini melibatkan seramai 91 orang responden yang terdiri daripada pelajar-pelajar semester tiga dari Jabatan Kejuruteraan Elektrik (JKE) dan Jabatan Kejuruteraan Mekanikal (JKM) di Politeknik Tuanku Sultanah Bahiyah (PTSB). Kajian ini dijalankan menggunakan reka bentuk kuantitatif melalui kaedah tinjauan. Instrumen soal selidik *Achievement Emotion Questionnaire (AEQ)* digunakan dalam kajian ini yang mana telah diadaptasi dari AEQ-S (Bieleke et al., 2021). Instrumen ini digunakan untuk mengukur emosi pencapaian pelajar dengan lebih mendalam terhadap subjek Matematik Kejuruteraan. Instrumen ini mengandungi 96 item yang dibahagikan kepada tiga bahagian emosi iaitu emosi semasa di kelas, emosi semasa pembelajaran, dan emosi semasa menghadapi ujian atau penilaian. Instrumen soal selidik bagi kajian ini terbahagi kepada 4 bahagian (A, B, C dan D).

Bahagian A mengandungi latar belakang responden yang terdiri daripada pelajar-pelajar dari jabatan Kejuruteraan Elektrik (JKE) dan Jabatan Kejuruteraan Mekanikal (JKM) serta gred pencapaian dalam kursus Matematik Kejuruteraan. Bahagian B mengukur emosi pelajar semasa di dalam kelas yang mengandungi 12 item emosi positif dan 20 item emosi negatif. Manakala, Bahagian C pula mengukur emosi pelajar semasa sesi pembelajaran kendiri yang terdiri daripada 12 item emosi positif dan 20 item emosi negatif. Akhir sekali, Bahagian D mengandungi elemen yang mengukur emosi pelajar semasa menghadapi ujian atau penilaian. Ia terdiri daripada 16 item emosi positif dan 16 item emosi negatif masing-masing.

Terdapat dua jenis emosi akademik yang diukur iaitu emosi positif dan emosi negatif. Emosi positif terdiri daripada keseronokan, harapan dan kebanggaan. Manakala emosi negatif terdiri daripada kemarahan, kebimbangan, rasa malu, putus asa, dan kebosanan. Pada skala Likert, respon diberikan mengikut kedudukan daripada 1 (Sangat Tidak Setuju), 2 (Tidak Setuju), 3 (Neutral), 4 (Setuju) dan 5 (Sangat Setuju). Data yang dikumpul telah dianalisis menggunakan *Statistical Package for the Social Science* (SPSS) Versi 27. Statistik deskriptif dalam bentuk min, sisihan piawai (sp) dan peratusan digunakan dalam analisa kajian.

3. Analisis Data Dan Dapatan Kajian

Jadual 2 menunjukkan demografi responden kajian yang terdiri daripada 58 orang (63.7%) pelajar lelaki dan 33 orang (36.3%) pelajar perempuan. Bilangan pelajar yang berbangsa Melayu merupakan bilangan responden yang paling ramai, iaitu seramai 67 orang (73.6%) diikuti oleh pelajar berbangsa India seramai 16 orang (17.6%) dan pelajar berbangsa Cina seramai 3 orang (3.3%). Manakala pelajar dari etnik lain-lain adalah seramai 5 orang iaitu sebanyak 5.5% daripada keseluruhan responden. Berdasarkan jadual di bawah, umur responden diantara 18 – 20 tahun merupakan kategori umur yang paling banyak terlibat dalam kajian ini, iaitu seramai 80 orang (87.9%), diikuti oleh umur 21 – 23 tahun seramai 8 orang (8.8%) dan umur diantara 24 – 26 tahun seramai 3 orang (3.7%). Kesemua responden yang terlibat terdiri daripada pelajar-pelajar dari Jabatan Kejuruteraan Elektrik (JKE) dan Jabatan Kejuruteraan Mekanikal (JKM) di mana masing-masing seramai 49 orang (53.8%) dan 42 orang (46.2%).

Jadual 2. Responden kajian

Kategori		Kekerapan	Peratus (%)
Jantina	Lelaki	58	63.7
	Perempuan	33	36.3
Bangsa	Melayu	67	73.6
	Cina	3	3.3
	India	16	17.6
	Lain-lain	5	5.5
Umur	18 - 20 Tahun	80	87.9
	21 - 23 Tahun	8	8.8
	24 – 26 Tahun	3	3.7
Jabatan	Jabatan Kejuruteraan Elektrik (JKE)	49	53.8
	Jabatan Kejuruteraan Mekanikal (JKM)	42	46.2

Jadual 3 menunjukkan data skor min dan sisihan piawai (sp) bagi emosi akademik mengikut 3 kategori iaitu emosi semasa di kelas, emosi semasa pembelajaran, dan emosi semasa ujian untuk pelajar-pelajar JKE dan JKM. Emosi positif yang diukur termasuklah emosi seronok, harapan, bangga dan kelegaan. Manakala, emosi negatif yang diukur termasuklah adalah seperti marah, bimbang, malu, putus asa dan bosan.

Jadual 3. Skor min dan sisihan piawai setiap kategori

Emosi			Jabatan			
			Jabatan Kejuruteraan Elektrik (JKE)		Jabatan Kejuruteraan Mekanikal (JKM)	
			Skor Min	Sisihan Piawai	Skor Min	Sisihan Piawai
Semasa di Kelas	Positif	Seronok	4.35	0.59	4.35	0.67
		Harapan	4.29	0.69	4.33	0.67
		Bangga	4.42	0.63	4.39	0.63
		Min	4.35	0.64	4.36	0.66
	Negatif	Marah	2.06	1.13	2.20	1.18
		Bimbang	2.30	1.13	2.38	1.21
		Malu	2.07	1.20	2.33	1.28
		Putus	1.77	1.09	1.76	1.03
		Bosan	1.91	1.18	1.85	1.12
		Min	2.02	1.15	2.10	1.16

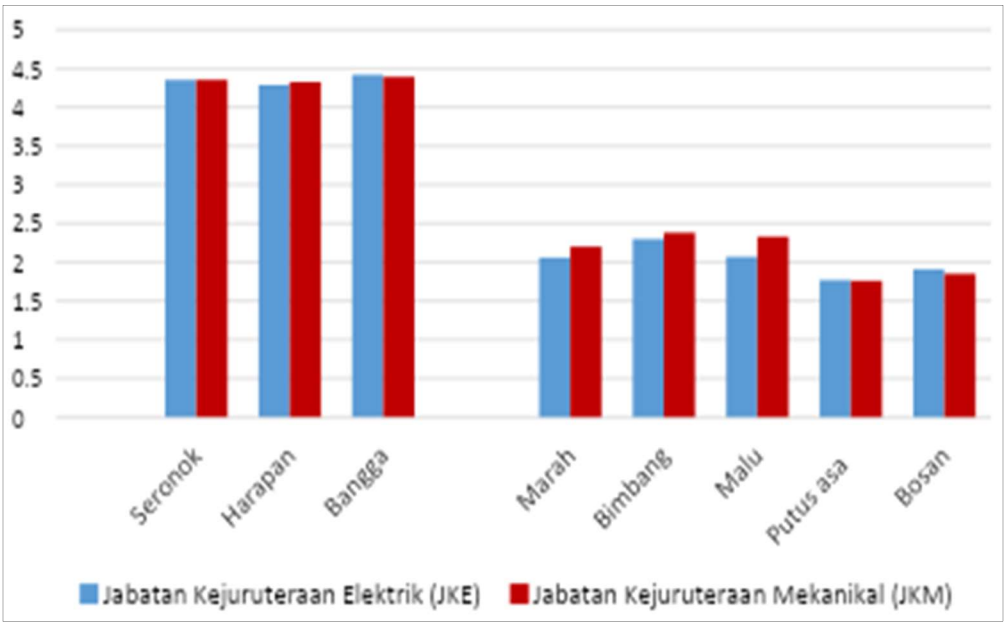
Semasa Pembelajaran	Positif	Seronok	4.41	0.62	4.33	0.71
		Harapan	4.22	0.65	4.24	0.76
		Bangga	4.23	0.76	4.10	1.02
		Min	4.29	0.68	4.22	0.83
	Negatif	Marah	1.90	1.14	1.79	1.08
		Bimbang	2.12	1.19	2.14	1.15
		Malu	1.96	1.06	2.02	1.21
		Putus	1.78	1.04	2.18	1.28
		Bosan	1.77	1.05	1.89	1.13
		Min	1.90	1.10	2.00	1.17
Semasa Ujian	Positif	Seronok	4.01	0.81	3.87	0.99
		Harapan	4.08	0.81	3.77	1.14
		Bangga	4.13	0.82	3.95	1.01
		Kelegaan	4.45	0.68	3.92	1.09
		Min	4.17	0.78	3.88	1.06
	Negatif	Marah	1.84	1.07	1.67	0.85
		Bimbang	2.43	1.27	2.24	1.17
		Malu	2.16	1.15	2.17	1.15
		Putus asa	1.78	1.02	1.93	1.14
		Min	2.05	1.13	1.96	1.06

3.1 Kategori 1: Emosi semasa di kelas

Merujuk kepada Jadual 3, untuk kategori emosi pelajar ketika menghadiri kelas, skor min tertinggi untuk kedua-dua jabatan (JKE dan JKM) adalah emosi bangga iaitu dengan nilai (min=4.42, sp=0.63) dan (min=4.39, sp=0.63) masing-masing. Data menunjukkan bahawa pelajar JKE lebih menunjukkan rasa bangga yang tinggi ketika menghadiri kelas Matematik berbanding dengan pelajar JKM. Diikuti oleh emosi seronok, dimana, JKE memperolehi nilai (min=4.35, sp=0.59) dan JKM memperolehi nilai (min=4.35, sp=0.67). Kedua-duanya menunjukkan skor min yang sama, dimana ia menggambarkan tahap keseronokan pelajar JKE dan JKM adalah sama semasa menghadiri kelas. Emosi harapan merupakan emosi positif yang mempunyai skor min paling rendah berbanding dengan emosi bangga dan seronok. Nilai skor yang diperolehi oleh pelajar JKE adalah sebanyak min=4.29, sp=0.69 dan JKM adalah sebanyak min=4.33, sp=0.67. Dapatan menunjukkan bahawa pelajar JKM lebih mempunyai harapan yang tinggi semasa di dalam kelas. Walaubagaimana pun, kedua-dua jabatan menunjukkan emosi positif yang sangat tinggi iaitu melebihi 4.0. Data mempamerkan pelajar dari kedua-dua jabatan berasa seronok dan gembira untuk hadir ke kelas Matematik.

Berdasarkan emosi negatif pula, pelajar JKE dan JKM memperolehi skor min yang tertinggi pada emosi bimbang iaitu dengan skor (min=2.30, sp=1.13) dan (min=2.38, sp=1.21) masing-masing. Hasil dapatan menunjukkan bahawa emosi marah dan malu bagi pelajar-pelajar JKM lebih tinggi iaitu dengan skor min=2.20, sp=1.18 dan min=2.33, sp=1.28 masing-masing. Manakala, pelajar JKE memperolehi skor yang lebih rendah untuk emosi marah dan malu dengan skor min=2.06, sp=1.13 dan min=2.07, sp=1.20 masing-masing. Walaubagaimana pun, putus asa mempunyai skor yang paling rendah untuk kedua-dua jabatan iaitu min=1.77, sp=1.09 dan min=1.76, sp=1.03 masing-masing. Hasil dapatan menunjukkan bahawa pelajar-pelajar dari JKE dan JKM

mempunyai rasa putus asa dan bosan yang sedikit ketika menghadiri kelas Matematik Kejuruteraan.



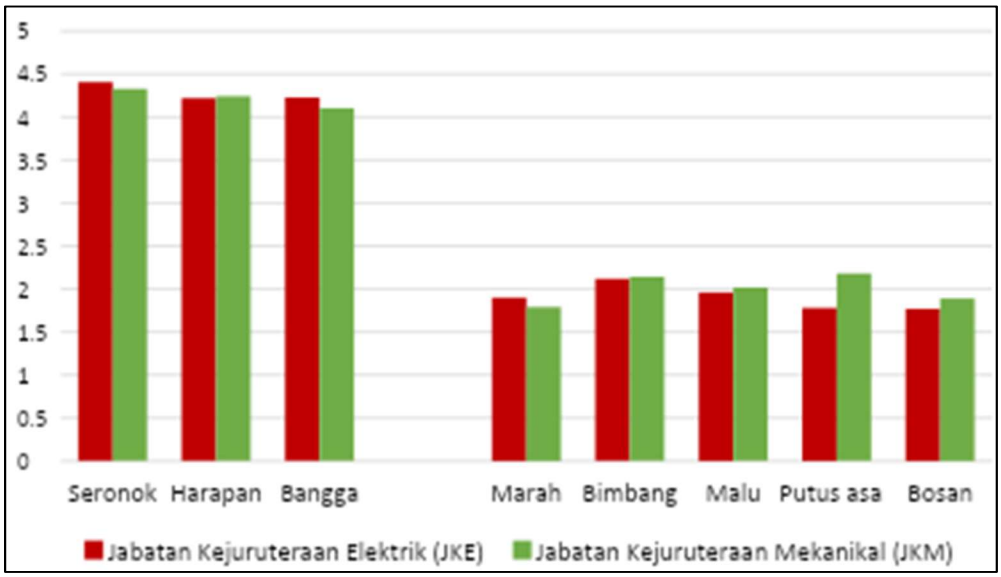
Rajah 1. Perbandingan emosi positif dan negatif pelajar semasa di kelas

Berdasarkan graf pada Rajah 1, kedua-dua jabatan mempamerkan skor emosi positif yang tinggi dan hampir sama. Ia dapat dilihat pada graf emosi seronok yang mempunyai skor yang sama bagi kedua-dua jabatan. Pelajar-pelajar JKE menunjukkan rasa bangga yang lebih tinggi berbanding dengan pelajar-pelajar JKM. Namun begitu, JKE menunjukkan emosi harapan yang lebih rendah berbanding dengan JKM. Manakala untuk emosi negatif, JKM menunjukkan emosi negatif yang lebih tinggi pada emosi marah, bimbang dan malu, tetapi mempunyai skor yang lebih rendah pada emosi bosan. Graf menunjukkan tahap putus asa bagi kedua-dua jabatan berada pada kedudukan yang paling rendah dan menyamai antara kedua-dua jabatan.

3.2 Kategori 2: Emosi semasa pembelajaran

Berdasarkan Jadual 3, untuk kategori emosi pelajar ketika proses pembelajaran kendiri pula, emosi seronok merupakan emosi positif yang mempunyai skor yang tinggi untuk kedua-dua jabatan JKE dan JKM dengan skor (min=4.41, sp=0.62) dan (min=4.33, sp=0.71) masing-masing. Namun, pelajar-pelajar JKE, menujukkan emosi harapan paling rendah dengan skor min=4.22 dan sp=0.65. Manakala, pelajar-pelajar JKM menujukkan emosi bangga paling rendah dengan skor min=4.10 dan sp=1.02. Namun, kedua-dua jabatan mempunyai emosi positif yang lebih tinggi dengan memperolehi skor melebihi 4.0. Berdasarkan emosi negatif, pelajar-pelajar JKE menujukkan rasa bimbang yang paling tinggi dengan skor min=2.12 dan sp=1.19. Namun, mereka tidak menunjukkan rasa bosan ketika membuat pembelajaran secara kendiri untuk subjek Matematik, kerana skor yang diperolehi sangat rendah iaitu min=1.77 dan sp=1.05. Pelajar-pelajar JKM menunjukkan rasa putus asa yang lebih tinggi berbanding dengan pelajar JKE ketika pembelajaran kendiri, dimana mempamerkan nilai min=2.18 dan sp=1.21. Dapatan menunjukkan tahap kemarahan pelajar-pelajar JKM lebih rendah ketika proses pembelajaran kendiri berbanding dengan pelajar-pelajar JKE iaitu memperolehi nilai min=1.79, sp=1.08 dan min=1.90, sp=1.14 masing-masing. Pelajar-pelajar JKM menunjukkan skor yang lebih tinggi dalam semua

aspek emosi negatif berbanding dengan pelajar-pelajar JKE. Namun, secara keseluruhannya, emosi negatif untuk kedua-dua jabatan masih rendah kerana mempunyai nilai kurang dari 2.0.



Rajah 2. Perbandingan emosi positif dan negatif semasa pembelajaran kendiri

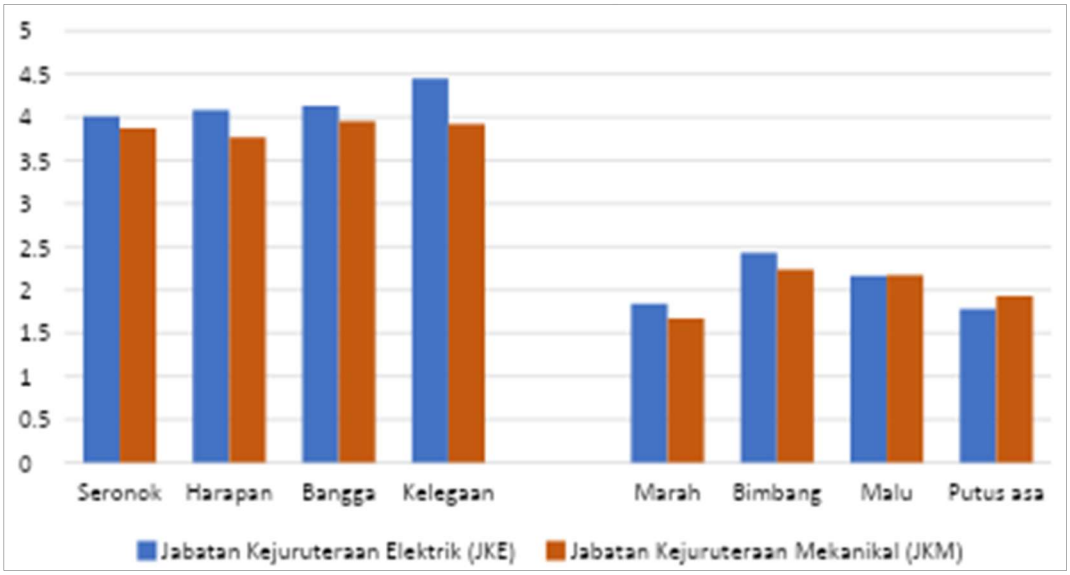
Graf pada Rajah 2 menunjukkan perbandingan antara emosi positif dan negatif untuk JKE dan JKM bagi kategori semasa pembelajaran kendiri. Pelajar JKE menunjukkan skor emosi positif yang lebih tinggi berbanding dengan JKM. Ini menunjukkan bahawa pelajar JKE lebih bersemangat dan optimis semasa proses pembelajaran. Namun, sebaliknya, pelajar JKM mempunyai skor emosi negatif yang lebih tinggi. Hasil kajian menunjukkan mereka lebih mudah berasa malu, putus asa, bosan semasa pembelajaran berbanding dengan pelajar JKE.

3.3 Kategori 3: Emosi semasa ujian atau penilaian

Merujuk kepada Jadual 3, untuk kategori emosi pelajar semasa menghadapi ujian, bagi emosi positif, didapati bahawa pelajar JKE lebih seronok ketika menghadapi ujian berbanding dengan pelajar JKM dengan masing-masing mempunyai skor (min=4.01, sp=0.81) dan (min=3.87, sp=0.99). Pelajar-pelajar JKE mempamerkan emosi harapan yang lebih tinggi semasa ujian iaitu dengan mendapat skor min=4.08, sp=0.81 berbanding dengan pelajar JKM yang mendapat skor yang lebih rendah iaitu min=3.77 dan sp=1.14. Pelajar JKE juga didapati menunjukkan emosi bangga dan kelegaan yang lebih tinggi semasa ujian iaitu masing-masing mendapat skor min=4.13, sp=0.82 dan min=4.45, sp=0.68. Manakala, pelajar-pelajar JKM mempamerkan skor yang lebih sederhana untuk emosi bangga dan kelegaan semasa ujian, berbanding dengan dengan pelajar-pelajar JKE dengan mendapat skor min=3.95, sp= 1.01 dan min=3.92, sp=1.09 masing-masing. Ini menunjukkan bahawa, pelajar-pelajar JKE mempunyai emosi positif yang lebih stabil, tenang dan yakin semasa menghadapi ujian berbanding dengan pelajar JKM.

Berdasarkan dapatan daripada emosi negatif, pelajar-pelajar JKE mempunyai rasa marah dan bimbang yang tinggi berbanding dengan pelajar JKM semasa menghadapi ujian dengan mendapat skor min=1.84, sp=1.07 dan min=2.43, sp=1.27. Manakala, skor emosi marah dan bimbang yang diperolehi oleh pelajar JKM adalah min=1.67, sp=0.85 dan min=2.24, sp= 1.17 masing-masing. Namun begitu, untuk emosi malu dan putus asa, pelajar JKM menunjukkan skor yang lebih tinggi berbanding pelajar-pelajar JKE, dengan nilai min=2.17, sp=1.16 dan 1.93,

sp=1.14 masing-masing. Pelajar JKE menunjukkan skor yang lebih rendah untuk emosi malu dan putus asa, dengan masing-masing mendapat skor min=2.16, sp=1.15 dan min=1.78, sp=1.02. Hasil dapatan menunjukkan bahawa, pelajar-pelajar JKE mempunyai tahap kebimbangan yang lebih tinggi semasa menghadapi ujian berbanding dengan pelajar JKM. Ini menunjukkan bahawa pelajar JKE lebih mengambil berat terhadap prestasi mereka dan mempunyai tahap motivasi yang tinggi untuk lebih cemerlang. Berdasarkan data yang diperolehi, pelajar JKM mempamerkan rasa putus asa yang lebih tinggi dan kurang berkeyakinan serta lebih cenderung kepada tekanan emosi yang lebih besar semasa menghadapi ujian. Namun, secara keseluruhannya, emosi negatif masih berada pada tahap yang rendah iaitu kurang daripada 2.5.



Rajah 3. Perbandingan emosi positif dan negatif semasa menghadapi ujian

Rajah 3 menunjukkan graf perbandingan antara emosi positif dan negatif semasa pelajar menghadapi ujian. Pelajar JKE menunjukkan skor yang lebih tinggi untuk semua emosi positif, tetapi sebaliknya untuk pelajar JKM. Ini menunjukkan, pelajar JKM kurang yakin dan berasa tertekan semasa ujian dilaksanakan. Manakala, untuk emosi negatif, tahap kebimbangan dikalangan pelajar JKE lebih tinggi berbanding pelajar JKM. Ini menandakan bahawa pelajar JKE menekankan prestasi dan pencapaian. Tahap putus asa yang tinggi dalam kalangan pelajar JKM menunjukkan mereka kurang bersedia dan tertekan untuk menghadapi ujian.

3.4 Pencapaian Pelajar

Jadual 4 menunjukkan peratus pencapaian pelajar JKE dan JKM dalam kursus Matematik Kejuruteraan. Berdasarkan analisis data, jumlah pelajar bagi Jabatan Kejuruteraan Elektrik (JKE) adalah seramai 49 orang, manakala Jabatan Kejuruteraan Mekanikal (JKM) seramai 42 orang pelajar. Seramai 25 orang (51%) pelajar dari JKE telah mendapat gred yang tinggi iaitu A+, A dan A- daripada keseluruhan pelajar JKE yang mengambil kursus Matematik Kejuruteraan. Manakala, seramai 19 orang (39%) pelajar mendapat gred B+, B dan B- yang menunjukkan pencapaian yang agak baik dan memuaskan. Pelajar yang mendapat gred C+, C dan C- adalah seramai 5 orang (10%) pelajar. Dapatan menunjukkan bahawa, seramai 23 orang (55%) pelajar JKM memperolehi gred tertinggi iaitu A+, A dan A-. Manakala seramai 12 orang (29%) pelajar JKM memperolehi gred B+, B dan B- dan seramai 7 orang (17%) pelajar JKM yang memperolehi gred C+, C dan C-.

Jadual 4 : Peratus Pencapaian Pelajar

Gred	JKE		JKM	
	Bil. pelajar	Peratus (%)	Bil. pelajar	Peratus (%)
A+	5	10.2	9	21.4
A	14	28.6	11	26.2
A-	6	12.2	3	7.1
B+	6	12.2	2	4.8
B	9	18.4	6	14.3
B-	4	8.2	4	9.5
C+	2	4.1	2	4.8
C	1	2.0	3	7.1
C-	2	4.1	2	4.8

Secara keseluruhannya, JKE mempunyai bilangan pelajar cemerlang paling ramai berbanding dengan pelajar JKM. Namun begitu, apabila dianalis berdasarkan peratusan pelajar cemerlang, JKM mempunyai peratusan yang lebih tinggi iaitu 55% berbanding dengan JKE sebanyak 51%. Namun, pelajar JKM menunjukkan bilangan dan peratusan yang lebih tinggi berbanding JKE untuk pencapaian yang sederhana, iaitu gred C dan ke bawah. Berdasarkan data dan analisis yang dibuat, pelajar JKE mempunyai prestasi pencapaian yang lebih baik jika dibandingkan dengan pelajar JKM. Ianya selari dengan tahap emosi pelajar JKE yang mempamerkan emosi positif yang lebih tinggi berbanding emosi positif pelajar JKM dimana mempunyai tahap emosi negatif yang lebih tinggi. Namun begitu, pelajar dari kedua-dua jabatan menunjukkan tahap emosi positif yang masih tinggi kerana masing-masing mempunyai skor lebih dari 4.0. Manakala, untuk emosi negatif pula, kedua-dua jabatan JKE dan JKM mempunyai skor kurang dari 2.5 dan ini menunjukkan bahawa tahap emosi negatif kedua-dua jabatan masih pada tahap yang rendah.

Kajian mendapati bahawa majoriti pelajar memberi maklumbalas positif terhadap pengalaman pembelajaran untuk kursus Matematik Kejuruteraan. Emosi positif ditunjukkan berhubung dengan keseluruhan pengalaman pembelajaran mereka, semasa sesi pembelajaran di kelas dan perasaan mereka ketika menghadapi ujian atau penilaian. Emosi yang dialami oleh pelajar berkaitan dengan pencapaian dan hasil mereka dikenali sebagai emosi pencapaian [Pekrun (2006), Stephen et al. (2019), Riegel & Evans (2021)]. Emosi yang dialami oleh pelajar semasa di kelas telah mencapai tahap emosi yang lebih tinggi untuk JKM dan JKE iaitu, min=4.36, sp=0.66 dan min=4.35, sp=0.64 masing-masing. Tahap emosi negatif yang rendah diperolehi oleh kedua-dua jabatan telah dibuktikan oleh purata masing-masing iaitu min=2.02, sp=1.15 dan min=2.10, sp=1.16. Emosi positif pelajar dari JKE menunjukkan skor tertinggi iaitu min=4.29, sp=0.68 untuk emosi pelajar semasa sesi pembelajaran. Namun, tahap emosi positif pelajar JKM adalah pada skor yang lebih sedikit iaitu min=4.22, sp=0.83. Hasil analisis mendapati bahawa tahap emosi negatif dikalangan kedua-dua jabatan adalah rendah iaitu min=1.90, sp=1.10 dan min=2.00, sp=1.13 masing-masing. Emosi positif pelajar JKE berada pada tahap yang tinggi untuk kategori semasa menghadapi ujian atau penilaian iaitu mendapat skor min=4.17, sp=0.78 dan pelajar JKM memperolehi skor min=3.88, sp=1.06. Tahap emosi negatif pelajar semasa menghadapi ujian adalah min=2.05, sp=1.13 untuk JKE dan min=1.96, sp-1.06 untuk pelajar JKM.

Merujuk kepada data yang diperolehi, didapati nilai min bagi setiap kategori untuk emosi positif dan negatif semasa di dalam kelas, semasa pembelajaran kendiri dan semasa menghadapi ujian atau penilaian menunjukkan trend yang sama untuk kedua-dua jabatan. Ia menunjukkan semasa di dalam kelas, emosi positif pelajar menunjukkan skor min yang tinggi untuk JKE dan JKM berbanding dengan semasa pembelajaran kendiri dan semasa menghadapi ujian atau penilaian.

Manakala untuk emosi negatif pula, skor min yang tertinggi adalah pada kategori semasa pelajar menghadapi ujian atau penilain. Ini menunjukkan bahawa pelajar mungkin merasa lebih selesa, yakin dan bermotivasi ketika sesi pengajaran dan pembelajaran di dalam kelas berbanding ketika berdepan dengan ujian atau penilaian yang sering menimbulkan tekanan dan kebimbangan. Ini mencerminkan bahawa suasana kelas mungkin lebih menyokong secara emosi, memberi rasa selamat, dan mendorong motivasi pelajar untuk belajar, dimana, pensyarah dapat membantu sekiranya berlaku ketidakfahaman terhadap sesuatu topik. Sebaliknya, ujian atau penilaian cenderung menimbulkan tekanan, kebimbangan atau kurang keyakinan, sekali gus menurunkan skor emosi positif pelajar.

4. Kesimpulan

Secara keseluruhannya, emosi akademik (emosi positif dan negatif) memainkan peranan penting dalam pencapaian prestasi seseorang pelajar khususnya dalam kursus Matematik Kejuruteraan. Pengkaji mendapati bahawa, kedua-dua jabatan JKE dan JKM menujukkan peraturan emosi yang cemerlang untuk setiap kategori yang dikaji iaitu emosi semasa di kelas, emosi semasa pembelajaran dan emosi semasa menghadapi ujian atau penilaian. Tahap emosi positif pelajar JKE dan JKM berada pada yang tinggi dan seimbang semasa di dalam kelas. Namun, tahap emosi negatif pelajar JKM lebih tinggi terutamanya malu dan bimbang semasa di dalam kelas, mungkin disebabkan kurangnya keyakinan diri dan interaksi. Emosi positif pelajar JKE semasa sesi pembelajaran berada pada tahap yang tinggi dan emosi negatif yang lebih rendah daripada JKM. Pelajar JKE mempamerkan tahap emosi positif yang tinggi dan terdapat sedikit peningkatan dalam kebimbangan semasa menghadapi ujian berbanding Pelajar JKM. Ini menunjukkan pelajar JKE lebih bersedia dan yakin, manakala pelajar JKM mungkin mengalami tekanan dan putus asa semasa menghadapi ujian.

Namun begitu, tahap min emosi positif dalam kajian ini masih agak tinggi, manakala tahap min emosi negatif adalah agak rendah. Pencapaian pelajar dalam memperoleh gred yang cemerlang amat dipengaruhi oleh faktor emosi positif seperti seronok, harapan dan bangga semasa menghadiri kelas dan sesi pembelajaran. Emosi negatif seperti rasa bimbang dan takut perlu ada dalam diri setiap pelajar agar lebih bersedia untuk menghadapi ujian atau penilaian. Walaupun umum mengetahui bahawa emosi positif mempunyai faedah dan emosi negatif mempunyai kelemahan, namun, kedua-dua jenis emosi ini mempunyai kelebihan yang tersendiri. Oleh yang demikian, emosi positif dan negatif perlu ada dalam diri setiap pelajar agar lebih cemerlang dalam pelajaran dan juga aspek kehidupan yang lain.

Kajian ini diharapkan dapat membantu para pensyarah, khususnya di Politeknik dalam memahami emosi positif dan negatif pelajar yang mempengaruhi pencapaian prestasi Kursus Matematik Kejuruteraan, sekaligus bersama-sama berusaha kearah meningkatkan peratus pencapaian dan penguasaan pelajar terhadap kursus Matematik Kejuruteraan. Kajian yang akan datang dicadangkan agar diperluaskan di sekolah-sekolah atau politeknik lain dengan mengambil kira populasi yang lebih ramai bagi mendapatkan gambaran yang lebih menyeluruh dan tepat. Selain itu, dicadangkan juga agar lebih banyak pembolehubah yang dikaji melibatkan korelasi antara emosi pelajar dan kaitannya dengan prestasi pelajar.

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THE INFLUENCE OF PRICE AND SERVICE QUALITY ON CONSUMER PURCHASE DECISIONS AT GERAI HANIA ONLINE STORE IN MEDAN CITY

Fitri Amalia Nst*, Cece Cece

Management Department, School of Management Studies, 20219 Medan, North Sumatra, Indonesia

*Corresponding author e-mail address: fitrinst512@gmail.com,

Abstract

This research aims to analyze the influence of price and service quality on consumer purchasing decisions at the Gerai Hania online store in Medan. The study uses a quantitative approach with a multiple linear regression analysis method. Data were collected through questionnaires distributed to 90 consumers who had made purchases at the store. The variables studied include price and service quality as independent variables, and purchasing decision as the dependent variable. The results show that both price and service quality have a significant positive effect on purchasing decisions, both partially and simultaneously. The coefficient of determination (R^2) indicates that 86.7% of the variation in purchasing decisions can be explained by the two independent variables. Among them, service quality is the most dominant factor influencing purchasing decisions, as shown by the highest standardized coefficient (Beta). These findings highlight the importance of competitive pricing and excellent service quality in increasing consumer interest and satisfaction in online retail settings. This study provides valuable insights for online business owners seeking to improve customer acquisition and retention strategies through pricing and service improvement.
Keywords: Price; Service Quality; Purchasing Decision.

1. Introduction

The rapid development of information and communication technology in recent years has brought fundamental changes in consumer behavior patterns, including in the city of Medan. This digital transformation has driven a shift from conventional transactions to online transactions, enabling consumers to purchase products or services without the need for physical presence in stores. Various e-commerce platforms and online shops have emerged, offering convenience, time efficiency, and practicality in the shopping process.

Gerai Hania is one of the businesses that has taken advantage of this opportunity. This online store, which specializes in women's and children's clothing, is located at Jl. Alfalah No.13 B, Suka Maju Subdistrict, Medan Johor District, Medan City, North Sumatra 20146. Established in early 2020 by a young couple who recognized the growing trend of online shopping during the COVID-19 pandemic, Gerai Hania initially marketed its products through a personal Instagram account with a limited collection. However, due to positive market responses, the store gradually expanded its marketing channels to TikTok and Shopee, actively using these platforms to promote content and facilitate sales transactions. In addition to its online presence, Gerai Hania also offers offline purchasing services at the same location, providing an alternative for customers who prefer to view the products in person.

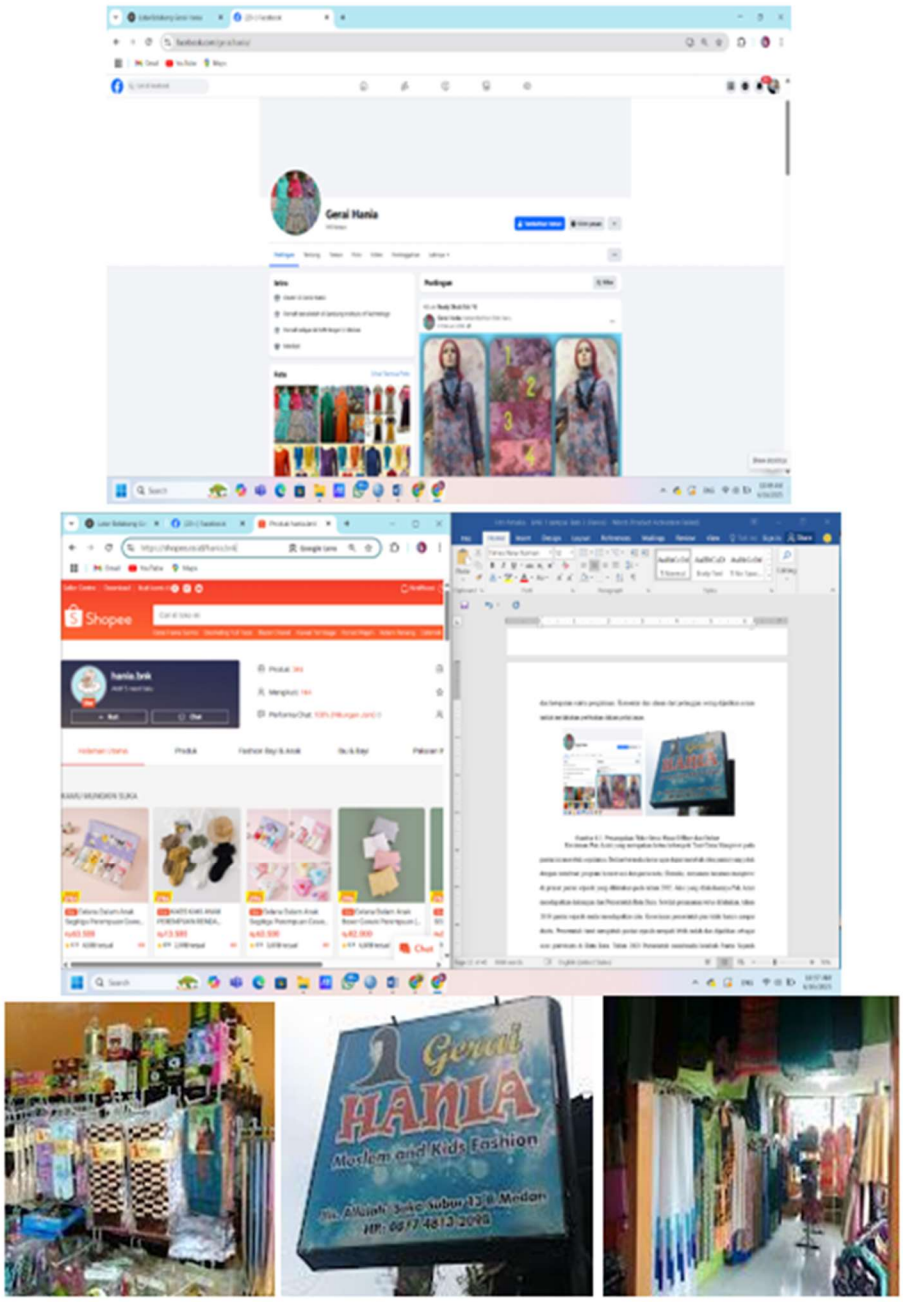


Fig. 1. Overview of Gerai Hania's Offline and Online Storefront

The products offered by Gerai Hania include a variety of women's and children's clothing, such as dresses, blouses, long dresses (gamis), sleepwear, and daily kids' outfits. All products are carefully selected in accordance with current fashion trends while maintaining affordable prices for the middle-income consumer segment. A competitive pricing strategy is one of Gerai Hania's key advantages, supported by efforts to provide comfortable and prompt service, both in communication and product delivery.

However, as the business has grown, Gerai Hania has encountered several challenges, particularly in maintaining the quality of its customer service. Based on initial observations and internal sales data, it was found that monthly transaction volumes fluctuate and do not always

correspond with the number of visits to the store's online pages. This indicates a gap between initial consumer interest and final purchasing decisions. Some customers have also provided feedback regarding slow response times and incomplete product information. With increasing competition in the online fashion industry, improving customer service has become essential to maintaining the store's reputation and customer loyalty.

In the context of online stores, consumer purchasing decisions represent a critical stage influenced by various factors. The purchase decision process involves a series of steps, starting from need recognition, information search, evaluation of alternatives, purchase decision, and post-purchase behavior. Throughout this process, consumers take into account the available information about the product, pricing, reviews from other customers, transaction security, and their previous shopping experiences. (Devi & Fadli, 2023; Zahira & Salamah, 2022).

Previous studies have shown that online purchasing decisions are strongly influenced by competitive pricing and adequate service quality. A study by Zubaidah and Latief (Devi & Fadli, 2023) revealed that factors such as discount promotions, free shipping, price, and product quality significantly affect consumer purchasing decisions on Shopee. Meanwhile, research conducted by Ghoni and Soliha (Dika Juliantari & Prawitasari, 2025) as well as Hermansyah et al. found that brand image, customer reviews, service quality, and price have a significant influence on purchase decisions (Hardianawati et al., 2024).

In this context, competitive and transparent pricing not only reflects the value of the product but also represents consumer trust in the store (Kotler & Keller, 2021). A study by Ulfah, Fadilah, and Fadli emphasizes that prices aligned with consumers' perceived value can significantly drive purchasing decisions (Devi & Fadli, 2023; Fadilah et al., 2023; Ulfah, 2023). Meanwhile, service quality—which includes response speed, clarity of product information, delivery reliability, transaction security, and friendly communication—has been proven to directly contribute to customer satisfaction and loyalty. Research conducted by Marbun, Antoni, and Faradila demonstrates that excellent service can encourage repeat purchases and strengthen consumer loyalty (Faradila et al., 2024; Marbun, 2022; Nufal & Kuswinarno, 2024).

As the store continues to grow, Gerai Hania has established a substantial customer base in Medan and its surrounding areas. Daily visits to the store's accounts and consumer interactions have increased significantly, especially during promotional events or seasonal discounts. The business has also created employment opportunities for additional staff, such as social media administrators, packaging teams, and customer service personnel. In navigating the rapidly evolving online market, Gerai Hania must gain a deep understanding of how price and service quality influence consumer purchasing decisions. An accurate understanding of the factors affecting purchase decisions will serve as a foundation for formulating more effective and relevant marketing strategies, thereby enhancing competitive advantage amid the increasingly intense competition in the online fashion industry.

Theoretically, the relationship between the variables Price (X1), Service Quality (X2), and Purchase Decision (Y) can be illustrated through a conceptual framework.

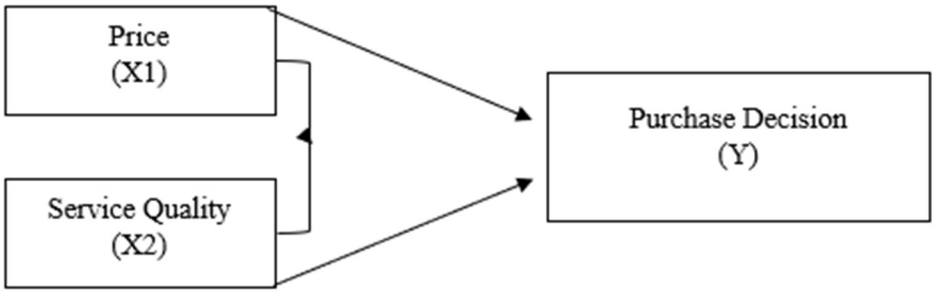


Fig. 2. Theoretical Framework

Based on the aforementioned explanation, the research hypotheses are formulated as follows:

H_1: Price has a positive and significant effect on consumer purchase decisions at the Gerai Hania online store in Medan City.

H_2: Service quality has a positive and significant effect on consumer purchase decisions at the Gerai Hania online store in Medan City.

H_3: Price and service quality simultaneously have a positive and significant effect on consumer purchase decisions at the Gerai Hania online store in Medan City.

Thus, this study is expected to provide both theoretical and practical contributions, as well as serve as a reference for Gerai Hania in formulating data-driven marketing strategies to enhance competitive advantage and customer satisfaction.

2. Methodology

This study involved customers of Gerai Hania Online Store, located at Jl. Alfalah No.13 B, Suka Maju Subdistrict, Medan Johor District, Medan City, North Sumatra, 20146. Gerai Hania specializes in selling women's and children's clothing through various digital platforms, including Instagram, TikTok, and Shopee, as well as operating a physical storefront. The study's target population included all customers who made purchases between November 2024 and March 2025, during which the store averaged 173 transactions per month. Using Slovin's formula and a 10% margin of error, the study determined a sample size of 90 respondents. Participants were selected based on the criterion that they had completed at least two purchases. This sampling method ensured the inclusion of informed and experienced customers, thereby improving the validity of the findings related to the impact of pricing and service quality on purchasing decisions.

The research was conducted from March to June 2025. The initial stages included the submission of the research title and the preparation of the proposal, followed by data collection through online questionnaires and data analysis using SPSS Version 22. The questionnaires were distributed digitally to Gerai Hania customers who met the participation criteria. Before data collection, participants were informed about the purpose of the study, and their consent was obtained voluntarily. The collected data were then coded, classified, and processed for statistical testing in accordance with the research objectives. Throughout the research process, ethical considerations such as confidentiality and data privacy were maintained to protect respondent identities.

The primary data in this study were obtained through an online questionnaire distributed via Google Forms (https://forms.gle/NYj4Dwh3w1Ft3c358). Secondary data were collected from relevant literature, including scholarly journals, books, articles, and supporting documentation.

The questionnaire was structured to include 15 statement items distributed across three main variables: Price (X1), Service Quality (X2), and Purchase Decision (Y). Each item was measured using a 5-point Likert scale with response options ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). This instrument was developed and refined based on existing literature and adapted to the research context of online consumers in Medan.

The operational definitions and indicators for each variable are as follows:

a) Price (X1) refers to the consumer's perception of the affordability, fairness, and attractiveness of product pricing. This variable was measured using 5 items related to:
   i. Price affordability
   ii. Satisfaction with price relative to quality
   iii. Price attractiveness compared to competitors
   iv. Influence of promotions or discounts
   v. Price transparency
b) Service Quality (X2) is defined as the perceived quality of service provided during the online shopping experience, including interaction and platform usability. Measured with 5 items covering:
   i. Product conformity with description
   ii. Admin responsiveness
   iii. Transaction safety and trust
   iv. Friendliness of service
   v. Interface appearance and ease of navigation of the online store
c) Purchase Decision (Y) refers to the customer's final decision to buy a product based on the evaluation of the product, price, and service quality. Measured with 5 items focusing on:.
   i. Product suitability with consumer needs
   ii. Information seeking before purchase
   iii. Comparison with other stores
   iv. Consideration of price and quality
   v. Purchase satisfaction and repurchase intention

Before full-scale data collection, the questionnaire was reviewed to ensure clarity of statements and consistency with research objectives. A pilot test was also conducted to assess internal reliability and refine wording where necessary.

The data collected through questionnaires were analyzed using SPSS version 22. A series of analytical procedures was applied to ensure that the data were valid, reliable, and met the classical assumptions necessary for conducting multiple linear regression analysis. The steps are as follows:

a) Validity Test: The purpose of this test is to ensure that each item in the questionnaire accurately measures the intended construct. The validity was assessed using the Corrected Item-Total Correlation, where a correlation coefficient greater than 0.30 indicates that the item is valid.
b) Reliability Test: This test measures the internal consistency of questionnaire items using Cronbach's Alpha. A value of $\alpha \geq 0.70$ indicates that the instrument is reliable.
c) Classical Assumption Tests. Before regression analysis, the dataset was tested for the following classical assumptions:
   i. Normality Test: Assesses whether the residuals are normally distributed, evaluated through Kolmogorov–Smirnov and Q–Q Plot analysis.

   ii. Multicollinearity Test: Detects the presence of high correlation among independent variables. The model is considered free from multicollinearity if Tolerance > 0.10 and VIF < 10.
   iii. Heteroscedasticity Test: Detects unequal variances of residuals. The absence of heteroscedasticity is confirmed if the scatterplot of residuals appears randomly distributed without a discernible pattern.

d) Coefficient of Determination (R^2), this test examines the proportion of variation in the dependent variable (Purchase Decision) explained by the independent variables (Price and Service Quality).
e) Partial Test (t-test): This test is used to determine the individual influence of each independent variable on the dependent variable. It shows whether Price and Service Quality have a statistically significant impact when considered separately.
f) Simultaneous Test (F-test): This test evaluates whether Price and Service Quality together have a statistically significant effect on the Purchase Decision.
g) Multiple Linear Regression Analysis, this analysis is used to assess both the simultaneous and partial effects of Price (X_1) and Service Quality (X_2) on Purchase Decision (Y). It determines how each independent variable influences the dependent variable while controlling for the other. The regression produces coefficient values that indicate the direction and strength of the relationship, as well as the coefficient of determination (R^2), which reflects the proportion of variance in the purchase decision explained by both variables. This method also supports hypothesis testing through t-tests (partial) and F-tests (simultaneous), allowing for a comprehensive evaluation of the model's predictive power.

The decision rule was established based on a 5% significance level (α = 0.05) for the hypothesis testing.

i. If p-value ≤ 0.05, the alternative hypothesis (Ha) is accepted, indicating a statistically significant effect.
ii. If p-value > 0.05, the null hypothesis (Ho) is accepted, indicating no statistically significant effect.

Additionally, for the t-test, significance is also confirmed if the t-statistic is equal to or greater than the t-table value. This analytical approach ensures that the findings are statistically valid and capable of accurately explaining the influence of Price and Service Quality on consumer Purchase Decisions at Gerai Hania Online Store in Medan.

3. Results and Discussion

This study conducted a descriptive analysis to understand the demographic background and purchasing preferences of consumers at Gerai Hania, an online store based in Medan, Indonesia. Data were collected through questionnaires distributed to 90 respondents, who were selected using the Slovin formula to represent the population accurately. The population consisted of all customers who made purchases at Gerai Hania, which recorded an average of 173 transactions per month between November 2024 and March 2025. Since the exact number of unique customers was unknown and the population was relatively large, probability-based sampling was not feasible.

The information gathered includes variables such as gender, age, education level, purchase frequency, source of information, preferred payment method, and the primary factors influencing purchasing decisions. All 90 questionnaires were fully completed and deemed valid for analysis,

resulting in a 100% response rate. Accordingly, both descriptive and inferential analyses were carried out based on this dataset, providing a representative insight into the characteristics and behavior of Gerai Hania's consumer base.

Table 1. Respondent Characteristics

No	Respondent Characteristic	Category	Frequency (n)	Percentage (%)
a)	Age	< 20 years	10	11.10%
		20 – 25 years	64	71.10%
		26 – 30 years	5	5.60%
		31 – 35 years	6	6.70%
		> 35 years	5	5.60%
b)	Gander	Male	33	36.70%
		Female	57	63.30%
c)	Last Education Level	Senior High School (SMA/SMK)	57	63.30%
		Diploma	6	6.70%
		Undergraduate/Graduate/Postgraduate (S1/S2/S3)	27	30.00%
d)	Purchase Frequency	Once	31	34.40%
		2–3 times	37	41.10%
		More than 3 times	22	24.40%
e)	Source of Information	Instagram	27	30.00%
		TikTok	21	23.30%
		Friends/Family	42	46.70%
f)	Payment Method	Cash on Delivery (COD)	45	50.00%
		E-wallet	22	24.40%
		Credit/Debit Card	7	7.80%
		Bank Transfer	16	17.80%
g)	Main Factor Influencing Purchase	Service Quality	34	37.80%
		Product Price	19	21.10%
		Recommendations from Others	12	13.30%
		Combination (price, quality, promo, service)	25	27.80%

Based on Table 1, the respondent characteristics in this study reflect the demographic profile and purchasing behavior of consumers at the Gerai Hania Online Store. These characteristics include age, gender, level of education, purchase frequency, source of information, payment method, and the main factors influencing purchase decisions. A detailed explanation of each characteristic is presented below:

a) Age Distribution
The majority of respondents (71.10%) were aged between 20 and 25 years, indicating that Gerai Hania's customer base is dominated by young adults. Meanwhile, 11.10% were under 20 years old, and smaller proportions were found in the 26–30 (5.60%), 31–35 (6.70%), and over 35 years (5.60%) age groups. This suggests that the store primarily appeals to consumers in early adulthood, a group typically active in online shopping and responsive to digital marketing.

b) Gender
Female respondents constituted a higher proportion (63.30%) compared to males (36.70%). This aligns with existing consumer behavior studies, which show that women tend to dominate

in online retail, particularly in fashion, beauty, and lifestyle-related products.

c) Educational Background
Most respondents (63.30%) had completed senior high school (SMA/SMK), followed by 30.00% who held undergraduate or postgraduate degrees (S1/S2/S3), and 6.70% with diploma-level education. This reflects a consumer group with relatively broad educational backgrounds, with a significant portion being early-stage working professionals or students.

d) Purchase Frequency
In terms of purchase frequency, 41.10% of respondents had purchased 2–3 times from the store, while 34.40% had only purchased once, and 24.40% had made more than three purchases. This indicates a relatively high level of repeat purchases, which may suggest customer satisfaction or effective promotional strategies.

e) Source of Information
When asked how they discovered the store, 46.70% cited recommendations from friends or family, 30.00% through Instagram, and 23.30% via TikTok. These findings highlight the role of word-of-mouth and social media—particularly Instagram—as primary marketing channels for attracting customers.

f) Payment Methods
Cash on Delivery (COD) was the most preferred payment method (50.00%), followed by e-wallets (24.40%), bank transfers (17.80%), and credit/debit cards (7.80%). The dominance of COD suggests that trust and convenience remain important factors in online transactions for this market segment.

g) Main Factors Influencing Purchase Decisions
Regarding the main factors influencing purchase decisions, 37.80% of respondents prioritized service quality, followed by price (21.10%), recommendations from others (13.30%), and a combination of factors (27.80%), including price, quality, promotions, and service. This implies that service excellence plays a crucial role in consumer decision-making, along with a balanced value proposition.

Overall, the respondent profile indicates that Gerai Hania's primary customers are young, digitally connected, and value-driven consumers who are sensitive to both service quality and peer influence. These insights are valuable for targeting and refining marketing strategies, as well as improving customer retention efforts.

3.1 Validity Test

To evaluate the accuracy of each measurement item in representing its respective construct, a validity test was conducted using the Pearson product-moment correlation technique. This method assesses the degree to which each questionnaire item correlates with the total score of its variable, thereby determining whether the item is capable of validly measuring what it is intended to measure.

The test was performed at a significance level of $\alpha = 0.05$, with 90 respondents included in the analysis. Based on the degrees of freedom ($df = N - 2 = 88$), the critical r-value (r-table) was determined to be 0.2071. Any item with a correlation coefficient greater than 0.2071 and a p-value less than 0.05 is considered statistically valid.

The validity test was applied to three key variables: Price (X_1), Service Quality (X_2), and Purchase Decision (Y), each of which was measured using five questionnaire items. The results of the validity test for each variable are detailed below:

a) Price (X_1), was measured through five indicators designed to capture consumer perceptions of pricing strategies, fairness, and value. The results of the validity test are presented in Table 2.

Table 2. Validity Test Results for Price (X_1)

Item	Correlation Coefficient (r)	r-table	Decision
1	0.792	0.2071	Valid
2	0.869	0.2071	Valid
3	0.841	0.2071	Valid
4	0.796	0.2071	Valid
5	0.809	0.2071	Valid

As shown above, the correlation coefficients for all five items range from 0.792 to 0.869, which are significantly higher than the r-table value. This indicates a strong and consistent correlation between each item and the total score of the Price variable. Consequently, all items are considered valid and accurately reflect the construct they are intended to measure.

b) Service Quality (X_2), The Service Quality variable was also assessed using five indicators that measured dimensions such as responsiveness, reliability, and customer satisfaction. The validity results are presented in Table 3.

Table 3. Validity Test Results for Service Quality (X_2)

Item	Correlation Coefficient (r)	r-table	Decision
1	0.834	0.2071	Valid
2	0.828	0.2071	Valid
3	0.784	0.2071	Valid
4	0.839	0.2071	Valid
5	0.836	0.2071	Valid

All items demonstrate correlation coefficients above the threshold, ranging from 0.784 to 0.839, with statistically significant p-values ($p < 0.05$). This confirms that each item effectively measures the Service Quality construct, making them all suitable for inclusion in further analysis.

c) Purchase Decision (Y), To assess Purchase Decision, five indicators were used to capture the factors influencing consumers' decision-making processes, including intention, behavior, and satisfaction. The results are provided in Table 4.

Table 4. Validity Test Results for Purchase Decision (Y)

Item	Correlation Coefficient (r)	r-table	Decision
1	0.828	0.2071	Valid
2	0.847	0.2071	Valid
3	0.769	0.2071	Valid
4	0.822	0.2071	Valid
5	0.83	0.2071	Valid

The correlation coefficients for this variable range from 0.769 to 0.847, which clearly exceed the critical value. All p-values are also below 0.05, affirming that these items validly measure the intended construct.

3.3 Reliability Test

To evaluate the internal consistency of the research instrument, a reliability test was conducted using Cronbach's Alpha coefficient. This statistical measure is commonly employed to determine the extent to which items within a construct yield consistent results. A Cronbach's Alpha value of 0.70 or higher is generally accepted as indicating a high level of reliability, suggesting that the items collectively measure the same underlying construct with adequate consistency.

The reliability test in this study was performed on three key variables: Price (X_1), Service Quality (X_2), and Purchase Decision (Y). Each variable was measured using five questionnaire items. The results of the analysis are presented in Table 5.

Table 5. Reliability Test Results of Research Variables

Variable	Number of Items	Cronbach's Alpha	Decision
Price (X_1)	0.88	5	Reliable
Service Quality (X_2)	0.882	5	Reliable
Purchase Decision (Y)	0.877	5	Reliable

The results indicate that:

a) The Price variable obtained a Cronbach's Alpha of 0.880, confirming strong internal consistency among the five items used to measure consumer perceptions related to pricing.
b) The Service Quality variable showed a Cronbach's Alpha of 0.882, suggesting a high degree of reliability in the measurement of service-related factors such as responsiveness, accuracy, and customer satisfaction.
c) The Purchase Decision variable achieved a Cronbach's Alpha of 0.877, indicating that the instrument used to assess consumer purchase behavior is also highly reliable.

These findings demonstrate that all measurement instruments used in this study possess an acceptable level of reliability. Therefore, the items are considered suitable for further statistical analysis, including regression modeling and hypothesis testing, which depend on the internal consistency of the variables involved.

3.4 Normality Test

To assess whether the data used in this study follow a normal distribution, a normality test was conducted using two approaches: the Shapiro–Wilk test, which is suitable for small to medium sample sizes, and a visual assessment using the Q–Q Plot. The assumption of normality is an essential prerequisite for conducting parametric tests, such as multiple linear regression.

Table 6. Normality Test Results

Variable	Kolmogorov–Smirnov Sig.	Shapiro–Wilk Sig.	Conclusion
Price (X_1)	0.009	0.200*	Normal
Service Quality (X_2)	0.004	0.057	Normal
Purchase Decision (Y)	0.002	0.094	Normal

The Shapiro–Wilk test results for all three variables show p-values greater than 0.05, indicating that the data are normally distributed and do not significantly deviate from the expected distribution. Even though the Kolmogorov–Smirnov test indicates lower p-values, the Shapiro–Wilk test is prioritized due to its higher sensitivity in small samples (N = 90). In addition to the statistical test, a Normal Q–Q Plot was examined to provide visual confirmation of normality. As shown in Fig. 2, the data points are closely aligned along the diagonal line, further supporting the conclusion that the residuals are normally distributed.

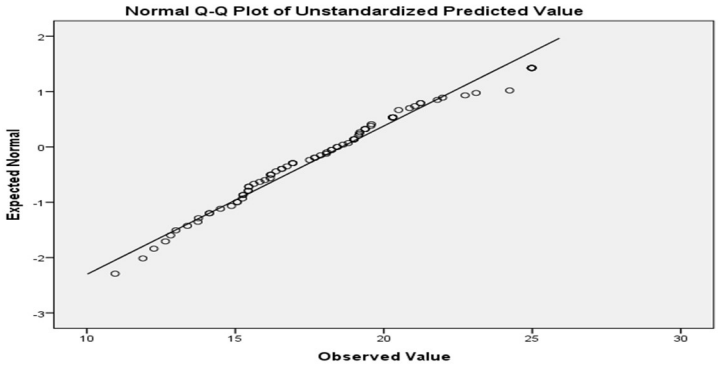


Fig.3. Normal Q–Q Plot of Unstandardized Predicted Values

The combination of statistical results and visual inspection confirms that the normality assumption has been satisfied, and thus the dataset is appropriate for further parametric analyses such as regression.

3.5 Multikolinearitas Test

To identify multicollinearity between independent variables, the analysis used the Variance Inflation Factor (VIF) and Tolerance. The test results are summarized in Table 7.

Table 7. Multicollinearity Test Results

Variable	Tolerance	VIF	Conclusion
Price (X_1)	0.22	4.537	No multicollinearity
Service Quality (X_2)	0.22	4.537	No multicollinearity

Both variables show VIF values below 10 and Tolerance above 0.10, indicating no multicollinearity. Thus, the independent variables can be reliably used in the regression model.

3.6 Heteroscedasticity Test

Heteroscedasticity was tested using a scatterplot of unstandardized residuals versus predicted values. As shown in Figure 4, the residuals are randomly dispersed without forming a specific pattern. This indicates that the assumption of homoscedasticity is met, and no heteroscedasticity is present in the model.

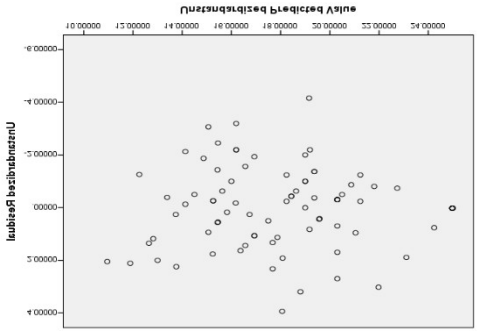


Fig.4. Scatterplot of Unstandardized Residuals

As shown in the scatterplot, the distribution of residuals appears to be randomly scattered around the horizontal axis, with no discernible pattern such as a funnel shape, curve, or systematic clustering. This indicates that the variance of the residuals remains relatively constant across all levels of the predicted values.

Based on this visual inspection, it can be concluded that heteroscedasticity is not present in the model. Therefore, the assumption of homoscedasticity is satisfied, and the regression analysis can proceed without bias related to unequal variance of residuals.

3.7 Multiple Linear Regression Analysis

A multiple linear regression was conducted to evaluate the effect of Price (X_1) and Service Quality (X_2) on Purchase Decision (Y). The results are shown in the table below:

a) Model Summary

Table 8. Model Summary

No	Type of Correlation	Correlation Value
1	R	0.931
2	R^2	0.867
3	Adj R^2	0.864

The correlation coefficient (R) of 0.931 indicates a very strong positive relationship between the variables. The coefficient of determination (R^2) of 0.867 means that 86.7% of the variation in Purchase Decision can be explained by Price and Service Quality. The Adjusted R^2 value of 0.864 confirms the model's consistency, making it suitable for interpretation and further analysis.

b) Simultaneous Test (F-Test)
To test the simultaneous effect of Price (X_1) and Service Quality (X_2) on Purchase Decision (Y), an F-test was conducted through ANOVA analysis. The results are presented below:

Table 9. F-Test

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1237.665	2	618.833	283.176	0
	Residual	190.123	87	2.185		
	Total	1427.789	89			

Note. a. Dependent Variable: Y_Total
b. Predictors: (Constant), X2_Total, X1_Total

At a significance level of α = 0.05, with $df_1 = 2$ and $df_2 = 87$, the F-table value is approximately 3.10. Since the computed F-value (283.176) is far greater than the F-table value and the p-value = 0.000 < 0.05, it can be concluded that the regression model is statistically significant. This indicates that Price and Service Quality simultaneously have a significant effect on Purchase Decision.

c) Partial Test (t-Test)

Table 10. t-Test Results

Variable	Coef. (B)	t-value	Sig.	t-table (df = 63)	Interpretation
Constant	1.773	1.843	0.070	1.987	Not significant
X_1 (Price)	0.327	4.606	0.000	1.987	Significant positive effect
X_2 (Service Quality)	0.265	3.555	0.001	1.987	Significant positive effect

At a significance level of α = 0.05 with df = 87, the critical t-table value is 1.987. Both independent variables meet the criteria for statistical significance, as their t-values exceed the t-table value and their p-values are below 0.05. This confirms that both Price and Service Quality have a significant and positive influence on Purchase Decision, with Price (X_1) exerting a slightly stronger effect.

d) Regression Equation

Based on the multiple linear regression analysis, the regression equation that models the relationship between the independent variables—Price (X_1) and Service Quality (X_2)—and the dependent variable Purchase Decision (Y) is expressed as follows:

$$Y= 1.602+0.370X1+0.565X2+e$$

Where:
Y = Purchase Decision
X_1 = Price
X_2 = Service Quality
E = Error Term (at α = 0.05)

The results of the multiple linear regression analysis yielded the equation $Y = 1.602 + 0.370X_1 + 0.565X_2 + e$, indicating that when both Price (X_1) and Service Quality (X_2) are zero, the baseline level of Purchase Decision (Y) is 1.602. The coefficient for Price (0.370) suggests that each one-unit increase in price contributes to a 0.370-unit increase in purchase decision, while the coefficient for Service Quality (0.565) implies a 0.565-unit increase in purchase decision for every one-unit improvement in service quality, assuming other variables remain constant. Both variables have p-values of 0.000, which are below the 0.05 significance threshold, confirming that Price and Service Quality each have a statistically significant and positive influence on consumer purchase decisions at Gerai Hania Online Store.

3.8 Discussion

The findings from the multiple linear regression analysis demonstrate that both Price (X_1) and Service Quality (X_2) significantly influence Purchase Decision (Y) among consumers of the Gerai Hania online store. The regression model is statistically valid, as indicated by the ANOVA significance value of 0.000 ($p < 0.05$), and shows high explanatory power with an R^2 value of

0.867, indicating that 86.7% of the variation in purchase decisions can be explained by the two independent variables, while the remaining 13.3% is attributed to other factors not included in the model.

Partially, Price (X_1) has a positive and significant effect on purchase decisions, with a regression coefficient of 0.370 and a significance value of 0.000. This suggests that competitive pricing plays an important role in influencing consumer decisions, particularly in online markets where price comparisons are easily accessible. This result is consistent with the studies by Mita Soraya and Yoestini as well as Zenada et al., which found that consumers tend to choose products that offer a balance between price and quality(Mita Soraya & Yoestini, 2024; Zenada et al., 2024). However, contrasting findings from Arisa and Wiranto and Amron (2024) indicate that in certain contexts, factors such as brand trust, product reviews, or promotional programs may have a stronger influence than price alone(Arisa, 2024; Wiranto & Amron, 2024).

Similarly, Service Quality (X_2) shows a significant positive influence on Purchase Decision, with a regression coefficient of 0.565 and a significance value of 0.000. This finding implies that improvements in service quality, such as responsive communication, accurate product information, delivery reliability, and effective return policies, can enhance customer satisfaction and increase the likelihood of purchase. These results are supported by the findings of Prihandoyo et al. and Muhtad, who emphasized that service excellence contributes significantly to purchase behavior, particularly in the online shopping environment (Muhtadi, 2024; Prihandoyo et al., 2025). However, some studies, such as those by Humairoh and Riski, Sirait and Arjuna, found that service quality did not significantly affect purchase decisions in some cases, as customers prioritized free shipping, discounts, or peer reviews over service interactions (Humairoh & Riski, 2024; Sirait & Arjuna, 2025).

Simultaneously, the combined effect of Price and Service Quality is confirmed through the F-test, with an F-value of 283.176 and a significance value of 0.000, demonstrating that these two variables together have a statistically significant impact on Purchase Decision. The high R^2 value supports the assertion that both price strategies and service performance are essential components in influencing consumer behavior. These findings align with the research of Widianti and Langga, who stated that the synergy between pricing and service factors contributes to customer loyalty and repeat purchases(Langga, 2024; Widianti, 2024). However, alternative perspectives from Adinitasya and Sulastri argue that in some settings, brand awareness, product quality, and consumer trust may have greater simultaneous influence than price and service (Adinitasya & Sulastri, 2024).

Taken together, the findings confirm that price and service quality both play critical roles in shaping purchase decisions in the context of online retail. However, the extent of their influence may vary depending on consumer characteristics, product types, and market dynamics. It is therefore essential for online businesses to not only offer competitive prices and superior service but also to consider other strategic elements such as branding, user experience, and promotional effectiveness.

4. Conclusion

This study aimed to investigate the effect of Price and Service Quality on consumer Purchase Decisions in the context of an online retail store, Gerai Hania in Medan. Based on the multiple linear regression analysis, the findings reveal that both Price and Service Quality have a significant and positive influence on purchase decisions, either partially or simultaneously. The R

Square value of 0.867 indicates that 86.7% of the variance in purchase decisions can be explained by these two variables. The t-test results confirmed that Price (Sig. = 0.000) and Service Quality (Sig. = 0.000) are individually significant predictors, while the F-test result (Sig. = 0.000) supports their combined effect. These results contribute to the growing body of knowledge on consumer behavior in digital commerce by reaffirming that competitive pricing and excellent service delivery are critical drivers of purchasing intent and decision-making. Practically, this suggests that online retailers should adopt a balanced strategy by ensuring both affordability and quality service to build trust, enhance customer satisfaction, and increase sales conversion.

Future research is encouraged to include other influencing variables such as brand trust, promotional strategies, customer reviews, and user experience to provide a more comprehensive understanding of consumer decision-making. It is also recommended that longitudinal or comparative studies be conducted across different product categories or regions to validate and enrich these findings.

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ANALYSIS OF STAKEHOLDER ROLES, ACCEPTANCE, AND COLLABORATION POTENTIAL IN USING LEARNIFY EDUCATIONAL INNOVATION BASED ON THE TRIPLE HELIX MODEL

Farizoh binti Hamid*, Sharipah Khadijah binti S. Hashim, Abdul Aziz bin Ishak

[1]Commerce Department, Politeknik Tuanku Sultanah Bahiyah, 09090 Kulim, Kedah Malaysia

*Corresponding author e-mail address: farizoh@ptsb.edu.my

Abstract

This study analyzes the roles, acceptance, and collaboration potential of key stakeholders in adopting LEARNIFY, an educational innovation and interactive application designed to support students with special needs. Anchored in the Triple Helix Model, which emphasizes dynamic collaboration between Higher Education Institutions (HEIs), industry, and the government/education sector, the research involved 100 respondents from HEIs, Schools/ Special Education Integration Program (SEIP), autism centers, and relevant organizations. Using a five-point Likert scale questionnaire, data were collected on stakeholder perceptions, readiness, and willingness to engage in collaborative actions such as training, pilot studies, Corporate Social Responsibility (CSR) support, and formal partnerships. The findings demonstrate a high level of acceptance and understanding of LEARNIFY's purpose, along with strong potential for strategic cross-sector engagement. This study offers valuable insights into how stakeholder alignment and commitment can advance inclusive education initiatives. It reinforces LEARNIFY's viability as a high-impact innovation model, supporting digital inclusion, personalized learning, and sustainable collaboration across academia, industry, and the community.
Keywords: LEARNIFY, Triple Helix, Special Education.

1. Introduction

Educational innovation plays a crucial role in improving teaching and learning processes in the 21st century. One such innovation, LEARNIFY, is a digital platform designed to support interactive, flexible, and learner-centered education through the integration of various educational technologies. Its design aligns with current educational transformation trends that emphasize active learning, accessibility, and stakeholder collaboration. The implementation of LEARNIFY involves various stakeholders, including educational institutions, support agencies, and policy makers, making it an appropriate subject of study within the framework of the Triple Helix model which focuses on the collaboration between universities, industries, and governments in driving innovation (Etzkowitz & Leydesdorff, 2000).

The importance of studying LEARNIFY lies in its potential to enhance the quality of education delivery, particularly in the post-pandemic era where hybrid and digital learning methods have become more prevalent. Understanding how LEARNIFY is adopted and utilized can guide policymakers, educators, and support institutions in making informed decisions about technology integration in education. Moreover, it provides insights into how collaborative networks can be strengthened to support educational reform through innovation (Carayannis & Campbell, 2012). Given the growing emphasis on digital transformation in education, this study contributes to both theoretical and practical understanding of innovation diffusion and stakeholder dynamics.

However, the successful implementation of LEARNIFY depends heavily on stakeholder acceptance and their willingness to collaborate. Current challenges include limited awareness of digital innovation frameworks, inconsistent technology adoption across institutions, and the lack of a unified model for collaboration among stakeholders (Zawacki-Richter et al., 2019). Without addressing these issues, efforts to scale educational innovations may face resistance or inefficiencies, thereby undermining their impact. Additionally, many initiatives tend to focus solely on technological capabilities, overlooking the socio-organizational elements that influence adoption and sustainability (Venkatesh et al., 2003).

In the ideal landscape of educational transformation, technological innovations like LEARNIFY are expected to function as catalysts for enhancing access, engagement, and quality in teaching and learning. Within the Triple Helix framework, universities, industries, and governments are meant to collaboratively support the integration and diffusion of such innovations (Etzkowitz & Leydesdorff, 2000). Ideally, this synergy should lead to a standardised and superior model of educational delivery, one that meets the demands of Industry 4.0, promotes lifelong learning, and fosters innovative pedagogy across institutions. However, in the Malaysian context, the implementation of educational technology like LEARNIFY remains inconsistent. Many stakeholders face challenges related to digital readiness, acceptance of new systems, and fragmented collaboration between key sectors (Saad & Zawdie, 2008). These gaps hinder the realization of a sustainable innovation culture and limit the potential to achieve a holistic synthesis of educational excellence and technological advancement.

The current situation reveals a disconnect between the intended policy outcomes and ground-level practices. While various institutions have adopted digital learning platforms, the level of acceptance, usage, and impact varies greatly. This fragmentation suggests that the innovation ecosystem lacks a structured mechanism to align stakeholder roles, responsibilities, and expectations (Zawacki-Richter et al., 2019). If left unaddressed, this could lead to underutilization of educational technologies, inefficient use of resources, and ultimately, a failure to achieve national education goals aligned with digital transformation agendas. Therefore, it is imperative to investigate how LEARNIFY is distributed, accepted, and supported through multi-stakeholder collaboration. Understanding these dynamics can help improve the current state, refine institutional strategies, and move towards an integrated system that embodies standard, superiority, specialty, and synthesis in digital education.

This study focuses on analyzing stakeholders' perceptions, readiness, and roles in the implementation of LEARNIFY within the Triple Helix framework. Specifically, it aims to:

a) Explore stakeholders' perceptions of LEARNIFY as an educational innovation for special needs learners, particularly those with autism.
b) Assess the level of acceptance and organizational readiness among key stakeholders for adopting LEARNIFY.
c) Identify the roles and potential commitment of Higher Education Institutions, Special Education Integration Program (SEIP), and Industry/ NGOs in supporting the implementation and sustainability of LEARNIFY.

2. Literature Review

The successful implementation of educational innovations such as LEARNIFY depends on a complex interplay of factors involving distribution and utilization across institutions, stakeholder acceptance, and multi-sector collaboration. This literature review critically examines these three

core areas with particular attention to their relevance in implementing LEARNIFY within special education settings, framed by the Triple Helix model.

2.1 Distribution and Utilization of Educational Innovations in Special Education

Distribution and utilization of educational innovations involve more than simply making a tool available; it requires active integration into educational practices and systems. Educational innovations, especially digital tools for learners with special needs, must navigate barriers such as limited access to technology, insufficient training, and varying institutional readiness (Alghamdi et al., 2023). For example, Leung et al. (2022) highlight that in inclusive classrooms, the effectiveness of assistive technologies depends heavily on ongoing technical support and adaptability to diverse learner profiles.

In the context of LEARNIFY, which targets students with special needs such as autism, distribution also means engaging various educational and support institutions, including schools, special education centers, and therapy providers, to adopt and consistently utilize the application. This aligns with Rogers' Diffusion of Innovation theory, which identifies communication channels and social systems as key factors influencing innovation uptake (Rogers, 2003). However, empirical studies show that distribution alone is insufficient without institutional capacity-building, tailored content, and alignment with curriculum standards (Wang et al., 2021; Ching & Hew, 2022).

Furthermore, the utilization of educational innovations must address equity concerns. Studies in Southeast Asia suggest that socioeconomic disparities impact access and usage, especially for learners with special needs who require customized interventions (Hussain et al., 2023). LEARNIFY must be user-friendly and contextually relevant to ensure it is used effectively.

2.2 Stakeholder Acceptance of Educational Innovations

Stakeholder acceptance is a critical determinant of whether an innovation such as LEARNIFY will be adopted and sustained in educational practice. The Technology Acceptance Model (TAM) has been widely used to assess perceived ease of use and perceived usefulness as primary factors affecting acceptance (Davis, 1989). In special education, teacher acceptance is particularly important, as teachers act as gatekeepers and facilitators of technology use (Al-Azawei et al., 2019).

Recent research reveals additional factors influencing acceptance in special education settings, including perceived alignment with pedagogical goals, confidence in handling the technology, and expectations about student benefits (Lee et al., 2023; Kurniawan & Utami, 2022). For LEARNIFY, designed to enhance learning among students with autism, acceptance extends to parents and administrators, who must support its implementation and integration.

Parental attitudes towards educational technology can significantly affect acceptance, especially in cultures where family involvement is integral to education (Mustafa & Rahman, 2022). Administrators' buy-in is linked to institutional priorities and resource allocation, emphasizing the need for evidence-based demonstrations of LEARNIFY's impact (Nguyen et al., 2023).

Moreover, acceptance is not static but evolves with continued exposure and training (Venkatesh et al., 2012). Longitudinal studies by Smith and García (2023) confirm that acceptance increases when users observe tangible improvements in student engagement and learning outcomes,

underscoring the importance of measuring LEARNIFY's impact on student achievement and engagement.

2.3 Collaboration Potential Based on the Triple Helix Model

The Triple Helix model offers a useful framework for understanding the collaboration potential among academia, industry, and government in the implementation of educational innovations like LEARNIFY. This model posits that innovation thrives through the dynamic interaction of these three spheres, which contribute to research, development, policy, and funding (Etzkowitz & Leydesdorff, 2000).

In special education technology, collaborative efforts can bridge gaps between research, product development, and policy implementation. Carayannis and Campbell (2012) emphasize that such collaborations enable co-creation and alignment of innovations with societal needs, increasing their relevance and sustainability. For LEARNIFY, academia can provide validation of its pedagogical efficacy, industry can drive technological development and scalability, while government institutions can facilitate regulatory frameworks and funding support.

Empirical evidence from recent studies highlights successful Triple Helix collaborations in educational innovation across various countries (Nguyen et al., 2023; Chong & Lim, 2021). These collaborations often lead to more integrated service delivery models that combine educational institutions, private technology developers, and public agencies to support learners with special needs.

In Malaysia and Southeast Asia, government initiatives such as the Malaysia Education Blueprint (2013-2025) encourage such partnerships to foster inclusive education and digital learning (Ministry of Education Malaysia, 2013). However, challenges remain in coordinating roles, sustaining engagement, and ensuring equitable access (Tan et al., 2022). Exploring stakeholder roles and collaboration potential within this framework will help identify pathways to scale and sustain LEARNIFY's impact.

Overall, the literature illustrates that the successful implementation of LEARNIFY depends on effective distribution mechanisms tailored to special education contexts, high levels of acceptance among diverse stakeholders, and robust collaborations across academia, industry, and government, as described by the Triple Helix model. Addressing these interconnected factors is essential for realizing LEARNIFY's potential to enhance learning outcomes and promote inclusive education.

3. **Methodology**

3.1 Research Design, Population and Sampling, and Research Instrument

This study employed a quantitative research design using a structured questionnaire as the primary instrument to assess the level of acceptance, readiness, and potential collaboration in implementing the LEARNIFY application. A total of 100 respondents were involved, representing three organizational types under the Triple Helix Model: Higher Education Institutions (HEIs), Special Education Integration Program (SEIP), and autism-related centers or industries. Although larger sample sizes are often associated with enhanced reliability and validity, Charter and Sweeney (2020) assert that a sample size of around 100 can still provide meaningful insights and robust data analysis, particularly in focused educational research.

The questionnaire consisted of three sections: Section A (respondent demographics), Section B (Perception of LEARNIFY Innovation), Section C (Acceptance and Readiness of LEARNIFY), and Section D (Roles and Potential Commitment). The items were adapted from validated instruments by Amin et al. (2021), Norlaila (2024), and Rabiatul Adawiyah et al. (2017). All items used a five-point Likert scale. Data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26. The analysis included descriptive statistics as well as inferential tests such as one-way ANOVA and independent-samples t-tests to compare group differences across the Triple Helix categories.

3.2 Data Collection Procedure

Data for this study were collected using an online survey distributed via Google Forms. The survey link was shared through official email channels and WhatsApp groups to ensure wide and timely participation among targeted stakeholders, which included representatives from higher education institutions (HEIs), special education schools (SEIP), and autism-related centers or industries. A cover letter accompanied the survey, explaining the purpose of the study, the voluntary nature of participation, and guarantees of anonymity and confidentiality. Information was obtained at the beginning of the survey in accordance with ethical research standards and institutional research guidelines. The data collection process took place over a period of three weeks to allow sufficient time for responses.

3.3 Data Analysis Techniques

Table 1. Data Analysis Techniques on Objective

Objective	Variables/Constructs	Analysis Technique
Objective 1	Perception of LEARNIFY Innovation	Descriptive statistics (mean, SD, frequency)
Objective 2	Acceptance and Readiness of LEARNIFY	Descriptive analysis (ANOVA or t-test for group comparison)
Objective 3	Roles and Potential Commitment	Descriptive + Factor analysis or Cross-tabulation for role patterns

According to Table 1, the data collected in this study will be analyzed using both descriptive and inferential statistical techniques**,** depending on the research objective and variable measured. For Objective 1**,** which focuses on stakeholders' perception of the LEARNIFY innovation, descriptive statistics such as means, standard deviations, and frequency distributions will be used to summarize and interpret the overall trends in responses. For Objective 2**,** which examines the acceptance and readiness of stakeholders to adopt LEARNIFY, both descriptive analyses will be applied. Specifically, independent samples t-tests or ANOVA will be employed to determine whether there are significant differences in acceptance and readiness across different stakeholder groups. For Objective 3, which explores stakeholders' roles and potential commitment, the data will be analyzed using descriptive statistics in combination with factor analysis or cross-tabulation techniques. These analyses will help identify underlying dimensions of stakeholder commitment and detect any patterns based on organizational roles.

4. **Results and Discussion**

4.1 Section A: Respondent Information

Table 2. Respondent Information

Demographic Characteristics	Category	n	Percentage (%)
Gender	Male	75	75
	Female	25	25
Ethnicity	Malay	80	80
	Chinese	10	10
	Indian	8	8
	Others	2	2
Age Group	24 years and below	5	5
	25–34 years	15	15
	35–44 years	40	40
	45–54 years	30	30
	55 years and above	10	10
Type of School	Government School (SMK, SK)	75	75
	Private School	10	10
	International School	5	5
	Others	10	10
Teaching Experience in Special Education	Less than 1 year	3	3
	1–5 years	10	5
	6–10 years	25	10
	11–15 years	30	30
	16–20 years	18	18
	More than 20 years	14	10
Organization Type	Higher Education Institution (HEI)	20	20
	School / Special Education Class (SEIP)	45	45
	Autism Centre	15	15
	Industry / Company	15	15
	Others (e.g., NGO, Parent Support Group)	5	5
Inclusive Education Involvement	Yes	90	90
	No	10	10

The demographic data of the 100 respondents, as presented in Table 2, show a majority of male participants (75%) and predominantly Malay ethnicity (80%). Most respondents fall within the 35–44 age range (40%), followed by those aged 45–54 (30%). The majority are employed in government schools (75%) and have 11–15 years of experience in special education (30%). In terms of organization type, the largest group represents special education schools or PPKI (45%), followed by HEIs (20%), autism centres (15%), and industry (15%). A significant portion (90%) reported involvement in inclusive education initiatives. This suggests that the sample comprises experienced and relevant stakeholders, aligning with the study's focus on the implementation of LEARNIFY within the Triple Helix framework.

4.2 Section B: Perception of LEARNIFY Innovation

The descriptive analysis of perceptions toward the LEARNIFY innovation among 100 respondents, categorized according to the Triple Helix framework (University, Industry, Government), reveals consistently positive perceptions across all sectors (referring to Table 3).

Higher Education Institutions (HEIs) recorded the highest mean score (M = 4.36, SD = 0.51), indicating strong support for LEARNIFY's educational value.

Table 3. Perception of LEARNIFY Innovation by Organization Type

Organization Type	n	Minimum	Maximum	Mean	Standard Deviation
Higher Education Institution (HEI)	30	3.50	5.00	4.36	0.51
Schools/ Special Education Integration Program (SEIP)	50	3.10	5.00	4.32	0.54
Autism Centre / NGO / Industry	20	3.40	5.00	4.35	0.49
Perception of Groups	100	3.10	5.00	4.34	0.52

This aligns with prior research highlighting HEIs as early adopters of assistive educational technologies (Ali et al., 2021; Salih & Yusof, 2020). Industry and community organizations, including autism centres and related NGOs, followed closely (M = 4.35, SD = 0.49), reflecting growing interest and readiness to integrate digital tools into special needs education, supporting findings from Ong et al. (2022) on increased NGO engagement in inclusive tech initiatives. The government sector, represented by SEIP schools, also reported favorable perceptions (M = 4.32, SD = 0.54), in line with national policy frameworks that promote inclusive education (Ministry of Education Malaysia, 2019). However, contrasting studies caution that despite positive perceptions, challenges such as digital literacy gaps and infrastructure limitations may hinder effective implementation, especially within public school contexts (Rahim et al., 2019; Jelas & Ali, 2014). These findings reinforce LEARNIFY's perceived relevance and inclusivity across all three helices while emphasizing the need to address contextual barriers to maximize its impact.

4.3 Section C: Organizational Acceptance and Readiness

Table 4. Organizational Acceptance and Readiness

Organization	Mean	Std. Dev	n
Autism Centre/Industry	3.92	0.12	20
HEI	4.32	0.11	30
Schools/Special Education Integration Program (SEIP)	4.11	0.11	50

Note. F-value: 162.10, p-value (Sig.): < 0.001

Referring to Table 4, the results of the one-way ANOVA revealed a statistically significant difference in the acceptance and readiness of LEARNIFY among the three organization types categorized under the Triple Helix model: Higher Education Institutions (HEIs), Schools/ Special Education Integration Program (SEIP) and Autism Centers/Industry ($F(2, 97) = 162.10$, $p < .001$). Among the 100 respondents, HEIs recorded the highest acceptance and readiness level (M = 4.32), which can be attributed to greater exposure to digital innovation, structured training programs, and an open academic environment that fosters educational technology adoption (Kirkwood & Price, 2014; Ahmad et al., 2020). Schools/ Special Education Integration Program (SEIP) demonstrated moderate readiness (M = 4.11), suggesting increasing engagement with inclusive learning tools. Meanwhile, Autism Centers and Industry partners reported slightly lower scores (M = 3.92), possibly due to limited resources or less formal frameworks for implementing digital solutions (Zhou et al., 2019). These findings are consistent with the Triple Helix model, which promotes synergistic collaboration among academia, industry, and government to drive educational transformation (Etzkowitz & Leydesdorff, 2000). The data reinforces the need for strong cross-sector partnerships to enhance organizational readiness and ensure the effective implementation of inclusive technologies like LEARNIFY.

4.4 Section D: Roles and Potential Commitment

Table 5. Roles and Potential Commitment

No.	Statement	HEI (n = 30)	School/PPKI (n = 50)	Industry/NGO (n = 20)	F-Value	Sig. (p)
D1	Can serve as primary user	4.08	4.45	4.25	5.213	.006**
D2	Willing to act as pioneers or referral centres	4.24	4.19	4.14	0.812	.446
D3	Contribute ideas, data, or feedback	4.41	4.32	4.19	3.549	.031*
D4	Share best practices	4.33	4.26	4.17	2.182	.115
D5	Ready to host pilot/case studies	4.36	4.13	4.00	4.902	.008**
D6	Provide training or guidance	4.18	4.11	4.12	0.309	.735
D7	Sign LoI or MoU	4.39	4.24	4.02	5.674	.004**
D8	Open to CSR/funding	4.13	4.05	4.30	2.239	.110
D9	Support HEI-Industry-Community collaboration	4.45	4.38	4.33	0.672	.512
D10	LEARNIFY as high-impact innovation in special education	4.48	4.39	4.32	1.203	.302

Note. Significance Level: * p < .05, ** p < .01. Mean scores ≥ 4.0 indicate positive commitment.

The ANOVA results (refer to Table 5) based on data from 100 respondents reveal significant differences in the perceived roles and commitment to LEARNIFY among the three sectors in the Triple Helix framework, Schools/Special Education Integration Program (SEIP) exhibit the strongest inclination to act as primary users (D1), reflecting their direct involvement in special education delivery. Higher Education Institutions (HEIs) demonstrate greater readiness to lead pilot studies (D5) and to formalize partnerships via Letters of Intent or Memorandums of Understanding (MoU) (D7), indicating their strategic role in research implementation and innovation scaling (Etzkowitz & Leydesdorff, 2000). Meanwhile, the industry or NGO group, though not always statistically distinct, shows relatively high agreement on openness to CSR or funding initiatives (D8), aligning with the role of industry in resource mobilization and corporate social responsibility (Yusof et al., 2012). These findings, as shown in Table 5, find that each sector exhibits specific strengths that uniquely and complementarily contribute to the adoption and sustainability of inclusive educational innovations like LEARNIFY. The results are consistent with prior research that emphasizes the importance of collaborative governance, cross-sector engagement, and shared ownership to embed impactful innovations in the education ecosystem (Ramli et al., 2018; Mokhtar et al., 2021).

4.5 Section E: Open Feedback (Optional)

Table 6. Roles and Potential Commitment

Triple Helix Sector	Suggestions for Improvement	Types of Collaboration Offered	Additional Comments
HEI (n = 30)	Enhance research-based content, increase flexibility for curriculum integration, and improve data tracking features.	Pilot research, joint publication, student involvement, and curriculum integration.	Recognize LEARNIFY's research potential and support scalability across institutions.
Schools /SEIP (n = 50)	Add more localized content, simplify interface for students with severe autism, and include Bahasa Malaysia audio support.	Content co-creation, classroom trials, feedback for improvement, and training sessions.	Highly supportive; teachers emphasize its usefulness in classroom and therapy sessions.
Industry / NGO (n = 20)	Improve accessibility features (e.g., larger fonts, assistive tools), integrate CSR reporting, and	Funding support, CSR collaboration, digital Infrastructure, and outreach activities.	View LEARNIFY as a social impact tool and Propose expansion to rural or underserved areas.

Triple Helix Sector	Suggestions for Improvement	Types of Collaboration Offered	Additional Comments
	Include outcome-tracking dashboards.		

Referring to Table 6, insights from the 100 respondents across the Triple Helix sectors reveal distinct yet complementary perspectives. Higher Education Institutions (HEIs), representing 30% of the respondents, emphasized the importance of evidence-based improvements and alignment with academic outputs, reflecting their role in driving innovation and scholarly validation (Etzkowitz & Leydesdorff, 2000 Schools/ Special Education Integration Program (SEIP), comprising 50% of the responses, proposed practical and context-specific enhancements such as local content adaptation and user-friendly features, and expressed strong interest in co-developing content and participating in training, demonstrating their critical frontline role in special education delivery (Ramli et al., 2018). Meanwhile, Industry and NGO representatives (20%) highlighted their readiness to support LEARNIFY through CSR initiatives, funding, and outreach activities, affirming their role as enablers in scaling and sustaining educational innovations (Yusof et al., 2012).

This multi-sectoral feedback supports the value of a collaborative co-creation model, in which each helix meaningfully contributes to the refinement, implementation, and long-term impact of inclusive educational tools such as LEARNIFY (Mokhtar et al., 2021).

5. Conclusion and Recommendations

This study set out to explore the perception, acceptance and readiness, roles and potential commitment of LEARNIFY, an educational innovation designed to support special education through technology integration, particularly for students with autism. Based on feedback from 100 respondents representing the Triple Helix sectors in Higher Education Institutions (HEIs), Schools/SEIP, and Industry/NGOs, the findings revealed a consistently high level of acceptance and positive perception across all groups. Schools/ SEIP emerged as the readiest for direct classroom implementation, while HEIs emphasized research integration, and Industry/ NGOs supported the initiative through CSR, infrastructure, and outreach roles. Importantly, stakeholders viewed LEARNIFY not only as a pedagogical tool but as a platform for interprofessional collaboration, knowledge exchange, and inclusive innovation.

These findings contribute valuable insights into how multi-stakeholder ecosystems can effectively support the adoption of technology in special education. The study confirms that co-developed innovations grounded in actual user needs are more likely to be adopted, sustained, and scaled.

For future research, it is recommended to expand the participant base to include more diverse stakeholders, such as parents, therapists, and policymakers, for a more holistic understanding of LEARNIFY's impact in both educational and therapeutic settings. Longitudinal studies could examine its long-term effectiveness and adaptability, while qualitative methods like interviews and focus groups can uncover deeper user insights and challenges. Furthermore, integrating Artificial Intelligence and data analytics within LEARNIFY could allow for personalized learning paths and better tracking of student outcomes, strengthening its potential across varied educational environments.

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FINAL YEAR PROJECT ENHANCES SOFT SKILLS AMONG COMMERCE DEPARTMENT'S STUDENTS

Syaiful Baharee bin Jaafar*, Nor Fathimah binti Fathil, Noor Faizah binti Yahya

Jabatan Perdagangan, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim, Kedah

*Corresponding author e-mail address: baharee@ptsb.edu.my

Abstract

This quantitative study examined how 126 final semester DPM and DPR students at Politeknik Tuanku Sultanah Bahiyah improved their skills while implementing their final year projects in Session 1, 2024/2025. The purpose of this study is to determine whether a final-year student can improve soft skills. The soft skills factors include time management, problem-solving, and communication abilities. The data were collected using google forms and analysis of the data was computed using Statistical Package for the Social Science (SPSS). Findings show that students were able to improve their communication skills (mean = 4.61), problem-solving skills (mean = 4.52), and time management skills (mean = 4.59). The relationship between these three skills was very significant, i.e. if students mastered one skill, they would tend to master the other skills. According to the study, students' final year projects successfully helped them build skills that are highly relevant in the workplace. The final projects honed their skills in a variety of areas, including decision-making, exchanging ideas, presentations, and time management to ensure projects were submitted on time.
Keyword: Communication; Problem-solving; Time Management; Final Year Project.

1. Introduction

Nowadays, soft skills have become increasingly important for employers as the business environment becomes more challenging. Soft skills are associated with employability because employers prefer to hire employees with strong soft skills, such as problem-solving, communication, teamwork, and time management, which benefit the organization. Good academic performance alone does not guarantee success in an organization. This is because organizations require both soft skills and technical skills to achieve better performance (Jones, 2021).

Without good soft skills may affect the future career or present jobs. Therefore, employer can identify the potential employee either have good or less soft skills because it affects the business growth. If the employee does not improve their soft skills in present job, then the business growth may be affected. According to Shaheen et al. (2012) and Porter (2017) stated that employers prefer to hire staff with better soft skills which are useful for communication and career development rather than technical skills. Therefore, soft skills should be learnt in higher education throughout the course offered.

Teaching and learning are closely associated with the development of soft skills. Assessments and exercises, such as the final year project, can contribute to the enhancement of these skills. Throughout the final year project, students can develop teamwork, communication, problem-solving, and time management skills. Soft skills tend to improve when students actively participate in the teaching and learning process. According to Gupta (2009), soft skills include communication, problem-solving, self-motivation, decision-making, and time management.

However, many students do not realize the importance of the final year project in developing soft skills for their future careers. Instead, most students primarily associate the final year project with achieving good academic results. The objective of this study is to investigate whether the student in the final year can enhance soft skills. The variables of the soft skills are communication skills, problem skills and time management.

The final year project is an essential element of the teaching and learning process, closely associated with the development of soft skills. Various soft skills can be applied throughout the final year project. During this process, students are expected to apply their previous knowledge while being supervised by a lecturer. The integration of both technical and soft skills is crucial to ensuring the successful completion of the project (Smith & Johnson, 2021). Figure 1 shows the final year project influences the soft skills among the students.



Fig .1. Conceptual Framework

Technical skills and soft skills are crucial for a successful final year project, as it integrates previous knowledge and various skills. Previous knowledge is essential to ensure the project operates smoothly without failure. However, the role of soft skills in a final year project is just as important as technical skills. Communication, time management, problem-solving, and presentation skills are associated with the project. The project process encounters fewer problems because the relationship between group members and supervision improves due to better soft skills.

The problem-solving process is complex, including cognitive, affective and behavioural activities to overcome obstacles to achieve something (Brand-Gruwela et al., 2005; Funke 2010; Kara 2012). Including the process of problem-solving improves an individual's higher thinking skills such as critical, scientific and creative thinking (Can et al., 2009).

Sinaga et al. (2023) assert that before students can make the right choices to address a problem, they must first obtain a thorough grasp of it. This crucial stage guarantees that the answers are well-informed and suitable for the given environment. In order to accomplish this goal, students can successfully analyze situations by combining new insights with their existing knowledge. In addition to increasing judgment accuracy, this method helps people remember problem-solving techniques over time.

Employer prefers to hire a candidate who has a good result which refers to knowledge level and the same time good in problem solving. Business problem such as marketing, production and others will be possibly solved if the employee has good problem-solving skills and creativity. Therefore, the final year project is a platform for the student to gain good problem-solving skills for better employability.

The final year project that starts with an idea and ends with a product shows that the process must be throughout the steps until the project is completed. Knowledge must be applied in order to improve the problem-solving skills of students. They need to discuss and brainstorm to solve the problem whether the project is problematic or to improve it. This shows that the final year project leads to better problem-solving among students, which is good for employability.

Problem-solving experience gained from final-year projects can improve problem-solving abilities that are applicable to various professional domains because every profession eventually has particular difficulties that need to be successfully overcome. People who show that they can think critically about problems and come up with creative solutions are always appreciated in the workplace (Kumar et al., 2022).

Communication is defined the process of sharing information, both verbally and nonverbally, between the individual providing and receiving. It also entails the goal-oriented sharing of information, thoughts, and opinions (Iksan et al., 2012). People communicate with one another in order to exchange information and instructions. Effective communication is necessary for activities to be successful, for businesses to thrive, and for goals to be met. Therefore, improved communication skills are a requirement for employee organizations. It is the duty of higher education to impart communication skills through various course components. Before entering the workforce, students can enhance their communication abilities by participating in a final year project.

Less effective communication between supervisor (lecturer) and student may cause the final year project delay or not completed. This situation may affect the student performance, either for subject matter or overall. This shows that bad communication doesn't only affect student performance but influence employability in the future. Most of the employer prefers to hire candidates with good communication. The final year project is a platform for lecturers and students to enhance good communication skills.

According to Kumar and Kirti (2023), one of the most important soft skills for employees is the capacity to interact effectively with superiors, peers, and customers. Effective communication is essential for any successful business or organization to have with its stakeholders, including customers and coworkers. Employees who are proficient in these areas are able to foster cooperative relationships, lessen conflict, and help everyone involved achieve greater productivity and long-term happiness.

Communication is about deliver instruction and information to ensure the project successfully. Instruction from lecturer to student to guide the project to complete success without further delay. Feedback from students is very important to ensure that the project is aligned with the instruction. Instruction and information related to the activities of discussion and brainstorming, used to find a solution of the problem or improve the progress of the project. The final year project may increase communication skills among the student.

Mészáros and Csiszárik-Kocsir (2024) assert that interpersonal skills including stress management, emotional intelligence, effective communication, and flexibility are essential for improving students' academic achievement and promoting their social growth. Students are able to refine their technical communication skills through presentations and when handling feedback when there are disagreements within a group, in addition to improving their interpersonal communication skills through the execution of their projects. This communication experience can prepare students for the real world of work after graduation.

Time management skills are very important because it is related to the success or failure of the project. If the project is overdue, it may cost for companies consider as a failure. However, the project completed before the due date will make profit for companies. This shows that the time management skills should increase among the student via final year project to be better employability.

In the study of Pehlivan (2013) stated it is commonly believed that students who possess strong time management abilities will continue to be able to efficiently manage their time once they graduate and start working. The final year project success depends on the end of the product function and completed during the period. The project starts from idea to end of product should be managed well to ensure that the process ends during the period.

In order to help with time management, a final year project task involves a range of abilities, strategies, and tactics used to manage time when finishing different activities, projects, and objectives. According to Yaacob et al. (2023), the complete process consists of a number of interconnected tasks, such as planning, goal-setting, assigning duties, record-keeping, progress tracking, resource organization, activity scheduling, and prioritization.

Without good time management, the project may face problem of progress. As a result, the project may not complete. Therefore, the final year project is a very good platform to gain time management skills. The student should know how to manage time from phase idea to end of product. Smooth progress and early completion can be ensured by managing discussion sessions effectively without unnecessary delays or interruptions.

A key element of leadership, according to Ranjan et al. (2025), is efficient time management, which enhances both individual productivity and business culture and performance. Using strategies like work prioritizing and achievement-based planning, students can effectively manage their time when completing their senior year tasks. This helps individuals become more resource-efficient and enhances the caliber of their academic work.

2. Methodology

This study used a quantitative method with final-semester students from the Department of Commerce at Politeknik Tuanku Sultanah Bahiyah who were enrolled in the Final Year Project course during Session 1 of the 2024/2025 academic year. The participants included students from two programs. There is Diploma in Business Studies (DPM) students for the Business Project course and Diploma in Marketing (DPR) students for Marketing Plan course.

The literature review is used to prepare the pilot survey questionnaire. The sample for the pilot is a student from semester 5 of diploma who is taking a final year project. The researcher can identify issues related to the questionnaire through the trial. If the questionnaire is not clear, it needs to be reviewed and rewritten. It is essential to ensure that respondents provide the correct answer. This study may require a time frame to determine whether the questionnaire provided to the respondent is reasonable or not. If time is sufficient, the questionnaire may be shortened without affecting the validity of the question.

The Cronbach's Alpha value was used to assess the questionnaire items' reliability. With a sample size of 10 students, Cronbach's Alpha score was strong, at 0.933 for every item on the questionnaire. Data was collected through online distribution of questionnaires via WhatsApp application using Google Forms. Out of 180 students registered in the Final Year Project during the stated session, 126 responded with completed responses.

In order to achieve the study's objective, the questionnaire is split into two parts. The first section of the questionnaire focuses on demographics. It examined gender, program and races. In the second section, the questionnaires consist of Part B – communication skills, Part C - problem

solving skills and Part D - time management skills. These sections are based on a self-assessment ratio on a five-point Likert scale.

3. Results and Discussion

This study's findings were analyzed utilizing descriptive methods. The descriptive analysis for this study included frequency, mean, percentage, standard deviation and Pearson correlation. The results of the analysis are detailed below:

Table 1. Demographic profile of respondents

Demographic	Frequency	Percentage
Program:		
Diploma in Business Studies (DPM)	77	61.1 %
Diploma in Marketing (DPR)	49	38.9 %
Gender:		
Male	46	36.5 %
Female	80	63.5 %
Race:		
Malay	107	84.9 %
Indian	17	13.5 %
Others	2	1.6 %

Table 1 presents the demographics of the respondents in this study, involving a total of 126 students. The respondent profile analysis reveals that 77 (61.1%) of the 126 respondents were Diploma in Business Studies (DPM) students, while 49 (38.9%) were Diploma in Marketing (DPR) students. There were 46 male responders (36.5%) and 80 female respondents (63.5%). In terms of race, the majority of respondents, 107 (84.9%), were Malay and followed by 17 (13.5%) Indians. Also, no Chinese responded and two (1.6%) were from other ethnic groups.

Table 2. Distribution of respondents by program, gender and race

	Gender				Race					
	M	%	F	%	M	%	I	%	O	%
DPM	25	19.8	52	41.3	68	54.0	8	6.3	1	0.8
DPR	21	16.7	28	22.2	39	31.0	9	7.1	1	0.8
Total	46	36.5	80	63.5	107	84.9	17	13.5	2	1.6

Table 2 shows the distribution of respondents by program, gender, and race. Out of 126 responses, 46 (36.5%) were male students, with 25 (19.8%) from the Diploma in Business Studies (DPM) program and 21 (16.7%) from the Diploma in Marketing (DPR) program. Of the students who responded, 80 (63.5%) were female. DPR students made up 28 (22.2%) of them, while DPM students made up 52 (41.3%).

Meanwhile, 107 respondents (84.9%) were Malay students, with 68 (54%) from the DPM program and 39 (31%) from the DPR program. For Indian students, there were 17 (13.5%) replies, with 8 (6.3%) enrolled in DPM and 9 (7.1%) in DPR. For other ethnicities, each program (DPM and DPR) is represented by one student (0.8%).

Table 3. Interpretation of the mean score

Level	Average mean
Very low	1.00 - 1.80
Low	1.81 – 2.60
Medium	2.61 - 3.20
High	3.21 - 4.20
Very high	4.21 – 5.00

This section describes a descriptive analysis based on data from the questionnaire presented to research participants. Moidunny (2009)'s interpretation of the mean score was utilized to classify the levels. Based on the average mean score, the levels were classified as very low, low, medium, high and very high.

Table 4. Mean score for communication skills

Items	Mean	SD
I always discuss with my peers about the final project.	4.56	0.627
Communication is important in the implementation of the final project.	4.71	0.591
Communication is important in the final project group.	4.74	0.582
A good final project presentation requires good communication skills.	4.65	0.584
I gave good answers during the Q&A session in the final project presentation.	4.38	0.643
I often discuss with my peers to complete the final project.	4.59	0.648
Overall mean score average	4.61	0.613

Table 4 shows the mean communication skills scores of DPM and DPR students during the final year project implementation. The data show that the third item, " Communication is important in the final project group," had the highest mean score (4.74), implying that communication is vital within the final year project group. In contrast, the item with the lowest mean score (4.38) was " I gave good answers during the Q&A session in the final project presentation," which reflected students' ability to offer strong responses during project presentation Q&A sessions.

Nonetheless, all communication skills-related measures scored quite high, with an overall mean score average of 4.61 (SD = 0.613). This reveals that final-year project students consistently demonstrate strong communication skills. Furthermore, students are capable of active listening, group interaction, and clear explanation of their ideas in technical reports and presentations. The finding also shows that students are required to participate in the project by communicating with either friends or lecturers. All of the final year processes enhance better communication skills.

Table 5. Mean score for problem solving skills

Items	Mean	SD
I was able to complete the final project well.	4.47	0.616
I often review the final project that is currently being undertaken.	4.40	0.67
Problem solving skills are essential to completing the final project.	4.65	0.624
I often contribute ideas for problem solving in the final project.	4.48	0.701
The final project presentation will enhance problem solving skills.	4.61	0.619
Overall mean score average	4.52	0.646

Table 5 shows the mean problem-solving skill scores among students enrolled in the final-year project course. The results show that the item "Problem solving skills are essential to completing the final project" (4.65) had the highest mean score, indicating the importance of problem-solving skills in finishing the final project. The item "I often review the final project that is currently being undertaken" shows a mean score (4.40), indicating that students do keep regularly monitoring their ongoing final project.

Nonetheless, all problem-solving skill items reached a very high competency level, with an overall mean score average of 4.52 (SD = 0.646). This shows that the final year project enhances student problem solving in order to recognize issues and resolve difficulties. The final year project provided space for students to utilize problem solving skills. The process of the final year project needs discussion, brainstorming and problem solving to ensure the project is completed. Participating in a final year project will enhance the student's problem solving. Final year project process benefits for students to enhance problem solving skills.

Table 6. Mean score for time management skills

Items	Mean	SD
I completed the final project on the due date.	4.56	0.614
I was able to submit the final project before the dateline.	4.57	0.638
I often come early for final project discussion sessions.	4.50	0.69
Good time management is important in the implementation of the final project.	4.67	0.591
I understand the importance of time management in completing the final project.	4.63	0.629
Overall mean score average	4.59	0.632

The mean score for time management skills ratings for DPM and DPR students completing their final projects are shown in Table 6. With an overall mean score average of 4.59 (SD = 0.632), the results show that every item attained a very high competency level. The item with the highest score, "Good time management is important in the implementation of the final project" (mean = 4.67), demonstrated how important efficient time management is to the execution of the final project. On the other hand, the item, "I often come early for final project discussion sessions" (mean = 4.50), assessed how consistently students arrive early for project discussion sessions.

The students gain good management skills throughout the final year project. The ability of students to effectively manage their time is also evidenced by their ability to create priorities, manage activities, meet deadlines, minimize last-minute pressure, and produce high-quality products (mean = 4.59). These findings show that although students are excellent at managing their time during project execution, they can still improve their preparation discipline, especially in terms of implementing more proactive strategies that can improve project outcomes. Due date of project, assessment via presentation of the project and appointment with lecturers which is related to the final year project make students aware of the importance of time management.

Table 7 above displays the findings of the Pearson correlation between skills and grades received by students in the final year project course. Correlation analysis shows that communication skills, problem solving, and time management are statistically significant and positively connected ($r>0.8$, $p<0.001$). This demonstrates that other skills will develop in proportion to the strength of one of these skills, in other words, that the more proficient one skill is, the more proficient the others will be. This is demonstrated by the fact that students with strong communication skills are more likely to have strong problem-solving capabilities, and vice versa.

Table 7. Pearson correlation on skills and grades of final year project students

		Communication skills	Problem solving skills	Time management skills
Communication skills	Pearson Correlation	1	.908**	.855**
	Sig. (2-tailed)		.000	.000
Problem solving skills	Pearson Correlation	.908**	1	.838**
	Sig. (2-tailed)	.000		.000
Time management skills	Pearson Correlation	.855**	.838**	1
	Sig. (2-tailed)	.000	.000	

Note. **. Correlation is significant at the 0.01 level (2-tailed).

4. Conclusion

This study indicated that the students in the Commerce Department who took Final Year Project courses at their institutions were able to develop very high levels of foundational skills, including time management, communication and problem-solving skills, all of which are closely related. High levels of skill in these three areas are a strong indicator of proficiency in other, more advanced areas.

These skills, which were developed as a result from completing their final year project, will be useful and advantageous to students when they participate in industrial training in the following semester. When students start working, these skills will also be further refined. Despite complaints from industry groups regarding students' lack of expertise, this could be due to a gap in self-perception and the actual needs of the industry. Nevertheless, the skills developed throughout the final year project have significantly aided students' skill development. The Ryder 2004 study's respondents claimed that they had been to improve widely applicable skills by undertaking a final year project.

According to the students, the supervision they received from their supervisors and the teamwork they received throughout the final project's execution also helped them to strengthen their skills. The final project also gave students experience in time management, problem solving, teamwork, and project management, which helped them get ready for industrial training and increased employability opportunities. According to Vanitha and Jaganathan's (2019) study in Al Asefer and Zainal Abidin's (2021) research, students who possess soft skills like problem-solving, teamwork, positive attitude, and effective communication are more likely to survive in the industry than those who don't. In the future, this study is expected to explore more findings when linked to student achievement grades from final year project results.

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KEBERKESANAN APLIKASI INTERAKTIF LEARNIFY DALAM MENYOKONG PEMBELAJARAN PELAJAR BERKEPERLUAN KHAS (PBK)

Nurfah Nabilah binti Mohd Fadzil*, Sharipah Khadijah binti S. Hashim, Aznira binti Zainal

Jabatan Perdagangan, Politeknik Tuanku Sultanah Bahiyah, 09090 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: nurfah@ptsb.edu.my

Abstrak

Pelajar berkeperluan khas, khususnya dalam kalangan murid autisme, sering berdepan cabaran dalam menerima pengajaran berkesan akibat kekurangan bahan bantu mengajar yang sesuai, terutamanya yang berasaskan teknologi. Isu ini semakin ketara pasca pandemik apabila transformasi digital dalam pendidikan menjadi keperluan, namun sokongan terhadap pendidikan khas masih rendah. Kajian ini bertujuan untuk menilai keberkesanan aplikasi LEARNIFY, iaitu aplikasi interaktif digital yang direka untuk menyokong pembelajaran pelajar autisme melalui aktiviti berasaskan permainan yang menyeronokkan dan mudah digunakan. Objektif kajian adalah untuk menilai hubungan antara kemudahan penggunaan aplikasi, kebolehgunaan aplikasi dan impak aplikasi LEARNIFY terhadap keterlibatan serta kemahiran asas pelajar. Seramai 12 orang guru pendidikan khas dilibatkan dalam kajian ini sebagai responden. Instrumen soal selidik digunakan untuk mengumpul data berkaitan kemudahan penggunaan, persepsi keberkesanan, dan pengalaman pengajaran menggunakan aplikasi LEARNIFY. Dapatan menunjukkan bahawa terdapat hubungan signifikan antara kemudahan penggunaan dan kebolehgunaan aplikasi dengan keberkesanan pengajaran dan pembelajaran. Guru menyatakan aplikasi ini dapat meningkatkan minat pelajar, menyokong perkembangan komunikasi sosial, serta memudahkan proses penyampaian pengajaran. Aplikasi juga didapati mesra pengguna dan fleksibel untuk disesuaikan mengikut tahap pelajar. Kajian ini mencadangkan penggunaan meluas aplikasi LEARNIFY sebagai alat bantu digital dalam pendidikan khas. Penggunaannya berpotensi meningkatkan keberkesanan pengajaran serta menyokong pembelajaran inklusif yang lebih holistik dan responsif kepada keperluan pelajar berkeperluan khas.
Kata Kunci: Pelajar Autisme; Aplikasi Interaktif; LEARNIFY.

1. Pengenalan

Perkembangan teknologi digital telah mengubah secara menyeluruh landskap pendidikan di peringkat global, termasuklah dalam pendidikan khas, dengan memperkenalkan kaedah pengajaran yang lebih inklusif serta fokus kepada keperluan pelajar. Dalam konteks ini, pelajar berkeperluan khas, terutamanya individu dalam spektrum autisme, berdepan pelbagai kekangan seperti kesukaran memahami arahan verbal, had komunikasi dua hala, serta masalah tumpuan dan pemprosesan maklumat (Alias & Ibrahim, 2019; Chua & Tan, 2020). Kebergantungan kepada kaedah pengajaran tradisional yang bersifat generik sering kali gagal memenuhi keperluan unik golongan ini, sekali gus menyumbang kepada penurunan penglibatan dan motivasi dalam pembelajaran formal.

Realiti semasa menunjukkan peningkatan signifikan dalam jumlah kanak-kanak yang didiagnosis dengan autisme di Malaysia. Statistik Jabatan Kebajikan Masyarakat dalam Kosmo Digital (2024) merekodkan lonjakan sebanyak 815% dalam tempoh sedekad, daripada 6,991 kes pada tahun 2013 kepada 63,966 kes sehingga September 2024. Fenomena ini mencerminkan peningkatan tahap kesedaran ibu bapa terhadap keperluan diagnosis awal dan intervensi pendidikan yang

bersesuaian. Namun demikian, peningkatan ini turut membawa cabaran besar kepada sistem pendidikan khas, terutamanya dari aspek penyediaan pendekatan pedagogi yang adaptif, menarik dan berkesan.

Seiring perkembangan tersebut, aplikasi interaktif muncul sebagai alat sokongan pedagogi yang mampu menyesuaikan kandungan pembelajaran mengikut keperluan individu. Aplikasi seperti permainan pendidikan digital, perisian adaptif, dan aplikasi mudah alih telah dibangunkan khusus untuk menyokong pelajar dengan autisme, *attention deficit hyperactivity disorder* (ADHD), disleksia dan masalah pembelajaran spesifik lain (Yusof et al., 2021). Ciri-ciri utama seperti visual dinamik, maklum balas serta-merta, serta kebolehsuaian kandungan menjadikan aplikasi interaktif sebagai medium yang berpotensi tinggi dalam merangsang fokus, motivasi dan kefahaman pelajar (Chua & Tan, 2020).

Walau bagaimanapun, terdapat jurang ketara dalam penyelidikan yang menilai keberkesanan aplikasi ini dalam konteks pembelajaran pelajar autisme di Malaysia. Sebahagian besar kajian masih bersifat konseptual, tanpa penilaian empirikal terhadap aspek kebolehgunaan (*usability*) dan keberkesanan kandungan aplikasi dalam menyokong pencapaian pembelajaran sebenar (Yusof et al., 2021). Justeru, keperluan untuk kajian menyeluruh yang menilai impak aplikasi interaktif dalam konteks sebenar bilik darjah amat mendesak.

Kajian ini dijalankan bagi menilai kemudahan penggunaan aplikasi, kebolehgunaan aplikasi dan keberkesanan kandungan aplikasi LEARNIFY dalam menyokong proses pengajaran dan pembelajaran pelajar berkeperluan khas, khususnya pelajar autisme. Penilaian ini bukan sahaja dapat menentukan sejauh mana aplikasi tersebut memenuhi keperluan pembelajaran dari aspek tumpuan, kefahaman, dan penglibatan pelajar, malah dapat menjadi rujukan penting kepada guru, pembangun kandungan digital dan pembuat dasar dalam merangka strategi teknologi pendidikan yang lebih inklusif, berkesan dan berimpak tinggi.



Rajah 1. Logo LEARNIFY

Rajah 1 menunjukkan logo aplikasi LEARNIFY. Ia merupakan akronim gabungan daripada perkataan *"Learn"* dan *"Modify"*, yang mencerminkan objektif utama pembangunan aplikasi ini, iaitu menyediakan pendekatan pembelajaran yang dapat diubah suai dan disesuaikan mengikut keperluan unik pelajar berkeperluan khas. Aplikasi ini dibangunkan sebagai satu inovasi pendidikan yang responsif terhadap kekurangan alat bantu mengajar yang efektif dan sesuai dalam konteks pengajaran dan pembelajaran pelajar autisme di peringkat pendidikan awal dan menengah.

LEARNIFY direka bentuk secara interaktif dan mesra pengguna dengan menampilkan permainan pendidikan yang menarik serta aktiviti pembelajaran yang menggalakkan kemahiran komunikasi, bahasa, tumpuan, dan pemprosesan visual. Visual berwarna-warni, animasi yang responsif serta

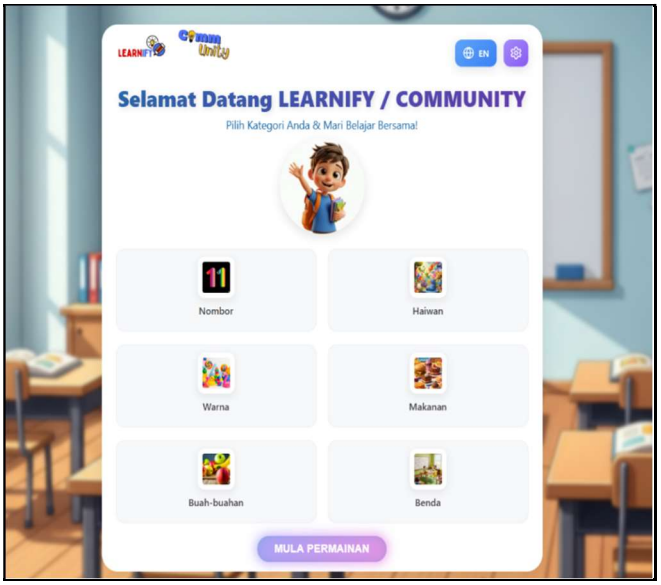
navigasi mudah menjadikan aplikasi ini sebagai alat bantu pembelajaran yang menyeronokkan dan sesuai untuk digunakan oleh pelajar dengan *autism Spectrum Disorder* (ASD) atau gangguan spektrum autisme.

Pembangunan aplikasi ini juga bertujuan untuk menyokong guru dalam membina dan mewujudkan persekitaran pembelajaran yang lebih inklusif, adaptif, responsif dan menyeronokkan, selaras dengan amalan pedagogi abad ke-21. Fungsi aplikasi ini bukan sahaja menyasarkan pembangunan kognitif dan sosial pelajar, tetapi turut memperkukuh keberkesanan pengajaran guru melalui kandungan yang bersifat visual dan interaktif.

1.1 Isu dan Justifikasi Pembangunan Aplikasi

Gangguan spektrum autisme (ASD) diklasifikasikan sebagai gangguan perkembangan neurologi yang mempengaruhi keupayaan individu dalam aspek komunikasi sosial dan corak tingkah laku. Kanak-kanak dengan ASD sering menunjukkan kekangan seperti kesukaran dalam komunikasi dua hala, kurangnya kontak mata, serta kelemahan dalam memahami norma dan jangkaan sosial. Selain itu, mereka turut menunjukkan tingkah laku berulang, minat yang sempit, dan tindak balas deria yang luar biasa terhadap bunyi, sentuhan, atau cahaya.

Ciri-ciri ini memberi kesan langsung terhadap keberkesanan penglibatan mereka dalam proses pembelajaran formal. Kanak-kanak autisme lazimnya tidak dapat mengenalpasti emosi atau memahami perasaan orang lain, tidak cenderung untuk berkongsi pengalaman, serta kurang menunjukkan inisiatif dalam komunikasi sosial. Ini menyebabkan kesukaran untuk menyesuaikan diri dalam konteks bilik darjah biasa tanpa intervensi atau sokongan khusus. Salah satu ciri yang paling ketara adalah kurangnya kontak mata ketika berkomunikasi, yang menyukarkan proses interaksi serta komunikasi dua hala antara guru dan pelajar. Rajah 2 di bawah menunjukkan antara muka aplikasi LEARNIFY yang menepati ciri-ciri yang dapat menarik minat tumpuan dan interaksi mereka.



Rajah 2. Antaramuka aplikasi LEARNIFY

Oleh itu, pembangunan aplikasi LEARNIFY adalah berasaskan kepada keperluan sebenar dalam menyediakan platform pembelajaran yang menyokong kekuatan visual dan minat pelajar

autisme, serta mengurangkan beban guru dalam menyediakan alat bantu mengajar yang sesuai. Melalui pendekatan digital interaktif, aplikasi ini mampu merapatkan jurang antara keperluan pembelajaran pelajar dengan strategi pengajaran guru, sekali gus menyokong matlamat pendidikan inklusif negara.

2. Kajian Literatur

Kajian literatur ini membincangkan dapatan penyelidikan terdahulu yang berkaitan dengan penggunaan teknologi interaktif dalam pendidikan khas, khususnya dalam kalangan pelajar autisme. Fokus diberikan kepada tiga aspek utama selaras dengan objektif kajian ini, iaitu keperluan pelajar berkeperluan khas terhadap aplikasi pembelajaran digital, keberkesanan kandungan aplikasi interaktif dalam menyokong pemahaman, dan peranan guru dalam pelaksanaan teknologi pendidikan. Sorotan ini penting bagi menyokong rasional pembangunan dan penilaian aplikasi LEARNIFY, serta memastikan reka bentuknya berasaskan bukti dan keperluan sebenar pengguna.

2.1 Teori Penerimaan Teknologi (TAM)

Teori Penerimaan Teknologi (TAM) yang dikemukakan oleh Davis (1989) menerangkan proses penerimaan dan penggunaan teknologi oleh pengguna, yang dipengaruhi oleh dua faktor utama iaitu kebolehgunaan aplikasi (*Perceived Usefulness*) dan kemudahan penggunaan (*Perceived Ease of Use*). Dalam konteks aplikasi LEARNIFY, teori ini relevan untuk menilai sejauh mana guru dan pelajar berkeperluan khas menerima penggunaan aplikasi ini dalam proses pengajaran dan pembelajaran. Sekiranya pengguna merasakan LEARNIFY mudah digunakan dan mampu meningkatkan keberkesanan pembelajaran khususnya pelajar autisme, maka tahap penerimaan terhadap teknologi ini dijangka lebih tinggi. TAM juga membantu dalam memahami faktor-faktor yang mendorong penggunaan aplikasi sebagai alat bantu pengajaran dalam membina persekitaran pembelajaran yang lebih inklusif dan interaktif.

2.2 Keperluan Pelajar Autisme terhadap Aplikasi Interaktif

Autisme ialah gangguan perkembangan neurologi yang menjejaskan komunikasi sosial, interaksi dan tingkah laku. Pelajar autisme cenderung menunjukkan pola perhatian yang terhad dan kesukaran memahami arahan lisan, menjadikan kaedah pengajaran konvensional kurang berkesan untuk mereka (American Psychiatric Association, 2022). Oleh itu, mereka memerlukan pendekatan pembelajaran yang lebih visual, interaktif dan berstruktur.

Kajian oleh Lai dan Szatmari (2023) menunjukkan bahawa alat bantu pembelajaran berasaskan teknologi dapat membantu pelajar autisme meningkatkan fokus dan pemprosesan maklumat. Penemuan ini menyokong matlamat kajian untuk menilai tahap kebolehgunaan aplikasi LEARNIFY, yang direka dengan elemen visual dan susun atur mesra pengguna, bagi menyokong keperluan unik pelajar autisme.

Di Malaysia, kajian oleh Mohd Zabidi dan Nordin (2022) menekankan kekurangan bahan bantu mengajar digital yang khusus untuk pelajar berkeperluan khas, menyebabkan jurang capaian terhadap pendidikan inklusif terus wujud. Oleh itu, LEARNIFY dibangunkan bagi mengisi keperluan ini melalui pendekatan yang bersesuaian dan mudah diakses oleh pelajar serta guru pendidikan khas.

2.3 Kemudahan Penggunaan Aplikasi dalam Menyokong Sesi Pengajaran Dan Pembelajaran Pelajar Autisme

Aplikasi pendidikan interaktif yang dibangunkan khusus untuk pelajar berkeperluan khas perlu mengandungi kandungan yang sesuai dari segi bahasa, tahap kesukaran, dan kaedah penyampaian. Aulia et al. (2022) menyatakan bahawa kandungan pembelajaran yang bercirikan visual, kinestetik dan unsur gamifikasi berupaya meningkatkan pemahaman serta minat pelajar autisme terhadap proses pembelajaran.

Dalam konteks ini, LEARNIFY menyediakan aktiviti yang direka bentuk untuk membina kemahiran asas seperti pengecaman warna, bentuk, ekspresi emosi, serta komunikasi sosial. Penilaian keberkesanan kandungan LEARNIFY dalam kajian ini dilihat penting untuk memastikan aktiviti yang ditawarkan benar-benar membantu pelajar memahami konsep pembelajaran dengan lebih baik.

Alzahrani et al. (2023) dalam ulasan sistematik mereka turut menyatakan bahawa aplikasi yang bersifat interaktif menyumbang kepada peningkatan motivasi belajar dan penglibatan aktif pelajar dengan spektrum autisme, sekaligus menyokong objektif kedua dan ketiga kajian ini yang berkaitan kefahaman serta keterlibatan pelajar.

2.4 Kebolehgunaan Aplikasi Bagi Menyokong Sesi Pengajaran Dan Pembelajaran Pelajar Autisme

Aplikasi teknologi dalam pendidikan kini semakin berkembang pesat, terutamanya dalam menyokong keperluan pembelajaran pelajar berkeperluan khas seperti autisme. Dalam konteks ini, penggunaan aplikasi interaktif seperti LEARNIFY, yang dibangunkan khusus bagi menyokong proses pengajaran dan pembelajaran pelajar autisme, merupakan suatu inovasi yang signifikan. Namun begitu, tahap penerimaan teknologi dalam kalangan pengguna, khususnya guru dan pelajar, perlu diteliti bagi menjamin keberkesanan sebenar aplikasi tersebut.

Azman et al. (2022) menyatakan bahawa aplikasi realiti tambahan (AR) untuk pelajar autisme menunjukkan bahawa kedua-dua faktor kemudahan penggunaan dan kebolehgunaan aplikasai memberi kesan yang signifikan terhadap niat untuk menggunakan aplikasi tersebut. Kajian ini juga menekankan pentingnya latihan dan sokongan teknikal kepada guru dalam memastikan penerimaan teknologi yang berkesan. Begitu juga dalam kajian oleh Hussain et al. (2020), guru pendidikan khas menunjukkan penerimaan yang tinggi terhadap penggunaan aplikasi pembelajaran digital, terutamanya apabila aplikasi tersebut mudah digunakan dan selaras dengan keperluan pedagogi pelajar mereka.

Selain itu, reka bentuk pedagogi dalam aplikasi interaktif juga memainkan peranan penting dalam meningkatkan keberkesanan pembelajaran dalam kalangan pelajar autisme. Kajian oleh Al-Azawei et al. (2019) mendapati bahawa integrasi prinsip reka bentuk universal untuk pembelajaran (*Universal Design for Learning* – UDL) dan elemen interaktif mampu meningkatkan motivasi dan penglibatan pelajar berkeperluan khas. Dalam konteks LEARNIFY, reka bentuk aplikasi yang responsif, visual yang jelas, serta elemen gamifikasi dapat membantu pelajar autisme belajar dalam persekitaran yang lebih menyeronokkan dan inklusif.

2.5 Keberkesanan Aplikasi Interaktif LEARNIFY Semasa Sesi Pengajaran Dan Pembelajaran Pelajar Autisme

Dalam kajian berkaitan pelajar autisme, kemudahan penggunaan dan kebolehgunaan aplikasi terbukti mempengaruhi sikap pengguna terhadap penggunaan aplikasi pembelajaran, termasuk dalam kalangan guru dan ibu bapa (Azizan et al., 2023).Kesimpulannya, literatur menunjukkan bahawa penggunaan aplikasi pembelajaran berasaskan teknologi seperti LEARNIFY dapat memberikan impak positif sekiranya ia direka bentuk dengan mengambil kira aspek kebolehgunaan dan keberkesanan. Penerapan elemen-elemen dalam TAM, sokongan pedagogi yang sesuai, serta pemahaman terhadap keperluan khusus pelajar autisme adalah penting dalam memastikan kejayaan aplikasi ini dalam menyokong proses pengajaran dan pembelajaran.

Kajian oleh Leung et al. (2021) mendapati bahawa penggunaan aplikasi mudah alih yang interaktif dapat menyumbang kepada peningkatan kemahiran kognitif dan sosial pelajar autisme. Aplikasi yang direka secara intuitif serta berasaskan visual lebih mudah difahami oleh golongan ini, seterusnya membolehkan mereka mengekalkan fokus yang lebih lama semasa sesi pembelajaran. Kajian yang melibatkan penggunaan aplikasi pendidikan di atas platform tablet juga menunjukkan bahawa tahap tumpuan pelajar meningkat dengan ketara berbanding kaedah pengajaran tradisional.
Selain itu, pendekatan seperti video modeling dan sokongan visual telah terbukti berkesan dalam membantu pelajar autisme memahami arahan, rutin harian, serta situasi sosial. Kandungan berbentuk video yang diterapkan dalam aplikasi seperti LEARNIFY mampu meningkatkan keupayaan pelajar untuk menumpukan perhatian kerana ia bersifat konkrit, berulang, dan sesuai dengan keperluan individu.

Secara keseluruhannya, penemuan daripada kajian-kajian terdahulu menunjukkan bahawa aplikasi interaktif seperti LEARNIFY berpotensi tinggi dalam mempertingkatkan tumpuan dan keterlibatan pelajar autisme sepanjang sesi pengajaran dan pembelajaran. Penggabungan elemen visual, ciri gamifikasi, serta kandungan interaktif dilihat mampu mendorong pelajar untuk lebih fokus, bermotivasi, dan terlibat secara aktif. Oleh itu, kajian ini dijalankan bagi menilai keberkesanan aplikasi LEARNIFY dalam konteks bilik darjah sebenar daripada aspek-aspek tersebut.

2.6 Peranan Guru dalam Penggunaan Aplikasi Interaktif

Guru memainkan peranan penting dalam keberkesanan penggunaan aplikasi pendidikan, khususnya dalam kalangan pelajar pendidikan khas. Aplikasi yang kompleks atau tidak mesra pengguna boleh membebankan guru dan mengurangkan keberkesanan pengajaran. Justeru, maklum balas guru terhadap aspek kebolehgunaan dan keberkesanan LEARNIFY adalah penting untuk menentukan keberkesanan pelaksanaan aplikasi ini di bilik darjah.

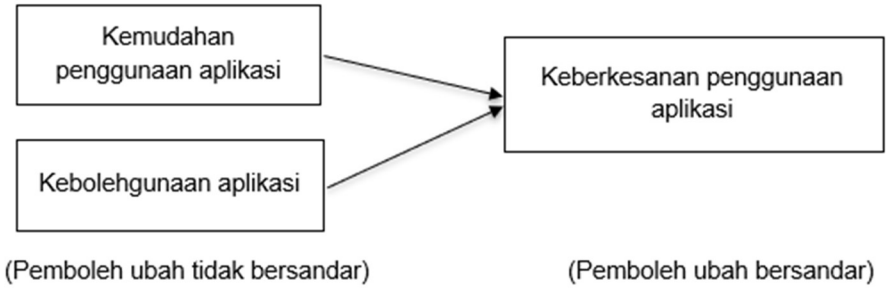
Chen et al. (2023) menekankan bahawa guru memerlukan aplikasi yang bersifat fleksibel, mudah disesuaikan, dan memiliki antara muka yang mesra pengguna. Ciri-ciri ini membolehkan mereka menyesuaikan kandungan mengikut keperluan individu pelajar serta memantau perkembangan pelajar dengan lebih berkesan. Dalam konteks kajian ini, persepsi guru terhadap aplikasi LEARNIFY akan menjadi indikator penting dalam menilai keberkesanannya sebagai alat bantu pengajaran yang praktikal dan menyokong amalan pembelajaran inklusif.

Ismail et al. (2022) turut mencadangkan agar pembinaan aplikasi pendidikan khas melibatkan input guru sejak awal bagi memastikan kandungan yang dihasilkan adalah selaras dengan

amalan pengajaran sebenar. Oleh itu, dapatan daripada guru akan memberikan gambaran lebih tepat terhadap keberkesanan LEARNIFY di persekitaran pembelajaran sebenar.
Secara keseluruhan, kajian-kajian terdahulu menunjukkan bahawa teknologi pendidikan, apabila direka secara inklusif dan berfokus kepada keperluan pelajar autisme, mampu meningkatkan kefahaman, keterlibatan dan keberkesanan proses pembelajaran. Di samping itu, aplikasi interaktif seperti LEARNIFY berpotensi membantu guru dalam merancang dan melaksanakan pengajaran yang lebih sistematik dan menyeronokkan. Oleh itu, penilaian terhadap kebolehgunaan dan keberkesanan LEARNIFY dalam kajian ini adalah penting bagi menyokong agenda pendidikan khas yang lebih berimpak dan berpusatkan pelajar.

3. Metodologi

Kajian ini dilaksanakan secara kuantitatif dengan menggunakan borang soal selidik sebagai instrumen pengumpulan data bagi mengetahui sejauh mana keberkesanan penggunaan aplikasi LEARNIFY. Kajian ini melibatkan seramai 12 orang guru sekolah yang mengajar dalam aliran Pendidikan Khas sebagai responden. Soal selidik tersebut terdiri daripada tiga bahagian iaitu Bahagian A (demografi responden), Bahagian B (kebolehgunaan aplikasi) dan Bahagian C (keberkesanan kandungan). Soalan-soalan ini diadaptasi daripada kajian Lezawati et al. (2024) serta kajian oleh Rabiatul Adawiyah et al. (2017). Soal selidik ini menggunakan skala Likert 5 mata, di mana setiap item dinilai berdasarkan tahap persetujuan responden yang merangkumi skala dari (1) “Sangat Tidak Setuju” hingga (5) “Sangat Setuju”. dan dianalisis melalui perisian Statistical Package for Social Science (SPSS) versi 22.0.



Rajah 3. Kerangka Teori

Kerangka teori kajian ini dibina berasaskan Teori Penerimaan Teknologi (TAM) yang menjelaskan faktor utama penerimaan pengguna terhadap sesuatu teknologi. Dalam konteks kajian ini, emudahan penggunaan aplikasi dan kebolehgunaan aplikasi bertindak sebagai pemboleh ubah tidak bersandar, manakala keberkesanan penggunaan aplikasi menjadi pemboleh ubah bersandar. Mengikut prinsip TAM, persepsi terhadap kemudahan penggunaan merujuk kepada tahap sejauh mana seseorang percaya bahawa menggunakan sesuatu aplikasi tidak memerlukan usaha yang tinggi. Manakala kebolehgunaan aplikasi pula merangkumi sejauh mana aplikasi tersebut memenuhi keperluan pengguna secara efektif dan efesien. Melalui kerangka ini, dapat difahami bahawa semakin mudah dan boleh digunakan sesuatu aplikasi, maka semakin tinggi tahap keberkesanan penggunaannya, terutamanya dalam konteks pendidikan khas. Oleh itu, teori TAM digunakan sebagai asas untuk menilai sejauh mana aplikasi LEARNIFY dapat diterima dan memberi impak kepada tumpuan serta keterlibatan pelajar autisme dalam sesi pembelajaran.

Jadual 1. Jadual Keputusan Alpha Cronbach

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.930	.931	20

Nilai Alpha Cronbach menunjukkan bahawa terdapat konsistensi yang sangat tinggi dalam kalangan item-item yang digunakan dalam instrumen atau soal selidik tersebut. Secara amnya, nilai Alpha Cronbach yang lebih besar daripada 0.9 dianggap sangat baik, yang bermaksud item-item dalam instrumen itu mengukur konstruk yang sama dengan sangat konsisten. Dalam kes ini, nilai 0.930 menunjukkan bahawa instrumen atau skala tersebut sangat boleh dipercayai.

4. Hasil Dapatan dan Perbincangan

Bahagian ini membentangkan hasil utama kajian berkaitan tahap kebolehgunaan dan keberkesanan kandungan aplikasi interaktif LEARNIFY dalam menyokong proses pembelajaran pelajar autisme. Dapatan dianalisis berdasarkan maklum balas responden melalui borang soal selidik yang telah dijalankan ke atas guru. Semua data dianalisis secara deskriptif dan dihubungkan dengan objektif kajian. Perbincangan turut merujuk kepada penemuan terdahulu bagi menjelaskan kepentingan aplikasi ini dalam konteks pendidikan khas, khususnya dari aspek tumpuan dan interaksi pelajar.

Jadual 1. Jadual Tafsiran Nilai Skor Min (Nunnally & Bernstein, 1994)

Skor Min	Interpretasi Skor Min
1.00 – 2.00	Rendah
2.01 – 3.00	Sederhana Rendah
3.01 – 4.00	Sederhana Tinggi
4.01 – 5.00	Tinggi

Skala interpretasi min ini turut merujuk kepada skala yang telah digunakan oleh penyelidik terdahulu dalam kajian mereka. Skala dalam Jadual 1, telah diaplikasikan oleh Norfadhilah (2014) serta Ghazali dan Mohd Khairi (2013).

4.1 Dapatan Bahagian A (Demografi)

Jadual 2 menunjukkan seramai 12 orang tenaga pengajar pendidikan khas terlibat dalam kajian ini. Majoriti responden ialah perempuan (75%) dan berbangsa Melayu (83.3%). Dari segi umur, kebanyakan berada dalam lingkungan 35–54 tahun (91.7%), menunjukkan penyertaan daripada kelompok guru berpengalaman. Kesemua responden berkhidmat di sekolah kerajaan. Dari segi pengalaman, 83.4% mempunyai tempoh perkhidmatan antara 6 hingga lebih 20 tahun. Dapatan ini menunjukkan bahawa responden terdiri daripada tenaga pengajar yang berpengalaman dan relevan untuk menilai keberkesanan aplikasi LEARNIFY dalam konteks pendidikan khas.

Jadual 2. Data demografi responden

Ciri–ciri demografi	N	Peratus (%)

Jantina	Lelaki	3	75 %
	Perempuan	9	25 %
Bangsa	Melayu	10	83.3 %
	Cina	0	0 %
	India	2	16.7 %
Umur	25–34 tahun	1	8.3 %
	35–44 tahun	6	50 %
	45–54 tahun	5	41.7 %
Jenis sekolah	Sekolah kerajaan (SMK, SK)	12	100 %
	Sekolah swasta	0	0 %
	Sekolah antarabangsa	0	0 %
Tempoh berkhidmat sebagai tenaga pengajar pendidikan khas	6 – 10 tahun	2	16.7 %
	11 – 15 tahun	5	41.7 %
	16 – 20 tahun	3	25 %
	Lebih dari 20 tahun	2	16.7 %

4.2 Kemudahan penggunaan aplikasi interaktif LEARNIFY terhadap pengajaran dan pembelajaran pelajar autisme.

Jadual 3. Kemudahan penggunaan aplikasi LEARNIFY

Bil.	Item	Skor min	Tafsiran
1	Isi kandungan disusun dengan teratur.	4.42	Tinggi
2	Ayat yang digunakan sesuai dan mudah difahami, dengan penerangan setiap topik yang jelas dan teratur.	4.42	Tinggi
3	Rekabentuk dan grafik yang digunakan adalah menarik.	4.50	Tinggi
4	Aplikasi ini mesra pengguna.	4.17	Tinggi
5	Pengajaran dan pembelajaran menggunakan aplikasi ini menyeronokkan.	4.67	Tinggi
6	Maklumat yang dipersembahkan mudah dan menarik.	4.58	Tinggi
7	Aplikasi ini sesuai digunakan dalam pengajaran dan pembelajaran pendidikan khas.	4.58	Tinggi
8	Aplikasi ini membantu saya dalam pengajaran dan pembelajaran pendidikan khas.	4.58	Tinggi
	Purata Keseluruhan	4.49	Tinggi

Jadual 3 menunjukkan tahap kemudahan penggunaan aplikasi LEARNIFY berdasarkan persepsi guru pendidikan khas. Secara keseluruhan, skor min purata adalah 4.49, yang berada pada tahap tinggi, menandakan penerimaan positif terhadap aplikasi ini sebagai alat bantu pengajaran.

Item dengan skor tertinggi ialah pengajaran dan pembelajaran menggunakan aplikasi ini menyeronokkan (min = 4.67), menunjukkan bahawa elemen interaktif LEARNIFY berjaya mewujudkan suasana pembelajaran yang menarik dan menyeronokkan untuk murid berkeperluan khas. Ini diikuti oleh item maklumat yang dipersembahkan mudah dan menarik**,** serta kesesuaian aplikasi dalam konteks pendidikan khas dan sokongan terhadap proses pengajaran**,** yang masing-masing mencatatkan skor min 4.58. Dapatan ini menunjukkan bahawa kandungan dan reka bentuk aplikasi bukan sahaja mudah difahami malah relevan untuk digunakan dalam situasi sebenar pengajaran.

Walaupun semua item menunjukkan tahap kemudahan penggunaan aplikasi yang tinggi, item yang mencatatkan skor min paling rendah ialah mesra pengguna (min = 4.17), walaupun masih berada dalam kategori tinggi. Ini menunjukkan terdapat sedikit ruang untuk penambahbaikan dari aspek antaramuka, navigasi atau kemudahan penggunaan bagi golongan pendidik.

Secara keseluruhan, dapatan ini mengesahkan bahawa aplikasi LEARNIFY mempunyai potensi yang tinggi sebagai alat bantu pembelajaran yang berkesan dalam pendidikan khas, khususnya untuk murid autisme. Ia memenuhi keperluan pedagogi guru dan memperkukuh pendekatan pembelajaran yang lebih inklusif dan menyeronokkan.

4.3 Kebolehgunaan aplikasi LEARNIFY terhadap pengajaran dan pembelajaran pelajar autisme.

Jadual 4. Kebolehgunaan aplikasi LEARNIFY

Bil.	Item	Skor min	Tafsiran
1	Penglibatan pelajar adalah aktif semasa penggunaan aplikasi ini.	4.50	Tinggi
2	Aplikasi ini menarik minat pelajar untuk berkomunikasi.	4.08	Tinggi
3	Papan ganjaran menarik minat pelajar untuk memberikan tumpuan.	4.08	Tinggi
4	Murid menunjukkan rangsangan terhadap bahan bantu belajar (aplikasi).	4.33	Tinggi
5	Pelajar mampu mengikut arahan yang diberikan.	4.08	Tinggi
6	Pelajar menggunakan bahan bantu belajar (aplikasi) dengan berkesan.	4.17	Tinggi
7	Pelajar menunjukkan tumpuan semasa pengajaran dan pembelajaran menggunakan bahan bantu belajar (aplikasi) ini.	4.25	Tinggi
8	Aplikasi ini menepati silibus kursus pendidikan khas.	4.42	Tinggi
	Purata Keseluruhan	4.24	Tinggi

Jadual 4 memperincikan dapatan mengenai kebolehgunaan aplikasi LEARNIFY berdasarkan penilaian guru pendidikan khas. Skor purata keseluruhan ialah 4.24, yang menunjukkan tahap keberkesanan tinggi**.**

Item yang mencatatkan skor tertinggi ialah penglibatan pelajar yang aktif semasa penggunaan aplikasi (min = 4.50), menandakan bahawa LEARNIFY berjaya merangsang penyertaan murid secara aktif dalam sesi pengajaran dan pembelajaran. Ini sejajar dengan keperluan murid autisme yang memerlukan pendekatan pembelajaran berbentuk visual dan interaktif untuk kekal fokus.

Dapatan seterusnya menunjukkan bahawa aplikasi ini menepati silibus kursus pendidikan khas (min = 4.42) dan mampu merangsang pelajar terhadap bahan bantu belajar (min = 4.33), yang menggambarkan kesesuaian kandungan dan reka bentuk aplikasi terhadap objektif kurikulum serta keperluan sebenar pelajar.

Item seperti minat berkomunikasi (min = 4.08), respon terhadap papan ganjaran (min = 4.08), dan pemahaman serta pelaksanaan arahan (min = 4.08) turut menunjukkan kebolehgunaan aplikasi dalam membina kemahiran asas pelajar autisme, walaupun mencatat skor sedikit lebih rendah berbanding item lain. Ini menunjukkan bahawa walaupun terdapat keberkesanan, terdapat juga ruang untuk penambahbaikan dari aspek interaktiviti dan respons pelajar terhadap elemen-elemen motivasi.

Secara keseluruhan, hasil kajian ini membuktikan bahawa LEARNIFY berkesan sebagai bahan bantu belajar digital yang menyokong perkembangan komunikasi, tumpuan, dan keterlibatan pelajar berkeperluan khas secara bermakna dalam proses pembelajaran.

4.4 Mengenalpasti tahap keberkesanan aplikasi interaktif LEARNIFY terhadap tumpuan dan keterlibatan semasa sesi pengajaran dan pembelajaran pelajar autisme.

Jadual 5. Tahap keberkesanan penggunaan LEARNIFY terhadap tumpuan dan keterlibatan pelajar

Bil.	Item	Skor min	Tafsiran
1	Penggunaan aplikasi dalam pembelajaran dapat meningkatkan minat pelajar serta menggalakkan tumpuan yang lebih tinggi.	4.50	Tinggi
2	Selain itu, penggunaan aplikasi ia turut membantu merangsang interaksi yang lebih aktif dalam kalangan pelajar.	4.50	Tinggi
3	Kandungan aplikasi membantu menarik minat pelajar dan meningkatkan tumpuan mereka.	4.58	Tinggi
4	Selain itu, kandungan aplikasi ini dapat meningkatkan tahap interaksi dan keterlibatan pelajar secara lebih aktif.	4.58	Tinggi
	Purata Keseluruhan	4.54	Tinggi

Berdasarkan Jadual 4, keputusan menunjukkan bahawa penggunaan aplikasi LEARNIFY memberikan impak yang sangat positif terhadap tumpuan dan keterlibatan pelajar berkeperluan khas. Skor purata keseluruhan yang diperoleh ialah 4.54, iaitu pada tahap tinggi.

Item yang mencatatkan skor tertinggi ialah kandungan aplikasi yang membantu menarik minat dan meningkatkan tahap interaksi pelajar secara aktif (min = 4.58). Ini menunjukkan bahawa reka bentuk kandungan aplikasi berperanan besar dalam mencetuskan minat serta memastikan penglibatan berterusan dalam sesi pembelajaran.

Selain itu, dapatan turut menunjukkan bahawa penggunaan aplikasi ini meningkatkan tumpuan serta merangsang interaksi aktif dalam kalangan pelajar (min = 4.50), sejajar dengan ciri-ciri pembelajaran yang efektif bagi pelajar autisme yang memerlukan rangsangan visual dan aktiviti interaktif.

4.5 Keputusan Kolerasi dan Regressi Pelbagai

Korelasi antara kemudahan penggunaan aplikasi dan keberkesanan aplikasi adalah sangat kuat dan signifikan (0.804). Ini menunjukkan bahawa semakin tinggi penilaian mengenai kemudahan penggunaan aplikasi semakin tinggi juga penilaian mengenai keberkesanan aplikasi**.** Nilai p = 0.002 menunjukkan bahawa hubungan ini adalah signifikan pada tahap 0.01, yang bermaksud terdapat hubungan yang nyata dan boleh dipercayai antara kedua-dua pembolehubah ini.

Korelasi antara kebolehgunaan aplikasi dan keberkesanan aplikasi adalah positif sederhana (0.644). Ini menunjukkan bahawa ada hubungan yang sederhana antara kedua-dua pembolehubah ini; semakin tinggi penilaian kebolehgunaan aplikasi, semakin tinggi juga penilaian keberkesanan aplikasi. Nilai p = 0.024 menunjukkan bahawa korelasi ini signifikan pada tahap 0.05, yang bermakna kita boleh mempercayai bahawa hubungan antara kedua-dua pembolehubah ini adalah nyata.

Secara keseluruhannya, keputusan ini mengesahkan bahawa LEARNIFY bukan sahaja berkesan dari segi penyampaian kandungan, tetapi juga mampu memupuk penglibatan aktif dan fokus

pelajar**,** sekaligus memperkukuh keberkesanan proses pengajaran dan pembelajaran pendidikan khas.

5. Kesimpulan dan Cadangan

Secara keseluruhannya, kajian ini membuktikan bahawa aplikasi interaktif LEARNIFY mencapai ketiga-tiga objektif kajian yang ditetapkan, iaitu menilai tahap kebolehgunaan, keberkesanan kandungan, serta impak aplikasi terhadap tumpuan dan keterlibatan pelajar autisme. Skor min yang tinggi dalam setiap komponen yang dinilai menunjukkan bahawa aplikasi ini telah memenuhi kriteria aplikasi pendidikan yang efektif untuk pelajar berkeperluan khas. Dapatan ini selaras dengan kajian oleh Sulaiman et al. (2023) yang menekankan bahawa pendekatan digital yang interaktif dan mesra pengguna berupaya meningkatkan penglibatan pelajar autisme dalam proses pembelajaran.

Hasil kajian ini turut mengesahkan dapatan terdahulu bahawa penggunaan teknologi pendidikan yang disesuaikan dengan keperluan individu mampu meningkatkan keberkesanan pengajaran serta memperkukuh pembelajaran bermakna dalam kalangan pelajar pendidikan khas (Zabidi et al., 2024; Noor et al., 2023). Aplikasi LEARNIFY telah terbukti bukan sahaja mampu mempertingkatkan tahap pemahaman pelajar melalui kandungan yang teratur dan visual yang menarik, malah berjaya mendorong pelajar untuk lebih fokus dan aktif semasa sesi pembelajaran dijalankan. Justeru, kajian ini memberikan sumbangan bermakna kepada pembangunan alat bantu mengajar berbentuk digital yang bersesuaian dengan keperluan pelajar autisme.
Secara teorinya, penemuan ini menyokong model-model kebolehgunaan klasik seperti TAM (Technology Acceptance Model), yang menekankan pentingnya persepsi terhadap kemudahan penggunaan sebagai faktor utama dalam menentukan penerimaan dan keberkesanan sistem (Davis, 1989). Implikasi praktikalnya pula menunjukkan bahawa pembangun sistem atau perisian harus memberi tumpuan kepada aspek reka bentuk yang mudah digunakan dan mudah difahami pengguna, bagi meningkatkan prestasi sistem secara menyeluruh.
Berdasarkan dapatan yang diperoleh, beberapa cadangan dikemukakan bagi menambah baik keberkesanan aplikasi LEARNIFY. Pertama, disarankan agar elemen interaktif seperti permainan pendidikan, audio naratif, dan animasi dinamik dipertingkatkan bagi merangsang minat serta motivasi pelajar, sejajar dengan cadangan oleh Tan et al. (2023) yang menekankan keperluan integrasi elemen multimedia dalam aplikasi pendidikan khas. Kedua, kajian lanjutan wajar dijalankan melibatkan saiz sampel yang lebih besar dan pelbagai kategori pelajar berkeperluan khas untuk memperkukuh kesahan dan kebolehgunaan aplikasi ini secara umum (Lee & Yusof, 2022).

Selain itu, penggunaan aplikasi LEARNIFY berpotensi untuk diperluaskan kepada semua jenis sekolah yang menawarkan program Pendidikan Khas. Ini seiring dengan inisiatif Kementerian Pendidikan Malaysia untuk memperkukuh pelaksanaan pendidikan inklusif dan memanfaatkan teknologi digital dalam pengajaran dan pembelajaran (MOE, 2023). Penggunaan aplikasi seperti ini perlu disokong melalui pengintegrasian ke dalam kurikulum pendidikan khas atau sebagai bahan bantu mengajar rasmi**,** agar impaknya dapat dirasai secara menyeluruh dan berterusan dalam sistem pendidikan.

Namun begitu, terdapat beberapa batasan dalam kajian ini. Saiz sampel yang kecil (n=12) mungkin menghadkan keputusan hasil kajian. Selain itu, semua data dikumpul secara kuantitatif melalui soal selidik, yang mana ini mungkin membawa kepada bias kendiri. Oleh itu, disarankan agar kajian lanjutan dijalankan dengan saiz sampel yang lebih besar dan reka bentuk campuran untuk mengesahkan dapatan ini.

Sebagai penutup, LEARNIFY bukan sahaja memenuhi objektif kajian secara menyeluruh, malah berpotensi besar sebagai alat bantu mengajar berasaskan teknologi yang relevan, berkesan dan bersifat inklusif dalam menyokong pendidikan pelajar autisme di Malaysia.

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KESEPADANAN KERJA BERBANDING KADAR GAJI GRADUAN KAJIAN KES: POLITEKNIK TUANKU SULTANAH BAHIYAH

Samsul bin Abd. Rashid[1], Nurul Ashikin binti Rahmad[1], Hasmida binti Mohamad Hassan[2]*

[1]Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim Hi-Tech Park, Kedah, Malaysia

[2]Jabatan Perdagangan, Politeknik Seberang Perai, 13500 Permatang Pauh, Pulau Pinang, Malaysia

*Corresponding author e-mail address: hasmida@psp.edu.my

Abstrak

Politeknik merupakan institusi TVET yang menganugerahkan diploma kepada graduannya. Menurut laporan Sistem Pengesanan Graduan (SKPG) tahun 2023, kadar kebolehpasaran graduan lepasan Politeknik Malaysia ialah 97.1%. Ini menunjukkan graduan lepasan politeknik mempunyai permintaan yang tinggi dalam pasaran kerja. Objektif kajian ini adalah untuk mengenal pasti sejauhmana kadar kebolehpasaran graduan ini dari aspek bekerja dalam bidang dan kadar gaji yang diperolehi adakah setara dengan kelayakan graduan. Petunjuk yang digunakan dalam kajian ini ialah gaji minimum dan Diploma Kemahiran Malaysia Tahap 4. Kajian ini menggunakan kaedah kajian kuantitatif melalui soal selidik dan penggunaan data sekunder kadar kebolehpasaran graduan Politeknik Tuanku Sultanah Bahiyah (PTSB) bagi tahun 2023 dan 2024 sebagai rujukan kajian kes. Bagi data penerimaan tawaran kerja pula, kajian ini memilih data pelajar tamat latihan industri bagi sesi 1 2023/2024, sesi 2 2023/2024 dan sesi 1 2024/2025. Keputusan yang diperolehi adalah kadar kebolehpasaran graduan PTSB pada tahun 2023 dan 2024 adalah 95% dan 98%. Dapatan juga mendapati sebanyak 75% hingga 85% pelajar PTSB yang tamat latihan industri ditawarkan pekerjaan dalam bidang. Daripada peratus tersebut kira-kira 14% hingga 23% memperoleh gaji di bawah gaji minimum. Manakala peratus yang menerima gaji ideal pula adalah di antara 5% hingga 15%. Tiga program yang perlu dipertingkatkan kadar kebolehpasarannya ialah Diploma Geomatik (DGU), Diploma Kejuruteraan Elektronik (Komunikasi) (DEP) dan Diploma Kejuruteraan Mekanikal Pembuatan (DTP). Kajian ini merumuskan bahawa data graduan yang bekerja dalam bidang dan kadar gaji yang diterima bagi graduan lepasan politeknik penting untuk diketahui. Ia dapat mengukur tahap sebenar penerimaan industri terhadap graduan lepasan politeknik dan sebagai panduan kepada program pengajian yang dilaksanakan di politeknik.

Kata Kunci: Politeknik; Gaji Minima; Diploma Kemahiran Malaysia (Tahap 4); Kebolehpasan Graduan

1. Pengenalan

Politeknik ialah institusi pengajian tinggi TVET terkemuka di Malaysia. Institusi ini menghasilkan graduan dalam bidang kejuruteraan seperti Awam, Mekanikal dan Elektrik dan bukan kejuruteraan iaitu Perdagangan. Politeknik Tuanku Sultanah Bahiyah (PTSB) merupakan politeknik ke-16 daripada 36 politeknik di Malaysia. PTSB mula beroperasi pada tahun 2002 terletak di Kulim Hi-Tech Park dengan keluasan 100 ekar yang boleh memuatkan kira-kira 4500 pelajar pada satu-satu masa. Pelajar diploma politeknik perlu menamatkan pengajian dalam tempoh 3 tahun (PTSB, 2019). Merujuk kepada Unit Pengesanan Graduan PTSB, kadar purata bilangan pelajar PTSB yang lulus atau bergraduasi setiap tahun adalah antara 800 hingga 1000.

Terdapat tiga kategori politeknik iaitu Politeknik Premier, Politeknik Konvensional dan Politeknik Metro. Politeknik Tuanku Sultanah Bahiyah adalah termasuk di bawah Politeknik Konvensional yang hanya menawarkan pengajian peringkat diploma dan mempunyai kursus yang kurang sedikit berbanding politeknik Premier. Terdapat 25 politeknik konvensional di seluruh Malaysia (UPU, 2023). Pihak Kementerian Pendidikan Tinggi telah membangunkan satu platform yang digunakan untuk mengumpulkan data kadar kebolehpasaran graduan bagi semua institusi pengajian tinggi di Malaysia termasuk Politeknik iaitu Sistem Pengesanan Siswazah (SKPG). SKPG dibangunkan oleh Kementerian Pengajian Tinggi (KPT) untuk mengumpul dan menganalisis data graduan yang tamat pengajian seluruh negara daripada universiti awam/swasta dan institusi pengajian tinggi yang lain terutama dari aspek status pekerjaan. Semua pelajar yang tamat pengajian dikehendaki menjawab semua soalan dalam SKPG sebelum graduan berkenaan layak menerima sijil konvokesyen. Data SKPG yang dikumpul adalah meliputi kadar graduan bekerja, kadar graduan tidak bekerja, kadar graduan melanjutkan pelajaran, dan kadar graduan meningkatkan kemahiran (Laporan Kajian Pengesanan Siswazah, 2023). Bagi sistem Pengurusan Politeknik Malaysia, sistem ini diuruskan oleh Pegawai Pengesanan Graduan dari setiap politeknik untuk mengumpul dan menganalisis data kebolehpasaran graduan baharu terutama maklumat pekerjaan graduan. Berdasarkan Pelan Tindakan Kebolehkerjaan Siswazah Kebangsaan 2012-2017, kebolehpasaran bermaksud keupayaan untuk dipasarkan dalam industri. Oleh itu, kebolehkerjaan Graduan merujuk kepada keupayaan graduan memasarkan diri mereka secara berkesan dalam pasaran kerja dan bersaing berdasarkan keperluan industri selepas menamatkan pengajian. Graduan boleh mendapatkan pekerjaan dan mengekalkan pekerjaan yang sesuai. Pengukuran kadar kebolehkerjaan menunjukkan keupayaan ekosistem pendidikan tinggi untuk menghasilkan graduan berkualiti dan memenuhi permintaan tenaga kerja daripada industri. Jadual 1 di bawah menunjukkan peratus kebolehpasaran graduan Politeknik Malaysia dari 2019 hingga 2023.

Jadual 1. Peratus Kebolehpasaran Graduan Politeknik Malaysia Tahun 2019-2023

Tahun	2019	2020	2021	2022	2023
Peratus Kebolehpasaran Graduan Politeknik	96.7%	91.4%	93.7%	96.2%	97.1%

Nota. Data diperoleh daripada Laporan Kajian Pengesanan Graduan, Kementerian Pengajian Tinggi

Berdasarkan Jadual 1 di atas menunjukkan kadar kebolehpasaran graduan Politeknik Malaysia adalah sangat baik. Purata kadar kebolehpasaran graduan Politeknik Malaysia dari tahun 2019 hingga 2023 ialah 95%. Peratus kadar kebolehpasaran ini merujuk kepada graduan yang bekerja, melanjutkan pengajian, meningkatkan kemahiran dan menunggu penempatan pekerjaan. Jadual 2 di bawah pula menunjukkan peratusan graduan politeknik yang mendapat pekerjaan setelah tamat pengajian. Data ini adalah berdasarkan kepada laporan dari SKPG bagi tahun 2019 hingga 2023.

Jadual 2. Peratus Graduan Politeknik Malaysia Yang Bekerja Bagi Tahun 2019-2023

Tahun	2019	2020	2021	2022	2023
Peratus Graduan Politeknik Malaysia Yang Bekerja	81.2%	69.2%	71.1%	75.2%	76.6%

Nota. Data diperoleh daripada Laporan Kajian Pengesanan Graduan, Kementerian Pengajian Tinggi

Berdasarkan Jadual 2 di atas menunjukkan bahawa kadar graduan Politeknik Malaysia mendapat pekerjaan setelah tamat pengajian amat baik iaitu lebih 75%. Walau bagaimanapun, timbul persoalan adakah peratusan graduan yang bekerja mengikut bidang, mendapat gaji yang setimpal dengan kelayakan. Data ini juga boleh menggambarkan situasi sebenar tentang kadar kebolehpasaran graduan Politeknik Malaysia dan ia merupakan objektif kajian ini dijalankan. Bagi menilai sama ada gaji yang dibayar kepada graduan lepasan dari Politeknik Malaysia adalah bersesuaian, kadar gaji minimum dan kadar gaji Diploma Kemahiran Malaysia (Tahap 4)

digunakan sebagai penunjuk penilaian. Gaji yang diperolehi oleh graduan Politeknik Malaysia hendaklah tidak kurang daripada gaji minimum dan gaji ideal pula mestilah sesuai pada kadar gaji yang dibayar kepada pemegang Diploma Kemahiran Malaysia (Tahap 4). Gaji yang diterima oleh pemegang Diploma Kemahiran Malaysia Tahap 4 yang ditetapkan oleh pihak Kementerian Sumber Manusia Malaysia adalah seperti Jadual 3 di bawah.

Jadual 3. Tangga Gaji untuk Sijil dan Diploma Kemahiran Malaysia

Tahap Kemahiran	Gaji Permulaan
Sijil Kemahiran Malaysia Tahap 1	RM1330.00 + a
Sijil Kemahiran Malaysia Tahap 2	RM1450.00 + a
Sijil Kemahiran Malaysia Tahap 3	RM1700.00 + a
Diploma Kemahiran Malaysia (Tahap 4)	RM2020.00 + a
Diploma Lanjutan Kemahiran Malaysia	RM2460.00 + a

Nota. a- Nilai tambahan kepada gaji asas permulaan yang meliputi lesen tambahan atau Sijil Kecekapan yang dimiliki oleh calon.
Data diperoleh daripada Kementerian Sumber Manusia (2020)

Gaji minimum telah ditakrifkan sebagai amaun saraan minimum yang diperlukan oleh majikan untuk membayar orang gaji untuk kerja yang dilakukan dalam tempoh tertentu, yang tidak boleh dikurangkan dengan perjanjian kolektif atau kontrak individu (Dube & Lindner, 2021) Menurut Kaviyarasu Elangkovan, (2012), gaji minimum (MW) ditakrifkan sebagai imbuhan setiap jam, harian atau bulanan terendah yang majikan bayar secara sah kepada pekerja dan ia merupakan upah terendah untuk penggunaan tenaga buruh. Gaji minimum di Malaysia telah diwartakan pada 16 Julai 2012 dan dilaksanakan secara rasminya bermula pada 1 Januari 2013. Pada tahun 2013 kadar gaji minimum yang dibayar kepada pekerja di Malaysia ialah RM1000 sebulan di Semenanjung Malaysia atau RM920 sebulan di Sabah, Sarawak, dan Wilayah Persekutuan Labuan. Pada tahun 2020, gaji minimum telah dinaikkan daripada RM1000 kepada RM1200. Manakala pada tahun 2022 sekali lagi berlaku peningkatan dalam pembayaran gaji minimum iaitu kepada RM1500 sebulan (Majlis Peguam Malaysia, 2022; Richard Seow Yeaw Chong, 2023).

Pemilihan kadar gaji Diploma Kemahiran Malaysia (Tahap 4) sebagai gaji rujukan dan gaji ideal adalah kerana graduan Politeknik Malaysia memiliki kemahiran teknikal dan mempunyai kelayakan akademik pada tahap diploma.

2. Metodologi

Metodologi kajian merujuk kepada kaedah yang digunakan untuk mendapatkan data dan menganalisis data. Ang Kean Hua (2016), menyatakan metodologi kajian ialah kaedah yang digunakan untuk mengumpul data melalui prosedur yang berkesan bagi menjawab objektif kajian. Berdasarkan Creswell, J (2014), turut menyatakan bahawa metodologi kajian ialah pendekatan kajian yang melibatkan pemilihan kaedah khusus dan sesuai untuk mengumpul, menganalisis, dan mentafsir data bagi menjawab objektif kajian. Dalam kajian ini, kaedah yang digunakan ialah data kuantitatif. Terdapat dua kaedah yang digunakan iaitu soal selidik dan kajian kes (data sekunder). Pemilihan kaedah ini adalah mengikut objektif kajian yang memerlukan data dalam skop yang luas dan berfokus untuk kumpulan tertentu. Merujuk kepada Felows, R. and Liu, A. (2015), menyatakan bahawa penggunaan kaedah berasaskan soalan seperti soal selidik, kajian kes, dan temu bual, adalah berbeza dari segi skop dan butiran kajian. Rajah 1 di bawah menunjukkan perbezaan di antara setiap kaedah yang dipilih dari segi keluasan skop kajian dan kedalaman kajian atau tujahan kajian.



Rajah 1. Keluasan Skop dan Kedalaman Perincian Kajian Bagi Kaedah Berbentuk Soalan (Fellows and Liu, 2015)

Berdasarkan Rajah 1, ia menunjukkan bahawa kaedah soal selidik digunakan untuk memperolehi data yang banyak dan meliputi skop yang pelbagai serta luas tetapi dengan perincian yang minimum. Manakala kaedah temu bual pula meliputi skop yang sangat spesifik dan fokus. Kaedah kajian kes pula skop kajian adalah sederhana luas dan sederhana dari segi kedalaman perincian kajian. Dalam kajian ini, kaedah yang dipilih adalah soal selidik dan kajian kes. Soal selidik yang digunakan adalah adaptasi daripada SKPG TVET. Oleh itu, soal selidik yang digunakan adalah boleh diterima dari segi kesahan dan kebolehpercayaannya. Responden dalam kajian ini adalah pelajar PTSB yang tamat latihan indusri Sesi 2 2023/2024 dan sesi 12024/2025. Jumlah responden yang terlibat bagi setiap sesi adalah seperti di dalam Jadual 4 di bawah

Jadual 4. Jumlah Pelajar Latihan Industri Mengikut Sesi

Sesi Latihan Industri	Bilangan Pelajar
Sesi 1 2023/2024	285
Sesi 2 2023/2024	533
sesi 1 2024/2025	307

Pelajar yang tamat latihan industri dipilih dalam kajian ini kerana ia dapat menunjukkan dengan jelas sejauhmana penerimaan pihak industri terhadap graduan lepasan politeknik dan kadar gaji yang boleh dibayar oleh pihak industri. Bagi mengukur kewajaran kadar gaji yang diterima oleh graduan lepasan politeknik adalah merujuk kepada kadar gaji minima semasa iaitu RM1500 manakala gaji ideal pula merujuk kepada kadar gaji yang ditetapkan oleh Kementerian Sumber Manusia untuk lepasan Diploma Kemahiran Malaysia (Tahap 4) iaitu RM2020. Dalam kajian ini politeknik yang dipilih ialah Politeknik Tuanku Sultanah Bahiyah (PTSB).

3. Dapatan Kajian

Jadual 5 berikut menunjukkan dapatan kajian berkaitan dengan kadar kebolehpasaran graduan yang telah direkodkan oleh Unit Pengesanan Graduan Politeknik Tuanku Sulatanah Bahiyah bagi tahun 2023 dan 2024.

Jadual 5. Kadar Kebolehpasaran Graduan PTSB Tahun 2023 dan 2024

Tahun	Kadar Peratus Kebolehpasaran Graduan PTSB
2023	95%
2024	98%

Nota. Data diperoleh daripada Unit Pengesanan Graduan PTSB (2024).

Berdasarkan jadual tersebut kadar keboehpasaran graduan PTSB adalah melepasi Petunjuk Prestasi Utama (KPIs) yang telah ditetapkan oleh pihak pengurusan PTSB dan juga Jabatan Pendidikan Politeknik dan Kolej Komuniti iaitu 95%. Ini menunjukkan bahawa kadar kebolehpasaran graduan Politeknik Tuanku Sultanah Bahiyah adalah baik. Perkara ini dibuktikan dengan lebih jelas lagi dengan merujuk kepada data yang direkodkan oleh pihak Unit Pengurusan Latihan Industri kepada pelajar yang diterima bekerja sebaik sahaja tamat latihan industri.

Jadual 6 di bawah menunjukkan kadar penerimaan bekerja oleh pihak industri kepada pelajar PTSB sebaik sahaja menamatkan sesi latihan industri.

Jadual 6. Kadar Penerimaan Bekerja Pelajar PTSB oleh Pihak Industri Sejurus Tamat latihan Industri

Sesi	Bilangan Pelajar	Bilangan		Peratus	
		Diterima bekerja	Tidak diterima bekerja	Diterima bekerja	Tidak diterima bekerja
Sesi 1 2023/2024	285	104	181	36.5	63.5
Sesi 2 2023/2024	583	182	351	34.1	65.9
Sesi 1 2024/ 2025	307	137	170	44.6	55.4

Nota. Data diperoleh daripada Unit Pengurusan Latihan Industri PTSB

Berdasarkan Jadual 6 di atas menunjukkan bahawa pihak industri menerima baik graduan lepasan politeknik di mana 35% hingga 45% pelajar lepasan politeknik diterima bekerja sebaik sahaja menamatkan sesi latihan industri. Selain daripada itu, penerimaan pihak industri terhadap pelajar lepasan politeknik bekerja sejurus tamat latihan industri merupakan indikator yang menunjukkan kemahiran yang dimiliki oleh pelajar lepasan politeknik adalah diiktiraf dan memenuhi kehendak pihak industri. Perkara ini dapat dibuktikan dengan merujuk kepada peratus pelajar politeknik yang diterima bekerja mengikut bidang pengajian yang diambil semasa belajar di politeknik sebaik sahaja menamatkan latihan industri adalah 75% hingga 85% (Rujuk Rajah 2).

Berikut adalah carta pai yang menunjukkan peratus pecahan pelajar yang mendapat tawaran pekerjaan mengikut bidang sejurus sahaja tamat latihan industri bagi setiap sesi iaitu bagi tahun 2023 dan 2024.

Berdasarkan carta pai tersebut amatlah penting bagi pelajar memilih tempat latihan industri yang sesuai. Ini kerana tawaran pekerjaan yang diterima oleh pelajar kebanyakannya adalah dari majikan tempat pelajar tersebut menjalankan latihan industri. Oleh itu sesi latihan industri sangat penting sebagai medium awal untuk proses memasarkan graduan lepasan politeknik. Melalui sesi latihan industri, pihak majikan dapat menilai kemampuan dan potensi pelajar yang datang membuat latihan industri tersebut. Ini secara tidak langsung menjadi medium kepada pihak industri untuk menyediakan pelajar tersebut ke arah situasi pekerjaan sebenar dan dapat singkatkan proses tempoh persediaan sebelum diambil bekerja secara tetap. Selain daripada itu, bukti lain yang menunjukkan pengiktirafan dan penerimaan pihak industri terhadap graduan lepasan politeknik dikukuhkan lagi dengan pemberian gaji yang ideal seperti yang digariskan oleh Kementerian Sumber Manusia (Rujuk jadual 3).

Berkaitan dengan penawaran dan pemberian gaji, pihak majikan sepatutnya memberikan gaji yang ideal kepada graduan lepasan politeknik. Ini kerana mereka mempunyai kelayakan akademik di peringkat diploma dan berkemahiran dalam bidang teknikal. Walau bagaimanapun memandangkan pelajar politeknik ini tidak mempunyai pengalaman dan masih diperingkat awal

dalam alam pekerjaan, maka pembayaran gaji yang sama atau lebih daripada kadar gaji minima boleh dianggap wajar. Jadual 8 di bawah menunjukkan kadar gaji yang diterima oleh pelajar politeknik yang bekerja sejurus tamat latihan industri.

Jadual 7. Kadar Gaji yang ditawarkan kepada Pelajar Politeknik PTSB Sejurus Tamat Latihan Industri

Kadar Gaji	Sesi 1 2023/ 2024		Sesi 2 2023/ 2024		Sesi 1 2024/ 2025		Peratus Penerimaan Kadar Gaji
	Bilangan pelajar	Peratus	Bilangan pelajar	Peratus	Bilangan Pelajar	Peratus	
>RM2500	1		3		2		
RM2300-RM2499	2	2.9%	1	2.2%	1	2.2%	Lebih
RM2000-RM2299	9	8.6%	7	3.8%	17	12.4%	Ideal
RM1800-RM1999	25	66.3%	41	79.7%	37	70%	Minimun
RM1500-RM1799	44		104		59		
<RM1500	23	22.1%	26	14.3%	21	15.3%	Kurang
	104	100%	182	100%	137	100%	100

Nota. Data diperoleh daripada Unit Pengurusan Latihan Industri PTSB

Merujuk kepada Jadual 7 di atas, 75% hingga 85% pelajar PTSB adalah ditawarkan gaji setara atau lebih daripada gaji minima iaitu RM1500 sejurus tamat latihan industri. Daripada nilai tersebut 5% hingga 15% adalah ditawarkan dengan gaji yang ideal. Terdapat juga pelajar yang ditawarkan gaji yang lebih rendah berbanding dengan gaji minima sejurus tamat latihan industri iaitu sebanyak 14% hingga 23%. Namun begitu kebanyakan pekerjaan yang ditawarkan tidak selari dengan bidang pengajian di politeknik. Ini kerana pelajar tersebut menjalani latihan industri di syarikat yang berskala kecil dan hanya melibatkan sebahagian kecil sahaja perkaitan dengan bidang yang dipelajari semasa di politeknik. Tambahan pula, pekerjaan tersebut juga adalah bersifat sementara sebelum pelajar tersebut melanjutkan pelajaran atau mendapat pekerjaan yang sebenar.

Jadual 8 berikut pula adalah data penawaran pekerjaan yang lebih spesifik iaitu pecahan penerimaan dan penawaran pekerjaan mengikut program yang ditawarkan di PTSB sejurus selesai tempoh latihan industri.

Jadual 8. Penawaran Kerja Mengikut Program Sejurus Tamat Latihan Industri

Program	Sesi 1 2023/2024		Sesi 2 2023/2024		Sesi 1 2024/2025		Jumlah keseluruhan	Jumlah Bekerja	Peratus Bekerja
	Terima	Tidak	Terima	Tidak	Terima	Tidak	Ikut Program		
DGU	2	22	11	39	9	4	87	22	23.3%
DKA	9	16	13	34	12	23	107	34	31.8%
DEE	3	12	14	33	6	8	76	23	30.3%
DEP	2	4	3	8	4	8	29	9	31%
DET	16	34	16	24	31	25	146	63	43.2%
DTK	6	15	12	20	12	9	74	30	40.5%
DEM	9	9	20	24	4	9	75	33	44%
DKM	9	17	27	46	11	10	120	47	39.2%
DTP	5	1	1	9	3	10	29	9	31%
DAT	15	17	14	42	10	24	122	39	31.9%
DPM	14	21	28	40	12	25	140	54	38.6%
DPR	13	13	23	32	23	15	119	59	49.6%

Berdasarkan jadual 8 di atas, bagi Jabatan Kejuruteraan Awam kedua-dua program yang ditawarkan iaitu Diploma Kejuruteraan Awam (DKA) dan Diploma Geomatik (DGU) mempunyai permintaan pekerjaan yang agak baik oleh pihak industri. Bagi pelajar program DKA, 31.8% daripada bilangan pelajar yang dihasilkan mendapat tawaran pekerjaan sebaik sahaja menamatkan latihan industri. Tetapi bagi Diploma Geomatik permintaan pekerjaan oleh pihak industri agak kurang sedikit. Hanya 23% sahaja pelajar yang dihasilkan menerima tawaran pekerjaan.

Bagi Jabatan Kejuruteraan Elektrik pula, program yang mendapat permintaan pekerjaan yang baik ialah Diploma Kejuruteraan Elektrik (DET) dan Diploma Kejuruteraan Komputer (DTK). Peratus pelajar yang menerima tawaran kerja bagi kedua-dua program tersebut ialah masing-masing 43% dan 40.5%. Bagi program Diploma Kejuruteraan Elektrik Elektronik (DEE) dan Diploma Kejuruteraan Eletrik (komunikasi) pula kadar penerimaan tawaran pekerjaan adalah sebanyak 30%. Walaupun begitu Diploma Kejuruteraan Eletrik (komunikasi) (DEP) lebih kritikal berbanding program DEE. Ini kerana kadar pengambilan bekerja oleh pihak industri adalah rendah jika dinisbahkan dengan pelajar yang dihasilkan.

Seterusnya bagi Jabatan Kejuruteraan Mekanikal, program yang mendapat penawaran pekerjaan yang baik adalah Diploma Kejuruteraan Mekatronik (DEM). Sebanyak 44% daripada 75 orang pelajar yang dihasilkan telah ditawarkan pekerjaan sebaik sahaja menamatkan sesi latihan industri. Keadaan ini dipengaruhi oleh keadaan persekitaran kampus PTSB yang berada di dalam kawasan perindustrian Kulim Hi-Tech yang mana kebanyakkan kilang yang dibina adalah berasaskan mekatronik. Diploma Kejuruteraan Mekanikal (DKM) pula adalah program yang paling tinggi kadar penghasilan pelajar bagi Jabatan Kejuruteraan Mekanikal iaitu seramai 120 orang pelajar. Daripada nilai tersebut sebanyak 39% pelajarnya telah ditawarkan pekerjaan sejurus tamat latihan industri. Ini menunjukkan bahawa Program DKM adalah merupakan salah satu bidang yang diperlukan oleh pihak industri. Jabatan Kejuruteraan Mekanikal juga mempunyai Program yang kritikal iaitu Diploma Kejuruteraan Mekanikal Pembuatan (DTP). Penghasilan pelajarnya adalah sedikit antara 6 hingga 13 orang pada satu-satu sesi. Kadar penawaran kerja setelah tamat latihan industri juga rendah direkodkan iaitu 31% daripada 29 orang pelajar yang di hasilkan. Ia memberi indikator bahawa keperluan pihak industri terhadap bidang ini adalah rendah. Pihak pengurusan politeknik perlu mengenalpasti apa kekurangan yang perlu ditambahbaik bagi meningkatkan kadar kebolehpasaran pelajar DTP.

Jabatan Perdagangan pula mencatatkan kadar penerimaan tawaran pekerjaan yang tertinggi direkodkan iaitu bagi Program Diploma Pemasaran (DPR). Hampir 50% pelajar program DPR mendapat tawaran pekerjaan sejurus tamat latihan industri. Bagi program Diploma Pengajian Perniagaan (DPM) dan Diploma Akauntansi (DAT) masing-masing merekodkan hampir 39% dan 32% pelajar yang dihasilkan mendapat penawaran pekerjaan sejurus tamat latihan industri. Bagi program DPM perkara ini kurang membimbangkan kerana pelajar lulusan bidang ini boleh bekerja sendiri dengan membuka perniagaan sendiri atau menjadi usahawan. Namun bagitu bagi program DAT ia memerlukan syarikat yang bertauliah untuk menerima mereka bekerja. Jika pelajar lepasan program DAT ingin bekerja sendiri, mereka perlulah mengambil sijil dan lulus syarat akauntan bertauliah.

Berdasarkan Jadual 8, antara program yang rendah dari segi peratusan penerimaan tawaran pekerjaan oleh pihak industri adalah program DGU, DEP dan DTP. Namun begitu secara keseluruhannya program yang ditawarkan di PTSB mempunyai potensi kerjaya yang baik di mana kadar peratusan pelajar ditawarkan pekerjaan sejurus tamat latihan industri adalah

melebihi 25% di mana pelajar ini tidak mempunyai pengalaman dan ditawarkan secara automatik tanpa perlu melalui fasa mencari dan membuat permohonan pekerjaan.

Merujuk kepada Akta Kerja 1955 (Pindaan) 2022, gaji adalah segala bayaran tunai yang harus dibayar kepada pekerja kerana kerja yang dilakukan berkait dengan kontrak perkhidmatan. Terdapat graduan politeknik dibayar dengan gaji yang sesuai dengan dengan kelayakan akademik yang dimiliki atau gaji ideal iaitu 5% hingga 15%. Manakala terdapat juga dibayar pada kadar yang lebih rendah daripada gaji minima iaitu 14% hingga 23%. Pembayaran gaji yang lebih rendah daripada gaji minima adalah kadar yang tidak wajar diterima oleh seorang graduan lepasan politeknik kerana mereka memiliki kelayakan akademik di peringkat diploma serta mempunyai kemahiran. Ia juga tidak menepati apa yang ditetapkan oleh Kementerian Sumber Manusia (rujuk Jadual 3). Pembayaran gaji pada kadar di antara gaji minima dan gaji ideal boleh diterima secara sementara terutama pada peringkat tempoh percubaan atau sebelum dilantik ke jawatan tetap.

4. Perbincangan

Situasi graduan lepasan politeknik tidak dibayar dengan kadar gaji yang setimpal dengan kelayakan akademik serta kemahiran yang dimiliki juga ada kaitan dengan situasi semasa dalam pasaran buruh dimana kadar penghasilan graduan adalah melebihi kadar penawaran kerja. Keadaan ini memberi kelebihan kepada pihak industri atau majikan untuk menawarkan kadar gaji mengikut kehendak mereka. Menurut Jabatan Perangkaan Malaysia (DOSM) (2023), jumlah penawaran pekerjaan bagi tahun 2022 adalah sebanyak 83,070 dimana sebanyak 48,600 kekosongan jawatan untuk pekerja berkemahiran dan pewujudan pekerjaan baharu pula adalah sebanyak 34,470. Graduan yang dihasilkan pula adalah melebihi penawaran iaitu seramai 282,038 orang. Keadaan ini akan meningkatkan lagi potensi berlakunya gaji yang dibayar tidak sepadan dengan kelayakan akademik dan kemahiran yang dimiliki.

Menurut Nor Shela Saleh dan Mohd Shafie Rosli (2019), kredibiliti kemahiran, pengetahuan dan tingkah laku manusia sering dinilai dan didiskriminasi oleh majikan dan pengurus atasan semasa proses pemilihan. Ini menyebabkan pekerja tidak dibayar gaji pada kadar yang sepatutnya. Tambahan pula pada situasi sekarang di mana penawaran pekerjaan adalah terhad dan terdapat ramai calon yang boleh dipilih untuk mengisi kekosongan tersebut. Bagi mengatasi isu tersebut, pihak pengurusan PTSB sentiasa bekerjasama dengan pihak industri di dalam memastikan kadar kebolehpasaran graduan politeknik sentiasa berada pada tahap terbaik. Pihak industri yang berkaitan dengan program yang ditawarkan di PTSB adalah dilantik menjadi Panel Penasihat Industri. Ia bertujuan untuk mewujudkan kerjasama yang lebih erat lagi agar pengisian silibus yang di sampaikan kepada pelajar adalah selari dengan perkembangan teknologi dan kehendak industri. Oleh itu pelajar politeknik lebih mudah diterima bekerja dengan gaji yang sesuai dengan kemahiran dan kelayakan akademik serta menjadi pilihan utama.

5. Kesimpulan

Data kebolehpasaran graduan politeknik adalah sangat penting bagi membolehkan pihak pengurusan politeknik membuat perancangan jangka pendek dan jangka panjang bagi meningkatkan tahap kebolehpasaran graduan. Maklumat ini berupaya menyokong usaha peningkatan tahap pencapaian graduan serta memperkukuh penghasilan modal insan yang berkualiti, berkemahiran dan holistik dalam memperkasakan generasi TVET negara. Cadangan kajian yang boleh dilaksanakan pada masa akan datang ialah mengenalpasti amalan terbaik yang

dilaksanakan oleh pihak pengurusan politeknik di dalam memperkasakan generasi TVET negara terutama program-program yang rendah dari segi kebolehpasaran.

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A PRELIMINARY STUDY ON ISLAMIC EDUCATION IN ROBLOX PLATFORM

Muhammad Amiruddin bin Rosli[1]*, Halizayanie binti Kimlin[1], Sharifah Nadiya binti Syed Yahya[1], Azlina binti Md. Nor[1], Suhaila binti Mustaffa[2]

[1]Department of Design and Visual Communication, Tuanku Syed Sirajuddin Polytechnic, Pauh Putra, 02600, Arau, Perlis, Malaysia

[2]Department of General Studies, Tuanku Syed Sirajuddin Polytechnic, Pauh Putra, 02600, Arau, Perlis, Malaysia

*Corresponding author e-mail address: m.amiruddin@ptss.edu.my

Abstract

The emergence of the metaverse presents new opportunities for educational innovation, particularly within the realm of Islamic education. However, its integration into Islamic learning remains significantly underutilized. Traditional Islamic education continues to rely heavily on text-based and in-person methods, with limited access to interactive and culturally relevant digital tools. This limitation results in reduced learner engagement and effectiveness. This preliminary study explores the potential of the Roblox platform to deliver immersive and engaging Islamic educational experiences through gamification elements such as quests, challenges, and rewards. An online survey was conducted with 51 voluntary respondents, including parents, educators, and students, to assess digital accessibility, engagement, and interest in faith-based content. The findings indicate strong enthusiasm for incorporating Islamic education into metaverse environments, with respondents demonstrating high technological readiness and willingness to participate. This study is significant as it provides initial insights into how immersive platforms like Roblox can modernize Islamic education and align it with the digital habits of younger learners. Despite challenges related to infrastructure and content creation, the results suggest Roblox holds significant promise as a platform for fostering interactive Islamic learning. The outcome of this survey will be used as a guide for an upcoming Roblox metaverse app in Islamic education.
Keywords: Roblox Metaverse; Islamic Education; Virtual Learning Environments.

1. Introduction

The rapid advancement of digital technologies has profoundly reshaped how education is delivered and experienced, influencing both teaching practices and student learning. Among these advancements, the concept of the metaverse has gained attention as a new frontier in interactive learning. The metaverse is commonly understood as a shared virtual environment that integrates physical and digital realities, offering users deeply immersive and interactive experiences (Zhang et al., 2022). The word “metaverse” is a combination of two words: “meta,” meaning beyond, and “verse,” derived from the universe, reflecting its conceptual foundation as a space beyond the physical world (Metin et al., 2023). Platforms such as Roblox, widely known for user-generated games and social interaction, present opportunities for educational innovation, especially for young learners.

Islamic education, traditionally delivered through conventional classroom settings, can potentially benefit from such immersive platforms. Previous research has shown that game-based learning can enhance student motivation, engagement, and understanding of abstract concepts (Al-

Azawei et al., 2020). Similarly, studies have emphasized the role of educational technology in promoting religious and moral development among children (Zulkifli et al., 2022).

Despite the growing use of digital tools in education, limited studies have explored their application in Islamic education within virtual environments like Roblox. This study aims to investigate user readiness and perceptions regarding the use of Roblox as a platform for delivering Islamic educational content, as a foundation for the future development of an interactive Islamic education application within the platform.

1.1 Research Objective

a) to develop engaging and educational experiences within the metaverse environment that effectively incorporate Islamic education and cultural context.
b) to employ gamification components such as quests, challenges, and rewards to enhance engagement and motivation among young learners.
c) to assess the usability of metaverse technologies in delivering Islamic educational content.

The motivation for carrying out this research stems from multiple factors related to cultural, Islamic education, and technological viewpoints. Therefore, the following sub-sections provide a detailed explanation of these contributing elements.

1.2 Addressing the Lack of Digital Islamic Education Tools

Despite global growth in educational technology, Islamic education still relies on textbooks and in-person delivery methods since there are limited number of digital applications that integrate Islamic values and curriculum into virtual environments. Previous studies have highlighted the need for localized and culturally sensitive digital learning tools (Norhayati et al., 2022). Most Islamic educational apps remain passive in nature, lacking interactivity and engagement. A gamified virtual platform like Roblox offers the opportunity to build a more dynamic and experiential learning space, especially for young children learning basic tenets of Islam, such as prayer, manners, and stories of the Prophets.

1.3 Preparing for Future Educational Trends in Metaverse

The metaverse is increasingly being recognized as a transformative educational space that merges digital and real-life experiences (Lee et al., 2021). It provides real-time interaction, collaboration, and 3D content visualization, which can be especially powerful for abstract or value-based subjects like religion. However, understanding user readiness and perception is critical before developing such platforms. According to Davis' (1989) Technology Acceptance Model (TAM), the likelihood of technology adoption increases when users perceive the technology as beneficial and user-friendly. This study serves as a foundational step to assess user perception of using Roblox for Islamic education, ultimately guiding the development of an effective and meaningful virtual Islamic learning environment.

2. Methodology

A survey was utilized to gather data and was issued to voluntary respondents through an online communication platform. The research was conducted over a period of five days, involving 51 participants from different backgrounds.

The goal of this investigation is to examine user knowledge and awareness regarding the use of the Roblox platform for Islamic education. The findings from this survey will serve as a foundation for the development of an interactive Islamic learning application within the Roblox environment.

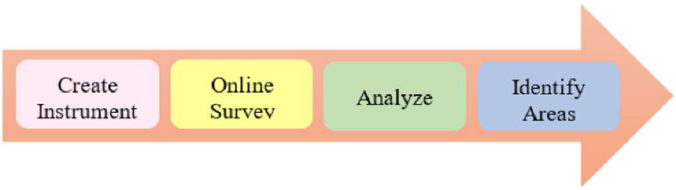


Fig. 1. The Preliminary Survey

A 15-question instrument was developed and structured into three sections which are demographic information, introductory items, and decision-making questions.

3. Analysis and Findings

Existing perspectives acknowledge that metaverse technology has promising potential in Islamic education. However, its application in this area remains underutilized. A preliminary study conducted using a descriptive data analysis method indicates that Roblox, as a metaverse platform, can offer great opportunities for Islamic education. The analysis involved summarizing survey responses from participants in the form of frequencies and percentages to understand their knowledge, readiness, and experiences with the metaverse and Roblox platforms. Despite the encouraging findings, the results also highlight that the development and integration of this technology for young learners requires thorough planning and preparation to ensure its effectiveness.

3.1 Respondent Demographic

This section presents the survey results on Islamic educational content within a metaverse-based environment. The preliminary findings of this study are grounded in respondents' insights regarding metaverse technology, their level of readiness, and their perceptions of its application within the context of Islamic education.

Table 1. Respondent Demography

Demography			
	Features	Occurrence	Percentage (%)
Ages	13 - 17	1	2
	18 - 24	5	9.8
	25-44	42	82.4
	45 and above	3	5.9
Gender	Male	22	43
	Female	29	57
Roles	Parents	26	51
	Educators	13	25.5
	Students of Primary or High School	2	3.9
	Students of higher education institutions.	10	19.6

Table 1 displays the demographic profile of the 51 respondents who took part in this survey. Results show 29 female and 22 male respondents participated in the preliminary survey. The

analysis of respondents' ages is distributed into 4 different groups since the level of acceptance toward the concept of the metaverse may vary across different age cohorts. From an age perspective, 82.4% of respondents are from age 25-44, 9.8% are from age 18-24, 5.9% are from age 45 and above, and the remaining 2% are from age 13-17. Based on this survey, 51% of respondents are parents, 25.5% are educators, 19.6% are students from higher education institutions, and 3.9% are students from primary or high school.

3.2 Result

The survey findings were analyzed to explore user readiness and opinions about carrying out metaverse technology in the Islamic education context. The result is shown in Table 2.

Table 2. Survey Questions and Results

Question/Statements	Result N (%)
Metaverse technology knowledge	27 (52.9%)
Ready to accept metaverse technology	50 (98%)
Explore metaverse platform	18 (35.3%)
Knowledge of support equipment in metaverse other than a smartphone	35 (68.6%)
Own a device other than a smartphone	40 (78.4%)
a. Type of device	
PC	22
Laptop	36
Tablet	23
Other	6
Willing to provide a device	46 (90.2%)
Interest in using Roblox as a metaverse platform for learning	44 (86.3%)
Experience using Roblox Metaverse	21 (41.2%)
a. Type of interaction used in Roblox	
Gaming	16
Social	13
Learning	11
b. The interaction is engaging	21 (100%)
Encountered technical difficulties or limitations while using a Roblox platform	16 (31.4%)
a. Limitations encountered in a Roblox platform	
Network Infrastructure	10
Content creation was limited	8
User experience (not user-friendly)	7
Hardware incompatibility	7
Roblox can be popular among the local education community	50 (98%)
Roblox potential in the education area	46 (96.1%)
Explore Roblox focus on Islamic education	11 (21.6%)
Positive if integrate Islamic education in Roblox metaverse	45 (88.2%)
Potential to increase knowledge about Islamic education using Roblox	47 (92.2%)
Interest in participating in enhancing Islamic education using Roblox	46 (90.2%)

N = Total number of participants, tables show number (%) with Yes answers only.

4. Discussion

Metaverse nowadays has gained major popularity, driven by fast progress in virtual reality and Web 3.0 technologies. However, despite this growing trend, public understanding of the metaverse remains limited. Based on the results, 52.9% (27 respondents) know metaverse technology while the other 47.1% (24 respondents) stated otherwise. Although the metaverse has

become trending worldwide, there is still a lack of awareness and understanding among general users (Sebastian, 2022).

Despite the still-lacking understanding of the metaverse, a total of 98% (50 respondents) indicated they are ready to accept and adopt metaverse technology. As proposed in the Technology Acceptance Model (TAM) by Davis (1989), individuals' intention to adopt new technology is primarily influenced by their perceptions of its usefulness and ease of use. This supports the third research objective, which aims to assess the usability of metaverse technologies in delivering Islamic educational content.

There are only 35.3% (18 respondents) had actually tried using the metaverse platform. This reveals a discrepancy between real use and awareness as stated by Park and Kim (2022), who observed that although users generally show a strong interest in cutting-edge technology, their hands-on engagement usually lags due to limited readiness, digital literacy, and infrastructure accessibility. Furthermore, access barriers such as subscription-based pricing schemes and content access limitations may increase the gap between interest and participation in a metaverse learning environment. Many metaverse platform requires users to subscribe or pay for premium features to unlock full access, while users who refuse to pay in full only get basic access (Alotaibi, 2023).

A total of 68.6% of respondents indicate they know Metaverse needs other support equipment apart from smartphones, such as high-performance PC, Tablets, and VR headsets. However, 31.4% of respondents did not know that some of the metaverse platforms require this support equipment. This support equipment is essential in the immersive metaverse as the literature highlights that hardware familiarity is a necessary condition for effective virtual engagement (Lee et al., 2021).

In terms of device ownership, 78.4% of respondents had a digital device beyond smartphones, such as a laptop (36 responses), tablet (23 responses), and personal computer (22 responses), indicating a substantial level of technological preparedness required for engaging with metaverse-based platforms, which often demand to use of high-performance hardware (Zhao et al., 2022). In addition, the willingness of 90.2% of respondents to provide the equipment to explore the metaverse is a group that needs to be targeted in order to help organizations achieve their goals. This further reinforces the third objective regarding the usability and readiness for metaverse-based Islamic education content.

Many popular metaverse platforms exist today, such as AltspaceVR, Meta Horizon Worlds, and Roblox. This metaverse platform is widely used for social, gaming, and education. In terms of how to enhance education, when asked about a specific platform, 86.3% of participants stated they were interested in using Roblox as a learning platform. Roblox has been identified as an effective learning and educational tool due to its gamified elements that show potential collaborative projects and the ability for constructivist interactions (Bakar & Jaafar, 2022). According to Jeong et al. (2024), the Roblox metaverse offers a dynamic and customizable environment that supports narrative-based experience, thereby requiring innovative instructional design that prioritizes enjoyment and learner autonomy. This finding aligns with the first research objective, which aims to develop engaging and educational experiences within the metaverse that incorporate Islamic values and cultural context.

Although Roblox has become one of the most popular metaverse platforms due to its accessibility and education potential, Kao et al. (2022) discovered that some users remain reluctant to adopt

it, claiming issues with perceived complexity, digital literacy, or a lack of connection to their educational goals. This can be proved with only 41.2% (21 respondents) having ever experienced the use Roblox platform, showing the need for wider exposure and training. For those who had used it, the majority use Roblox for gaming (16 responses), social activities (13 responses), and learning (11 responses), with 100% stating the Roblox platform is engaging. This supports the second objective, which focuses on the use of gamification components such as quests, challenges, and rewards to improve user motivation and participation. This verifies research by Yilmaz (2022), who emphasizes Roblox as a captivating metaverse platform because of its dynamic content creation tools, game-based structure, and ability to promote interactive and cooperative learning and educational settings.

Technical difficulties or limitations in any socio-technical system will always occur, which can lead to unexpected technical issues and challenges. This problem can also occur on the Roblox platform. Item 9 shows that 31.4% (16 respondents) faced problems during the experience on the Roblox platform. Limitations or technical issues while using Roblox, such as network limitations, content creation challenges, user experience difficulties, and hardware incompatibility, still pose adoption barriers, aligning with Choi and Kim's (2021) findings on the systematic challenges of immersive educational platforms. Although Roblox also has its own disadvantages, it’s still gaining popularity based on immersive and gamified content.

In recent years, Roblox has gained attention due to its interactive gamified content, and advancements in technology have made everyone create their own Roblox content in multiple areas, like education. Item 10 supports arguments that Roblox can be popular among the local education community, with 98% of 50 respondents agreeing with it. According to Green and Johnson (2023), Roblox is the most widely adopted metaverse platform in educational settings since it can create creative possibilities, user-friendliness, and demand among younger learners.

Roblox's metaverse has great potential to be developed in many areas, especially using local content such as education. Item 11 shows that 96.1% (46 respondents) agree with the statement, even though 3.9% (5 respondents) stated otherwise. Previous scholars, such as Shonfeld and Ronen (2023), highlighted that educators increasingly acknowledge the pedagogical value of Roblox mostly due to its immersive qualities and compatibility with constructivist teaching methodologies.

Nevertheless, if focuses on Islamic education, only 21.6% (11 respondents) have experienced exploring the Roblox metaverse that is related to Islamic education content. As cited in (Hassan & Latif, 2023) accessing metaverse environments dedicated to Islamic education seems challenging, mainly when platforms run under closed systems that restrict full membership to paying subscribers. The creation of Islamic education may be beneficial and feasible with a solid preparation in the foundation. These findings again contribute to the first objective, providing baseline data for designing culturally grounded Islamic content in immersive formats.

The integration of Islamic education into the Roblox metaverse received a highly positive response, with 88.2% of respondents (45 responses) expressing the belief that developments in this area hold the potential for further enhancement. Islamic education in Malaysia continues to exert a significant influence on the shaping of the nation's intellectual and spiritual identity. As the global education system evolves with the embracement of digital transformation, it has become essential for Islamic education to evolve in tandem with technological advancements to be effective and relevant in modern-day contexts (Lubis et al., 2023).

Developing and designing an immersive environment that preserves Islamic education elements can offer meaningful opportunities for users to deepen their religious understanding and engage with realistic educational contexts in virtual settings. Such an environment has been shown to foster deeper spiritual engagement and reflective learning when designed in accordance with Islamic pedagogical principles (Yusof & Baharuddin, 2022). Item 14 shows that 92.2% (47 respondents) strongly believe the statements development of the Roblox metaverse can improve knowledge about Islamic education. Although Roblox was not originally intended for religious instruction, it offers customizable and interactive features that can be adapted to support faith-based learning experiences (Shonfeld & Ronen, 2023).

The findings from item 15 indicate that 90.2% (46 respondents) are interested in participating in a project that utilizes the Roblox metaverse as a platform for the preservation of Islamic education. Social platforms rely heavily on active users who share similar interests, experiences, and viewpoints, which helps them connect on a deeper level and engage over time. According to Bennacer Seghouani et al. (2019), understanding users' interests and opinions is essential for designing effective social environments. When users find common ground, it enhances their emotional connection and encourages consistent involvement. This alignment of interests is therefore fundamental to the growth, relevance, and longevity of digital communities.

5. Conclusion

This preliminary study demonstrates that the viability of using Roblox as a metaverse platform holds substantial promise in enriching Islamic education through immersive, gamified, and culturally responsive experiences. The findings indicate a high level of interest and favourable perceptions among participants, highlighting the importance of educational planning that aligns with technological innovation. Such alignment is essential for fostering meaningful engagement and supporting the effective integration of virtual learning tools in religious education.

Despite persisting challenges related to access, infrastructure readiness, and user familiarity with platform-specific features, the overall enthusiasm and readiness among respondents suggest a promising foundation for innovation. These environments should not only meet educational standards but also uphold and reflect the spiritual values and identities of their intended users.

The findings suggest that with proper design and oversight, Roblox can serve as an effective tool for delivering Islamic instruction in the digital age. Future initiatives should emphasize collaborative design approaches involving educators, technologists, and Islamic scholars to ensure the sustainability, relevance, and integrity of metaverse-based Islamic education.

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THE INFLUENCE OF BUSINESS CAPITAL, MARKETING AND LOCATION ON THE SUCCESS OF MSMEs IN MANAGING THEIR BUSINESSES IN MEDAN AMPLAS DISTRICT

Renta Ulina Situmorang*, Vidya Fathimah

Program Studi Manajemen, Sekolah Tinggi Ilmu Manajemen Sukma Medan, Indonesia

*Corresponding author e-mail address: rentaulinasitumorangsitumorang@gmail.com

Abstract

The objective of this study is to examine the influence of business capital, marketing, and location on the success of Micro, Small, and Medium Enterprises (MSMEs) in managing their businesses in Medan Amplas District. The independent variables investigated include business capital (X1), marketing (X2), and location (X3), while the dependent variable (Y) is the success of MSMEs. This research adopts a quantitative approach using a survey method. Data were obtained and collected through questionnaires distributed to 74 culinary MSME actors in Medan Amplas District. Data analysis was conducted using multiple linear regression and processed with SPSS Version 27. Hypothesis testing was carried out both simultaneously and partially. The partial test results indicate that business capital (X1) has a positive influence on MSME success, marketing (X2) has a positive influence on MSME success, and location (X3) has a negative and insignificant influence on MSME success. Meanwhile, the simultaneous test results show that the variables of business capital (X1), marketing (X2), and location (X3) have a positive and significant influence on the success of MSMEs in Medan Amplas District.
Kata kunci: Business Capital; Marketing; Location.

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) constitute the foundation of a populist economy that can drive Indonesia's economic development. MSMEs in Indonesia are one of the national economic development priorities and contribute to strengthening both local and national economic resilience (Yulianingsih, 2021). Micro, small, and medium enterprises play a strategic role in supporting economic growth, creating employment opportunities, and reducing poverty and unemployment in Indonesia, particularly in Medan Amplas District. MSMEs strive to serve as a pillar of the community's economy. Their existence is capable of making a tangible contribution to increasing community income. The determination of MSME success in the business environment, among other factors, includes business capital, marketing, and location.

One of the factors that determines the success of MSMEs is business capital. Capital is a crucial aspect because it is directly related to the ability of MSME actors to carry out business operations, purchase raw materials, and expand the scale of their businesses. Many MSME actors have promising business ideas and potential, but face limitations in terms of capital. This condition prevents them from meeting production needs, expanding market reach, or enhancing the competitiveness of their products. Therefore, the availability and proper management of adequate business capital constitute one of the main factors influencing the success of MSMEs.

In addition to business capital, marketing is also a second important factor in determining the success of MSMEs. Through effective marketing, a business can promote and advance MSMEs operating in Medan Amplas District. Micro, Small, and Medium Enterprises (MSMEs) require

marketing strategies, which are actions designed to promote products by utilizing various digital platforms such as Facebook, Instagram, TikTok, and others to engage with prospective customers or consumers, build communities, and promote MSME products. (Nasional et al., 2022).

The determination of location is also an important aspect in running a business. A strategic location can increase consumer accessibility and expand sales opportunities. In Medan Amplas District, there is a wide variety of business locations, ranging from those situated along main roads to those hidden within densely populated residential areas. Inappropriate location selection may lead to a low number of consumers, resulting in decreased sales profits. Therefore, selecting the right location can be a key determinant of MSME success in managing their businesses in Medan Amplas District. The selection of an appropriate location is based on considerations that include accessibility, operational costs, and the market potential of the surrounding area.

There are several examples of business capital reports from MSMEs located in Medan Amplas District, including Dimsum 1000 MSME and Pohay Beverage MSME.

a. The following is the calculation of business capital for the food MSME: “Dimsum 1000”

Table 1. Calculation of Business Capital of Dimsum 1000 MSME

Description	Initial capital
Cart	Rp.3.000.000
Stove + Gas	Rp. 600.000
Raw materials	Rp. 500.000
Promotion costs	Rp. 600.000
Total Capital	Rp.3.450.000

From the table above, it can be seen that the initial business capital of Dimsum 1000 MSME amounted to IDR 3.450.000. Therefore, the business capital can be deducted from the gross profit to obtain the net profit, as shown in the calculation below

Table 2. Calculation of Net Profit of Dimsum 1000 MSME

Income calculation: 50 portions/days x 5.000 x 30 days= Rp. 7.500.000
profit : gross profit – total capital
: Rp. 7.500.000 – 3.450.000
: Rp. 4.050.000

b. Based on the calculation above, it can be concluded that the net profit of Dimsum 1000 MSME is IDR 4,050,000 per month.

The calculation of business capital for the beverage MSME “Pohay” is as follows.

Table 3. Calculation of Initial Investment Capital for the Beverage Business of Pohay MSME

Description	Initial capital
Cart	Rp.2.500.000
Blender	Rp. 700.000
Fruits	Rp. 500.000
Cups	Rp. 600.000
Total Capital	Rp.4.300.000

From the table above, it can be seen that the initial business capital of Pohay MSME amounts to IDR 4,300,000. Therefore, the business capital can be deducted from the gross profit to obtain the net profit as shown in the calculation below.

Table 4. Calculation of Net Profit of Pohay MSME

Income calculation: 30 cups/day ×10.000 x30 days= Rp.9.000.000	
Net Profit	: gross profit – total capital
	: Rp 9.000.000 – 4.300.000
	: Rp 4.700.000

Based on the calculation above, it can be concluded that the net profit of Pohay MSME amounts to IDR 4,700,000 per month.

In the study by Aprilia & Melati (2021), business capital was found to influence the success of MSMEs in managing their enterprises. Business capital can affect the development of a business in achieving its desired goals, and it represents the highest category in terms of influencing the success of business management. However, this finding differs from the study by Sali & Rahmadhan (2024), which showed that business capital did not have a significant effect on the success of MSMEs in managing their businesses in Banguntapan and Bantul Districts. This was due to the intense competition among vendors, which led to competitive pricing and provided consumers with a wider range of choices.

The study by Aprilia & Melati (2021) found that marketing was able to influence business management success, as marketing can optimize business performance in increasing sales by developing product innovation. However, in the study by Millati & Sofwan (2022) marketing did not have a significant effect on the success of MSMEs in Jepara District, because MSME actors were not responsive to marketing strategies for improving their business success.

The study by Astriyani (2024) found that business location can influence the success of business management, as location selection is an important aspect that needs to be considered by beginners; choosing an appropriate location can affect business success. In contrast, the study by Sali & Rahmadhan (2024) showed that business location did not have an impact on the success of MSMEs in managing their businesses in Banguntapan and Bantul Districts, because customers preferred products with lower prices, making business location not a determining factor in MSME success.

The research question in this study is whether business capital, marketing, and location are able to influence the success of MSMEs in managing their businesses in Medan Amplas District. The objective of this research is to determine whether business capital, marketing, and location can affect the success of MSMEs in managing their businesses in Medan Amplas District. The benefit of this research is to enhance the knowledge and insight of MSME actors, particularly in understanding the influence of business capital, marketing, and location on the success of MSMEs in managing their businesses in Medan Amplas District, and to serve as input for business development.

2. Methodology

In this study, the researcher employed a quantitative research design, where the quantitative approach aims to obtain generalizations from a sample to a broader population (Sugiyono, 2013). Data collection techniques are effective methods carried out by the researcher to gather data from MSME actors, particularly in Medan Amplas District, to explain the research problems. To collect the data, the researcher used questionnaires. The data obtained were then processed to generate

the information required in this research. This study utilized both primary and secondary data. According to Sugiyono (2019), primary data are data collected directly from respondents through questionnaires and direct interviews with MSME owners in Medan Amplas District, while secondary data are data obtained within a certain period, such as MSME financial reports for the year 2023.
The population in this study consists of MSME actors in the culinary sector, totaling 287 business units in Medan Amplas District. The sample was determined using the Slovin formula, resulting in 74 MSME actors in Medan Amplas District. The tests applied in this research are as follows:

a. t-Test (Partial Test)

The partial test is an analytical technique used to compare an independent variable by comparing the calculated t-value (t-count) with the critical t-value (t-table). This technique is also referred to as an individual regression parameter test to examine whether a specific value differs significantly from the sample mean (Sujarweni, 2020). The criteria used to interpret the results are as follows:

i. If t-count ≤ t-table, then variable X does not influence variable Y.
ii. If t-count ≥ t-table, then variable X influences variable Y.

b. F-Test (Simultaneous Test)

The simultaneous test (F-Test) is used to examine whether independent variables (X1), (X2), and (X3) simultaneously affect the dependent variable (Y). The test is conducted at a 95% confidence level or a significance level of α = 0.05, with the following criteria:

i. If F-count ≤ F-table, it means that, simultaneously, the independent variables do not affect the dependent variable.

ii. If F-count ≥ F-table, it means that, simultaneously, the independent variables affect the dependent variable.

c. R^2 Test (Coefficient of Determination)

The coefficient of determination (R^2) is a statistical measure that indicates the extent to which the model is capable of explaining the dependent variable (Sujarweni, 2020). The higher the coefficient of determination (approaching one), the greater the influence of the independent variables (X1), (X2), and (X3) on the dependent variable (Y).

d. Multiple Linear Regression Test

Multiple linear regression is a regression model that involves more than one independent variable. Accordingly, multiple linear regression is expressed in the following equation:

$Y=a + \beta 1X1 + \beta 2X_2 + \beta 3X_3 + e$
Description:
Y = Dependent variable (MSME Success)
X_1 = Independent variable (Business Capital)
X_2 = Independent variable (Marketing)
X_3 = Independent variable (Location)
a = Constant
β_1 = Regression coefficient of the business capital variable

β_2 = Regression coefficient of the marketing variable
β_3 = Regression coefficient of the location variable
e = Error term (Unobserved variables)

3. Results and Discussion

3.1. Respondent Characteristics

The characteristics of respondents in this study aim to provide a general overview of the background of MSME actors who are the subjects of research in Medan Amplas District. The respondent characteristics examined include gender, type of business, and monthly turnover.

a. The table below presents the characteristics of respondents based on gender.

Table 5. Respondent Characteristics by Gender

No.	Gender	Frequency	Percentage (%)
1.	Male	26	35,1%
2.	Female	48	64,9%
	Total	74	100%

Based on Table 5, it can be seen that the majority of respondents are female, totaling 48 individuals (64.9%), while male respondents account for 26 individuals (35.1%).

b. The table below presents the characteristics of respondents based on the type of business.

Table 6. Respondent Characteristics by Type of Business

No	Type of Business	Frequency	Percentage (%)
1.	Food	37	50,0%
2.	Beverage	37	50,0%
	Total	74	100%

Based on table 6, it can be seen that the number of MSME actors engaged in food businesses and beverage businesses is the same, with 37 respondents each (50%) of the total respondents. This indicates that the food and beverage sectors have an equally strong appeal among MSME actors in Medan Amplas District.

c. The table below presents the characteristics of respondents based on monthly turnover:

Table 7. Respondent Characteristics by Monthly Turnover

No	Monthly turnover	Frekuensi	Percentage (%)
1.	< Rp.5jt	62	83,8%
2.	Rp.5jt-10jt	12	16,2%
3.	Rp.10-20jt	0	0%
4.	> 20jt	0	0%
	Total	74	100%

Based on Table 7, it can be seen that the category of monthly turnover less than IDR 5 million accounts for 62 respondents (83.8%), while the category between IDR 5–10 million includes 12 respondents (16.2%). The categories between IDR 10–20 million and turnover exceeding IDR 20 million had no respondents.

3.2 Recapitulation of Respondents' Answers

a. Recapitulation of Responses on the Business Capital Variable (X1)

Table 8. Recapitulation of Respondents' Answers on the Business Capital Variable

No	Respondents statement	Respondents Answers (SS) F	%	(S) F	%	(N) F	%	(TS) F	%	(STS) F	%	Total
1.	I have sufficient capital to start my business.	30	41%	36	49%	8	11%	0	0%	0	0%	74
2.	The availability of capital affects the smooth operation of my business.	20	27%	33	45%	21	28%	0	0%	0	0%	74
3.	The capital I have comes from clear and legal sources.	33	45%	31	42%	10	14%	0	0%	0	0%	74
4.	I am able to circulate business capital to increase profits.	36	49%	36	49%	2	3%	0	0%	0	0%	74
5.	I obtain capital from various sources (e.g., personal funds, loans, investors).	35	47%	30	41%	8	11%	1	1%	0	0%	74
6	Sufficient business capital supports my business in carrying out innovation.	33	45%	40	54%	1	1%	0	0%	0	0%	74
	Average		42%		46%		11%		0%		0%	

Based on Table 8, it can be seen that regarding the statements on the business capital variable, most respondents answered “agree,” accounting for 46%. Furthermore, 42% of respondents answered “strongly agree,” and 11% answered “neutral.” There were no respondents who answered “disagree” or “strongly disagree.”

b. Recapitulation of Responses on the Marketing Variable (X2)

Table 9. Recapitulation of Respondents' Answers on the Marketing Variable

No	Respondents statement	Respondents Answers SS F	%	S F	%	N F	%	TS F	%	Total (STS) F	%	Total
1.	I use social media to support marketing activities.	29	39%	35	47%	10	14%	0	0%	0	0%	74
2.	I actively promote my products to prospective consumers.	32	43%	35	47%	7	9%	0	0%	0	0%	74
3.	I regularly participate in bazaars, exhibitions, or other promotional activities.	35	47%	30	41%	9	12%	0	0%	0	0%	74
4.	I use attractive packaging as part of my marketing strategy.	37	50%	26	38%	11	15%	0	0%	0	0%	74
5.	I use attractive packaging as part of my marketing strategy	30	41%	28	38%	16	22%	0	0%	0	0%	74
6.	I have a pricing strategy that is appealing to consumers.	29	39%	36	49%	9	12%	0	0%	0	0%	74
	Average		43		43		27		0		0	

Based on Table 9, it can be seen that regarding the statements on the marketing variable, most respondents answered “strongly agree,” accounting for 43%, followed by those who answered “agree,” also at 43%, and those who answered “neutral,” at 27%. There were no respondents who answered “disagree” or “strongly disagree.”.

c. Recapitulation of Responses on the Location Variable (X3)

Table 10. Recapitulation of Respondents' Answers on the Location Variable

No	Respondents statement	Respondents Answers										Total
		SS		S		N		TS		STS		
		F	%	F	%	F	%	F	%	F	%	
1.	My business location is easily accessible to consumers.	17	23%	40	54%	13	18%	4	5%	0	0%	74
2.	My business location is strategic for reaching the target market.	8	11%	31	42%	29	39%	6	8%	0	0%	74
3.	The environment around my business location supports business activities.	7	9%	31	42%	26	35%	10	14%	0	0%	74
4.	I do not experience obstacles in terms of transportation access to my business location.	13	18%	30	53%	29	39%	2	3%	0	0%	74
5.	My business location makes a significant contribution to increasing business income.	21	28%	27	36%	22	30%	4	5%	0	0%	74
6.	The rental or operation costs of my business location are in line with the profits earned.	17	23%	39	57%	14	19%	4	5%	0	0%	74
	Average		19%		45%		30%		7%	0%	0%	

Based on Table 10, it can be seen that regarding the statements on the location variable, most respondents answered “agree,” accounting for 45%, followed by those who answered “strongly agree,” at 19%, and those who answered “neutral,” at 7%. There were no respondents who answered “disagree” or “strongly disagree.”

d. Rekapitulasi hasil jawaban variabel keberhasilan UMKM (Y)

Table 11. Rekapitulasi jawaban responden variabel keberhasilan UMKM

No	Respondents statement	Respondents Answers										Total
		SS		S		N		TS		STS		
		F	%	F	%	F	%	F	%	F	%	
1.	The capital I have is sufficient to run and develop the business.	29	39%	40	54%	5	7%	0	0%	0	0%	74
2.	I carefully plan business activities.	20	27%	34	46%	20	27%	0	0%	0	0%	74
3.	I continuously develop products according to market needs.	28	38%	34	46%	12	16%	0	0%	0	0%	74
4.	I actively promote products through social media or other media.	27	36%	39	53%	8	11%	0	0%	0	0%	74
5.	My business location is easily accessible to customers.	28	38%	32	43%	14	19%	0	0%	0	0%	74
6.	The surrounding environment supports the smooth operation of my business.	33	45%	38	51%	3	4%	0	0%	0	0%	74
	Average		35%		50%		14%		0%		0%	

Based on Table 11, it can be seen that regarding the statements on the MSME success variable, most respondents answered “agree,” accounting for 50%, followed by those who answered

"strongly agree," at 35%, and those who answered "neutral," at 14%. There were no respondents who answered "disagree" or "strongly disagree."

3.3. Results of Linear Regression and Hypothesis Testing

a. Results of the t-Test (Partial Test)

The following table presents the results of the partial test conducted using SPSS Version 27:

Table 12. Partial Test (t-Test)

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	0.294	2.962		0.099	0.921
	Business capital	0.538	0.089	0.518	6.074	0.000
	Marketing	0.351	0.088	0.362	3.987	0.000
	Location	0.096	0.065	0.131	1.469	0.146

Note. a. Dependent Variable: MSME success

Based on the table above, the results of the t-test are as follows:

i. The Business Capital variable (X1) can influence the MSME Success variable (Y). From the table, the calculated t-value is 6.074, with a critical t-value at the 5% significance level (5%:74–1–3)=70, resulting in a t-table value of 2.3808. The results show that t-count 6.074 > t-table 2.3808, and the significance value is 0.000 < 0.05. Therefore, the Business Capital variable (X1) has a positive and significant influence on MSME Success (Y).

ii. The Marketing variable (X2) can influence the MSME Success variable (Y). From the table, the calculated t-value is 3.987, with a critical t-value at the 5% significance level (5%:74–1–3)=70, resulting in a t-table value of 2.3808. The results show that t-count 3.987 > t-table 2.3808, and the significance value is 0.000 < 0.05. Therefore, the Marketing variable (X2) has a positive and significant influence on MSME Success (Y).

iii. The Location variable (X3) does not influence the MSME Success variable (Y). From the table, the calculated t-value is 1.469, with a critical t-value at the 5% significance level (5%:74–1–3)=70, resulting in a t-table value of 2.3808. The results show that t-count 1.469 < t-table 2.3808, and the significance value is 0.146 > 0.05. Therefore, the Location variable (X3) does not have a significant influence on MSME Success (Y).

b. Results of the F-Test (Simultaneous Test)

The following table presents the results of the simultaneous test conducted using SPSS Version 27:

Table 13. Simultaneous Test (F-Test)

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	218.164	3	72.721	24.536	.000[b]
	Residual	207.471	70	2.964		
	Total	425.635	73			

Note. a.Dependent Variabel: MSME Success
b.Predictors: (Constant) Business capital, Marketing and Location

Based on the table above, it can be seen that the F-count value is 24.536, which is greater than the F-table value of 2.74, where (df = k = number of independent variables = 3 and df = n – k – 1 = 74 – 3 – 1 = 70, resulting in an F-table value of 2.74). The significance value is 0.000, which is less than the alpha level of 0.05. Therefore, the decision is to reject H0 and accept H1. The acceptance of H1 indicates that the independent variables—business capital (X1), marketing (X2), and location (X3)—are able to explain the variability in the dependent variable, MSME success (Y). Thus, it can be concluded that simultaneously, the variables Business Capital (X1), Marketing (X2), and Location (X3) have a positive and significant influence on the success of MSMEs (Y) in Medan Amplas District.

c. Results of the R^2 Test (Coefficient of Determination)

The following table presents the results of the coefficient of determination test conducted using SPSS Version 27:

Table 14. Coefficient of Determination Test (R^2 Test)

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.716[a]	0.513	0.492	1.72159

Note. a.Predictors: (Constan) Location, Business Capital, Marketing.

Based on the coefficient of determination, the value obtained is 0.513 or 51.3%. This indicates that the variables business capital, marketing, and location are able to explain 51.3% of the influence on MSME success, while the remaining 48.7% is explained by other variables not examined in this study, such as products, services, pricing, and others.

3.4. Results of Multiple Linear Regression Analysis

The following table presents the results of the multiple linear regression analysis conducted using SPSS Version 27:

Table 15. Multiple Linear Regression Test (R^2)

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
Model		B	Std. Error	Beta		
1	(Constant)	0.294	2.962		0.099	0.921
	Business capital	0.538	0.089	0.518	6.074	0.000
	Marketing	0.351	0.088	0.362	3.987	0.000
	Location	0.096	0.065	0.131	1.469	0.146

Note. a. Dependent Variable: MSME Success

Based on the data in the table above, the results of the multiple linear regression equation are as follows:

$Y = 0.294 + 0.538X_1 + 0.351X_2 + 0.096X_3$

i. Constant (c) = 0.294, indicating the constant value where, if all independent variables are equal to zero, the MSME success variable (Y) is 0.294.

ii. Business Capital variable (X_1) = 0.538, which means that, based on this study, if the other variables remain constant and business capital increases by 1 rupiah, MSME success will increase by 0.538. The positive coefficient value indicates that there is a positive relationship between the business capital variable (X_1) and MSME success (Y). This means that if business capital increases, the success of MSMEs in managing their business will also increase.

iii. Marketing variable (X_2) = 0.351, which means that, based on this study, if the other variables remain constant and marketing increases by 1 rupiah, MSME success will increase by 0.351. The positive coefficient value indicates that there is a positive relationship between the marketing variable (X_2) and MSME success (Y). This means that if marketing improves, the success of MSMEs in managing their business will also increase.

iv. Location variable (X_3) = 0.096, which means that, based on this study, if the other variables remain constant and location increases by 1 rupiah, MSME success will increase by 0.096. The positive coefficient value indicates that there is a positive relationship between the location variable (X_3) and MSME success (Y). This means that if the location variable improves, MSME success in managing the business will also increase, although this effect is not significant.

4. Discussion

4.1 The Influence of Business Capital on MSME Success

Based on the test results, it was found that the business capital variable has a positive and significant partial effect on MSME success. This is evidenced by the fact that the t-count value for the business capital variable was 6.074, which is greater than the t-table value of 2.3808, and the significance value was 0.000, which is less than the alpha level of 0.05. Therefore, it can be concluded that H1 is accepted. This finding indicates that business capital is a factor influencing the success of MSMEs, because without adequate capital, a business will not be able to operate as expected.

The results of this study are in line with the research conducted by Aidina & Rudini (2021) entitled The Influence of Business Capital and Business Location on the Success of Micro, Small, and Medium Enterprises (MSMEs) in the Food Sector in Sampit. Based on the partial test (t-test), it was concluded that business capital has an influence on the success of MSMEs. Similarly, the simultaneous test (F-test) also indicated that business capital affects MSME success.

However, these findings differ from the study by Sali & Rahmadhan (2024), which found that business capital did not have a significant effect on the success of MSMEs in managing their enterprises in Banguntapan and Bantul Districts. This was due to the high level of competition among traders, which resulted in competitive pricing and a wider range of choices for consumers.

4.2 The Influence of Marketing on MSME Success

Based on the test results, it was found that the marketing variable has a positive and significant partial effect on MSME success. This is evidenced by the fact that the t-count value for the marketing variable was 3.987, which is greater than the t-table value of 2.3808, and the significance value was 0.000, which is less than the alpha level of 0.05. Therefore, it can be concluded that H2 is accepted. This finding indicates that marketing is also a factor influencing

MSME success, as through marketing activities, MSMEs can reach consumers and fulfill their needs effectively.

The results of this study are in line with the research conducted by Tirtayasa et al. (2021) entitled "Marketing Strategies to Improve MSME Performance Moderated by Technology During the Covid-19 Pandemic". The study stated that, partially, marketing has an effect on MSME performance moderated by technology during the Covid-19 pandemic, and simultaneously confirmed that marketing affects MSME performance within the context of technological modernization during the pandemic.

However, these findings differ from the study by Millati & Sofwan (2022), which found that marketing did not have a significant effect on MSME success in Jepara District. This was because MSME actors were not responsive to marketing strategies aimed at improving business success.

4.3 The Influence of Location on MSME Success

Based on the test results, it was found that the location variable has a positive but not significant partial effect on MSME success. This is evidenced by the fact that the t-count value for the location variable was 1.469, which is less than the t-table value of 2.3808, and the significance value was 0.146, which is greater than the alpha level of 0.05. Therefore, it can be concluded that H3 is rejected. The results indicate that location has a positive but insignificant influence on MSME success, meaning that the impact of location is not strong enough to be considered a decisive factor in the success of MSMEs.

Therefore, MSME actors need to pay attention to appropriate site selection because it affects the progress and success of their businesses. The findings of this study are consistent with research conducted by Sudiantini et al. (2023) entitled The Influence of Business Location Selection on MSME Business Success*, which stated that* location has a significant influence on MSME business success. However, these results are not in line with the study by Sali & Rahmadhan (2024), which found that business location did not influence MSME success in managing their enterprises in Banguntapan and Bantul Districts, as customers were more interested in low prices, making location a less determining factor in business success.

5. Conclusion

Based on the results of this research on MSMEs in Medan Amplas District, several conclusions can be drawn. The capital variable has a positive and significant effect on MSME success, and the marketing variable also has a positive and significant effect on MSME success. In contrast, the location variable has a negative and insignificant effect on MSME success. However, when the variables of capital, marketing, and location were tested simultaneously, they showed a positive and significant effect on MSME success.

Based on these conclusions, the researcher proposes several recommendations that can serve as input and considerations for MSMEs:

i. MSME actors are encouraged to be willing to allocate sufficient capital in running their businesses, as the larger the invested capital, the greater the potential market reach.

ii. MSME actors should further enhance the attractiveness of their business locations by evaluating and selecting strategic and comfortable sites to attract more customers.

iii. MSME actors should be prudent in developing business strategies, as this is the key to sustaining and growing MSMEs amid intense market competition.

iv. Supporting institutions, such as financial institutions, cooperatives, and MSME assistance organizations, are advised to actively provide education on capital management, planning effective marketing strategies, and selecting business locations aligned with product characteristics and target consumers.

v. Local governments are expected to offer more concrete support in the form of training on capital management, assistance in digital marketing, and information services related to identifying strategic locations with potential for MSME development.

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BEHAVIORAL INTENTION TO USE AUGMENTED REALITY (AR) IN EDUCATION AMONG COMMUNITY COLLEGE LECTURERS: A TAM-BASED STUDY WITH ATTITUDE AS A MEDIATOR

Noor Idda binti Idris[1]*, Nur Hidayah binti Jaaffar[2], Nurul Imamah binti Tajri[2]

[1]Unit Pengoperasian Perniagaan, Kolej Komuniti Bagan Serai, Perak, Malaysia

[2]Unit Pengajian Am, Kolej Komuniti Bagan Serai, Perak, Malaysia

*Corresponding author e-mail address: nooridda@kkbaganserai.edu.my

Abstract

Augmented reality (AR) technology is increasingly seen as an innovative tool in education that can enrich the teaching and learning process. However, the acceptance of AR technology among Kolej Komuniti lecturers in Malaysia is still low, making this study is important to understand the factors that influence this acceptance. This study uses the Technology Acceptance Model (TAM) to study the behavioral intentions of lecturers to use AR, emphasizing the role of attitude as a mediating variable. The focus of the study is to assess the effects of perceived usefulness, ease of use, and awareness on lecturers' attitudes and intentions in applying AR in teaching. A quantitative approach through a questionnaire was used, with the involvement of 85 lecturers as respondents, and the data were analyzed using the 'Partial Least Squares Structural Equation Modeling (PLS-SEM)' method. The results of the analysis showed that awareness, perceived usefulness, and attitude significantly influence behavioral intention, with awareness showing the strongest effect. The findings of this study suggest that increasing awareness, perceived usefulness and attitude are important to promote AR technology, while perceived ease of use is not a significant factor in this model. Overall, this study provides an important contribution to the literature on technology adoption in education as well as practical recommendations for management and policymakers in facilitating the integration of AR technology into teaching practices.

Keywords: Technology Acceptance Model; Behavioral Intention; Attitude.

1. Introduction

Augmented Reality (AR) has garnered increasing attention in global education due to its ability to create immersive and interactive learning environments by integrating digital elements into the physical world. As highlighted by Alalwan et al. (2020), AR facilitates learners' understanding of complex concepts, enhances motivation, and supports real-time, visual engagement with instructional content. With the ongoing integration of technology into educational settings, AR is emerging as a valuable tool to enrich teaching and learning across diverse subject areas (Pranahadi et al., 2022).

In the context of Technical and Vocational Education and Training (TVET), AR offers specific advantages in delivering practical, hands-on learning experiences. For instance, Kohn and Heidig (2019) demonstrated that AR supports students in developing procedural knowledge by simulating real-world environments and machinery interactions. This aligns with the pedagogical objectives of TVET, which prioritize experiential learning and the development of job-relevant competencies.

Despite these benefits, the adoption of AR among Kolej Komuniti lecturers, particularly in the state of Perak, remains limited. Barriers to adoption may include limited exposure to AR technologies, inadequate professional development opportunities, and uncertainties regarding the effectiveness of AR in educational contexts (Rahman et al., 2020). Lecturers' behavioral intentions to adopt AR are likely shaped by their perceptions of the technology's usefulness, ease of use, and their overall attitudes toward integrating digital tools in teaching.

This study aims to examine the behavioral intention of Kolej Komuniti lecturers in Perak to use AR in education. Grounded in the Technology Acceptance Model (TAM), the study investigates how perceived usefulness and perceived ease of use influence the intention to use AR, with attitude functioning as a mediating variable. The findings are expected to contribute valuable insights into lecturers' readiness to adopt AR and support policy development for professional training and digital innovation in TVET.

2. Literature Review

2.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model (TAM), originally proposed by Davis (1989), is a widely applied framework for understanding individuals' acceptance and use of new technologies. In educational settings, TAM is particularly useful in examining how educators' perceptions of a technology's usefulness and ease of use influence their willingness to adopt it. Recent extensions of TAM have incorporated additional constructs such as attitude, which functions as a mediating variable that significantly influences behavioral intention (Teo, 2021; Al-Qaysi et al., 2020). The inclusion of attitude enhances the model's explanatory power, especially in contexts involving innovative technologies. TAM thus remains a robust theoretical foundation for investigating the adoption of emerging tools like Augmented Reality (AR) in teaching and learning environments.

2.2 Awareness of Augmented Reality (AR)

Awareness of Augmented Reality (AR) plays a crucial role in shaping educators' intentions to adopt and integrate the technology into their teaching practices. When educators are informed about the existence, functionality, and pedagogical potential of AR, they are more likely to explore its applications in the classroom. Awareness serves as a foundational stage in the technology adoption process, influencing attitudes and perceived relevance. Alaulamie and Alshwiah (2021) found that higher levels of AR awareness among pre-service teachers significantly enhanced their willingness to experiment with and eventually adopt AR tools in education. Thus, increased awareness not only fosters interest but also helps position AR as a credible and practical instructional resource, potentially leading to greater behavioral intention to use the technology in the future. Therefore, hypothesis 1 is as follows: -

H1: Awareness of AR in Education is Positively Related to Lecturers' Behavioral Intention to Use AR

2.3 Perceived usefulness of Augmented Reality (AR)

Perceived usefulness is defined as the degree to which an individual believes that using a particular technology can enhance job performance. In the context of higher education, lecturers are more likely to adopt augmented reality (AR) when they perceive it as effective in improving teaching delivery and student learning. According to Ahmad et al. (2021), Malaysian university

lecturers indicated a positive inclination to use AR when they believed it would support interactive teaching and increase student motivation. This finding supports the central premise of the Technology Acceptance Model (TAM), which emphasizes that perceived usefulness significantly affects the intention to adopt technology in educational settings (Davis, 1989). Therefore, hypothesis 2 is as follows: -

H2: Perceived Usefulness of AR is Positively Related to Lecturers' Behavioral Intention to Use AR

2.4 Perceived ease of use of Augmented Reality (AR)

Perceived ease of use is a key element in determining the acceptance of new technologies. When lecturers perceive augmented reality (AR) as user-friendly and straightforward to operate, they are more likely to integrate it into their teaching practices. In the context of Malaysian higher education, Yusoff et al. (2020) reported that educators were more receptive to adopting AR tools when they found the applications intuitive and easy to navigate. This aspect of usability plays a vital role in building user confidence and reducing hesitation towards technology adoption, particularly in academic settings. Therefore, hypothesis 3 is as follows:

H3: Perceived Ease of Use of AR is Positively Related to Lecturers' Behavioral Intention to Use AR

2.5 Educators' Attitudes on the Adoption of Augmented Reality (AR)

Attitude refers to an individual's overall evaluation of a technology, reflecting their favourable or unfavourable perception of its use. In the case of augmented reality (AR), a positive attitude often leads to a stronger intention to adopt the technology in teaching. Educators who view AR positively are more open to exploring its potential in the classroom, which can reduce uncertainty and promote experimentation. As highlighted by Rosli et al. (2021) found that positive attitudes among educators significantly influenced their willingness to integrate AR into their instructional practices, demonstrating the importance of attitude as a key predictor of adoption behaviour. Therefore, hypothesis 4 is as follows: -

H4: Attitude Towards Using AR is Positively Related to Lecturers' Behavioral Intention to Use AR

2.6 Attitude as a Mediator between Awareness and Behavioral Intention

While awareness may initially stimulate interest in a particular technology, it is often the development of a positive attitude that determines one's behavioural intention to adopt it. Awareness can lead individuals to cognitively and emotionally evaluate the usefulness and relevance of a technology, thereby influencing their overall perspective. According to Alias and Ahmad (2020), educators' attitudes toward augmented reality (AR) play a significant role in shaping their intention to use it in teaching and learning. This indicates that awareness alone is not enough; it must be accompanied by a favourable attitude to effectively translate into future usage behaviour. Therefore, hypothesis 5 is as follows: -

H5: Attitude towards Using AR Mediates the Relationship between Awareness of AR and Behavioral Intention to Use AR

2.7 Attitude as a Mediator between Perceived ease of use and Behavioral Intention

Perceived ease of use can indirectly influence an individual's intention to use a technology by shaping their attitude. When lecturers perceive augmented reality (AR) as simple and uncomplicated, they are more likely to develop a positive attitude towards it, which in turn increases the likelihood of adoption. According to Hussin et al. (2021), ease of use significantly affects users' attitudes, which serve as a critical pathway in forming behavioural intentions. This highlights the importance of intuitive and accessible design in promoting the acceptance of educational technologies such as AR. Therefore, hypothesis 6 is as follows: -

H6: Attitude towards Using AR Mediates the Relationship between Perceived Ease of Use of AR and Behavioral Intention to Use AR

3. Methodology

This study applied a quantitative approach to explore the factors influencing Kolej Komuniti lecturers' intention to use Augmented Reality (AR) in education, based on the Technology Acceptance Model (TAM) framework with attitude as a mediating variable. The research focused on lecturers from Kolej Komuniti in Perak, Malaysia. A self-administered questionnaire distributed via Google Form was used to collect the data that measured five main constructs: awareness of AR, perceived usefulness, perceived ease of use, attitude toward using AR, and behavioral intention to use AR. Respondents were selected through purposive sampling. The collected data was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to evaluate both the measurement and structural models. This analysis allowed for the identification of key relationships among variables and assessed whether lecturers' attitudes significantly mediate the connection between their awareness of AR and their intention to implement it in educational settings.

4. Findings

This section presents the data analysis procedures and research findings. Initially, the collected data were screened and cleaned using SPSS Version 29, which also facilitated the normality testing and descriptive analysis. Subsequently, the data was analyzed using Partial Least Squares (PLS) software to examine the measurement model and the structural model.

4.1 Common Method Variance (CMV)

From this study, the collected data were tested for CMV to estimate the risk of bias occurring in one variable to another variable because the data came from the same source or method (Shehnaz Tehseen et al., 2017). Therefore, to test for the presence of CMV for this study, Harman Single Factor analysis was adopted. Typically, this analysis would be performed after data collection was conducted. From this study, the CMV value was 37.7% which is less than the 40.0% level (Podsakoff et al., 2003; Shehnaz Tehseen et al., 2017). Therefore, the findings of this analysis clarify that CMV is not an issue in this study.

4.2 Respondents' Profile and Characteristics

Based on the descriptive analysis from Table 1, the majority of respondents were female (64.7%), while males accounted for 35.3%. In terms of age distribution, most respondents were between 45 and 54 years old (36.5%), followed by those aged 35 to 44 years (33.8%), and a smaller

proportion were aged 25 to 34 (15.3%), below 25 (2.4%), and 55 and above (3.5%). With regard to teaching experience, a significant number had more than 10 years of experience (72.9%), whereas 15.3% had 1 to 5 years, 9.4% had 6 to 10 years, and only 2.4% had less than 1 year of experience. Concerning academic qualifications, 38.8% held a Master's degree, 31.8% had a Bachelor's degree, 25.9% possessed a Diploma, and 3.5% had a Doctorate. Notably, only 35.3% of respondents reported having used Augmented Reality (AR) in their teaching, while the remaining 64.7% had not. However, 61.2% had attended a training session or workshop on AR, indicating a positive level of exposure to AR-related professional development despite limited practical application in teaching.

Table 1. Descriptive Analysis

Demographic Information	Frequency	Percentage
Gender		
Male	30	35.3
Female	55	64.7
Age		
Below 25	2	2.4
25-34	13	15.3
35-44	36	42.4
45-54	31	36.5
55 and above	3	3.5
Teaching Experiences (Years)		
Less than 1 year	2	2.4
1-5 years	13	15.3
6 -10 years	8	9.4
More thank 10 years	62	72.9
Academic Qualification		
Diploma	22	25.9
Bachelor's Degree	27	31.8
Master's Degree	33	38.8
Doctorate	3	3.5
Have you ever used Augmented Reality (AR) in your teaching?		
Yes	30	35.3
No	55	64.7
Have you attended any training/workshop on AR?		
Yes	52	61.2
No	33	38.8

4.3 Measurement Model Assessment

The measurement model assessment shows that all the constructs meet the required standards for reliability and validity. First, internal consistency reliability is confirmed as all values for Cronbach's Alpha and Composite Reliability (CR) are above 0.70. This means the items used to

measure each construct are consistent with one another (Hair et al., 2021). Second, convergent validity is supported because all Average Variance Extracted (AVE) values are above 0.50. The AVE values range from 0.866 for Behavioral Intention to 0.94 for Perceived Usefulness, showing that each construct explains a good amount of the variance in its items (Fornell & Larcker, 1981). Third, all item loadings are above 0.90, which indicates strong indicator reliability. This means each item is a good representation of the construct it measures (Hair et al., 2021). Overall, the constructs of Awareness, Perceived Usefulness, Perceived Ease of Use, Attitude, and Behavioral Intention are reliable and valid, and suitable for further analysis in the structural model.

Table 2. Goodness-of-Fit Measurement Model (n=85)

Latent Variable	Items	Loadings	Cronbach's Alpha	Composite Reliability	Average Variance
Awareness	AW1	0.973	0.985	0.985	0.929
	AW2	0.935			
	AW3	0.975			
	AW4	0.976			
	AW5	0.953			
	AW6	0.970			
Perceived Usefulness	PU1	0.941	0.987	0.988	0.94
	PU2	0.938			
	PU3	0.949			
	PU4	0.940			
	PU5	0.956			
	PU6	0.933			
Perceived Ease of Use	PEU1	0.941	0.978	0.98	0.903
	PEU2	0.947			
	PEU3	0.903			
	PEU4	0.965			
	PEU5	0.927			
	PEU6	0.900			
Attitude	ATT1	0.954	0.975	0.976	0.889
	ATT2	0.951			
	ATT3	0.925			
	ATT4	0.954			
	ATT5	0.954			
	ATT6	0.963			
Behavioral Intention	BI1	0.980	0.969	0.97	0.866
	BI2	0.968			
	BI3	0.966			
	BI4	0.978			
	BI5	0.978			
	BI6	0.946			

The next step subsequently evaluate the discriminant validity. The result shows that all HTMT values in the analysis were below the recommended threshold of 0.90 as recommended by Henseler, Ringle, and Sarstedt (2015), indicating that the constructs for Attitude, Awareness, Behavioral Intention, Perceived Usefulness, and Perceived Ease of Use are distinct from one another. The highest HTMT value was 0.861 (between Awareness and Perceived Usefulness),

while the lowest was 0.592 (between Behavioral Intention and Perceived Ease of Use). These results confirm that each construct in the model measures a unique concept, thus supporting the adequacy of discriminant validity in this study.

Table 3. Heterotrait-Monotrait (HTMT) Ratio

	Attitude	Awareness	Behavioral Intention	Perceived Usefulness	Perceived Ease of Use
Attitude					
Awareness	0.8				
Behavioral Intention	0.788	0.683			
Perceived Usefulness	0.821	0.861	0.638		
Perceived Ease of Use	0.695	0.735	0.592	0.811	

4.4 Structural Model Assessment

Table 4 presents the Variance Inflation Factor (VIF) values for each construct, including Attitude, Awareness, Behavioral Intention, Perceived Usefulness, and Perceived Ease of Use, used to assess multicollinearity in the model. All VIF values are below the threshold of 5, ranging from 1.000 (Behavioral Intention) to 4.833 (Perceived Usefulness), indicating that multicollinearity is not a significant concern. This suggests that the predictor variables are not highly correlated with one another and that the regression estimates are stable and reliable. According to Hair et al. (2020) VIF values below 5 are acceptable and indicate that multicollinearity is within a tolerable range, supporting the validity of the model's structural relationships.

Table 4. Variance Indicator Factor (VIF)

	Attitude	Awareness	Behavioral Intention	Perceived Usefulness	Perceived of Use
Attitude			1		
Awareness	3.655				
Behavioral Intention					
Perceived Usefulness	4.833				
Perceived of Use	2.825				

The hypothesis testing results from Table 5 indicate that several relationships in the model are statistically significant. Specifically, Awareness has a strong and significant influence on Behavioral Intention (β = 0.768, t = 16.651), while Perceived Usefulness also significantly affects Behavioral Intention (β = 0.266, t = 2.111). Attitude significantly predicts Behavioral Intention (β = 0.362, t = 2.929), and the mediation effect of Attitude between Awareness and Behavioral Intention is also significant (β = 0.266, t = 2.111). However, both the direct effect of Perceived Ease of Use on Behavioral Intention (β = 0.042, t = 0.423) and its indirect effect through Attitude (β = 0.042, t = 0.423) are not significant. These results suggest that Awareness, Perceived Usefulness, and Attitude are key predictors of Behavioral Intention, while Perceived Ease of Use does not play a significant role in this model (Hair et al., 2020).

Table 5. Hypothesis testing results

Hypothesis	Relationship	Std. Beta	Std. Error	t-value	Decision
H1	AW -> BI	0.768	0.046	16.651	Significant
H2	PU -> BI	0.266	0.126	2.111	Significant
H3	PEU -> BI	0.042	0.099	0.423	Insignificant
H4	ATT -> BI	0.362	0.124	2.929	Significant
H5	AW -> ATT -> BI	0.266	0.126	2.111	Significant
H6	PEU -> ATT -> BI	0.042	0.099	0.423	Insignificant

5. Discussion and Conclusion

Hypothesis 1 (H1): This study found that awareness has a strong and significant effect on behavioral intention to use AR among Kolej Komuniti lecturers. This means that when lecturers are more aware of AR and its benefits, they are more likely to use it. This result is supported by Rese et al. (2020), who found that higher awareness of new technologies leads to greater interest and willingness to adopt them. Similarly, Dube and Hlalele (2021) emphasized that early exposure to educational technologies encourages positive responses from educators.

Hypothesis 2 (H2): The findings show that perceived usefulness significantly influences lecturers' intention to use AR. This indicates that if lecturers believe that AR can improve their teaching and student learning, they are more likely to adopt it. This result aligns with Moslehpour et al. (2022), who found that perceived usefulness is a strong predictor of intention to use technology. In the educational context, Purwanto et al. (2020) also found that university lecturers' belief in the usefulness of online tools increases their willingness to use them in teaching.

Hypothesis 3 (H3): This hypothesis was not supported, meaning that perceived ease of use does not directly affect the intention to use AR. This may be because lecturers are more concerned with the usefulness and impact of AR rather than how easy it is to use. Fatima et al. (2020) reported a similar finding, showing that users sometimes accept challenging technology if they believe it will be beneficial. In this case, ease of use may not be a priority for lecturers who are already skilled or willing to learn new systems.

Hypothesis 4 (H4): Attitude towards AR has a significant positive effect on behavioral intention. Lecturers with a more positive attitude towards AR are more likely to use it in the classroom. This supports the findings of Abed (2021), who highlighted that user attitude plays a key role in predicting technology usage. A good attitude can increase motivation and openness to adopt new teaching tools like AR.

Hypothesis 5 (H5): The results show that attitude mediates the relationship between awareness and behavioral intention. This means that awareness leads to a more positive attitude, which in turn increases the likelihood of using AR. Wu and Chen (2021) found that when users are more informed about a technology, they tend to develop a better attitude toward it, which then affects their usage intention. Therefore, raising awareness can improve both attitude and behavioral intention.

Hypothesis 6 (H6): This hypothesis was not supported, suggesting that perceived ease of use does not influence attitude or behavioral intention through attitude. Chao (2019) also found that in some educational settings, ease of use is not a major concern, especially when users are more

focused on learning outcomes. In this case, Kolej Komuniti lecturers may prioritize the benefits of AR rather than how simple it is to use.

5.1 Limitations of the Study

This study has several limitations that should be considered. Firstly, the sample was limited only to lecturers from Kolej Komuniti, which may not reflect the views of all lecturers under the PolyCC (Politeknik dan Kolej Komuniti) system in Malaysia. As such, the findings may not be fully generalizable to polytechnic lecturers or other higher education institutions. Secondly, the cross-sectional design only captures data at one point in time, limiting the ability to observe changes in attitudes or behavioral intentions over time. The use of self-reported questionnaires also poses the risk of bias, such as overestimation or underestimation of actual AR usage behavior. Lastly, although the Technology Acceptance Model (TAM) offers a solid framework, other influencing factors such as infrastructure, training, and institutional support were not explored in depth.

5.2 Impact of the Research

Despite these limitations, this study makes a significant contribution to the field of educational technology by offering new insights into how augmented reality (AR) is perceived and potentially adopted among technical and vocational educators in Malaysia. The findings help policymakers and curriculum planners understand the key factors, such as awareness, perceived usefulness, and attitude, that influence lecturers' behavioral intention to adopt AR. Furthermore, the study supports the relevance of TAM in predicting technology adoption in educational contexts and introduces practical recommendations to enhance professional development programs and digital readiness among lecturers. Finally, future research may consider adopting longitudinal designs and conducting cross-institutional comparisons to enhance the generalizability of the findings beyond the Kolej Komuniti setting.

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ASSISTANCE IN OFFLINE AND ONLINE MARKETING STRATEGIES FOR KJ RATNA ACEH EMBROIDERY MSME TO ENHANCE THE COMPETITIVENESS OF LOCAL PRODUCTS

Esti Alemia Puspita, Erni Wiriani*, Jamali, Abdul Aziz, Tamara

Akadami Keuangan Perbankan Nusantara, Peureulak, Aceh Timur, Aceh, Indonesia

*Corresponding author e-mail address: erniwiriani71@gmail.com

Abstract

Enhancing the competitiveness of local products requires the implementation of appropriate marketing strategies, both offline and online. KJ Ratna Aceh Embroidery MSME, a local business located in Gampong Seunebok Pidie, Peureulak Subdistrict, East Aceh Regency, faces challenges in developing effective marketing approaches. This community service program aimed to assist in designing and applying offline and online marketing strategies to improve the visibility and competitiveness of its traditional Acehnese embroidery products. The methods employed included direct observation, interviews with the business owner, formulation of marketing strategy concepts, and technical assistance in utilizing marketing media. The results of the program indicated a significant improvement in the partner's knowledge and skills in using various marketing tools, such as business cards, product catalogs, and social media platforms (WhatsApp, Facebook, and Instagram). The response from the business owner was highly positive, demonstrated by their enthusiasm and active participation throughout the mentoring sessions. As a follow-up, the team disseminated the training materials and information to the surrounding community through an information post activity held at the village hall. This initiative is expected to serve as a model for empowering local MSMEs through integrated marketing strategies.
Keywords: MSME; Marketing Strategy; Offline; Online; Aceh Embroidery.

1. Introduction

In the digital era, the ability of local products to compete in broader markets is increasingly determined by how effectively businesses implement integrated marketing strategies. Micro, Small, and Medium Enterprises (MSMEs) play a critical role in promoting regional economic development and preserving cultural heritage. However, many local MSMEs still struggle to reach wider audiences due to limitations in their marketing capabilities, both in offline and digital contexts.

Recent studies emphasize that the adoption of hybrid marketing approaches combining conventional and digital tools can significantly improve market access, customer engagement, and brand recognition for small businesses (Kotler et al., 2021). The increasing use of social media platforms, online catalogs, and personalized digital content has proven to enhance the visibility of local products and foster more dynamic interactions with consumers (Chaffey & Ellis-Chadwick, 2019). Nevertheless, many rural entrepreneurs lack the digital literacy and strategic insight required to implement such tools effectively (Zaki, 2024).

One of the local enterprises facing such challenges is KJ Ratna Aceh Embroidery, located in Gampong Seunebok Pidie, Peureulak Subdistrict, East Aceh Regency. Despite offering traditional

embroidery products with strong cultural and aesthetic value, the business has not fully leveraged modern marketing strategies to expand its customer base or elevate its brand presence.

This community service initiative was therefore designed to provide tailored mentoring in the design and implementation of offline and online marketing strategies suited to the business's specific needs. Beyond addressing practical issues, this program aimed to enhance the owner's marketing skills and contribute to the broader empowerment of rural MSMEs. As suggested by Park (1995), community-based empowerment initiatives can be most impactful when they emphasize both skill development and sustainability. This program not only filled a practical knowledge gap but also provided a replicable model for other local businesses seeking to grow through integrated, low-cost marketing efforts.

2. Methodology

This study employed a qualitative descriptive approach to explore the process of designing and implementing integrated marketing strategies for KJ Ratna Aceh Embroidery MSME, located in Gampong Seunebok Pidie, Peureulak Subdistrict, East Aceh Regency. A qualitative approach was chosen because it enables an in-depth understanding of the real conditions, challenges, and capacities of the target MSME in the context of marketing development (Creswell & Poth, 2018).

Data collection was carried out using multiple methods, including direct observation**,** semi-structured interviews**,** and document analysis**.** Observation was conducted to examine the existing marketing practices, packaging, and promotion tools used by the business. Interviews were held with the owner to identify specific problems, expectations, and opportunities for development. Documentation involved collecting materials such as promotional designs, training records, and photos from the field activities.

The implementation process followed several key stages: (1) Needs assessment through preliminary visits and discussions with the business owner. (2) Formulation of marketing strategies, integrating both offline (e.g., business cards, printed catalogs) and online approaches (e.g., social media platforms such as WhatsApp, Facebook, and Instagram). (3) Technical mentoring**,** which included training on digital content creation, social media management, and basic brand development.(4) Evaluation**,** conducted through post-activity interviews and observation to assess the changes in the partner's marketing practices and the perceived benefits of the training.

The data were analyzed through the process of data reduction, data display, and conclusion drawing**,** as outlined (Miles, Huberman, and Saldaña, 2014). To ensure data validity, the source of triangulation was applied by cross-checking interview results with observations and documentation. In addition, active participation and feedback from the MSME owner served as an important component in validating the relevance and impact of the intervention.

3. Results

The implementation of the community service program at the KJ Ratna Aceh Embroidery MSME generated several key findings that reflect significant improvements in the partner's marketing capacity. These findings are presented according to the sequence of activities conducted:

a. Initial Needs Assessment of the Partner
   The initial stage involved field observation and in-depth interviews with the business owner. The assessment revealed that the partner lacked adequate promotional tools to reach a broader customer base. Marketing activities primarily relied on word-of-mouth and repeat

customers within the Peureulak area. There were no formal promotional materials such as business cards, product catalogs, or active social media accounts. This highlighted a substantial gap in the use of information and communication technology for marketing purposes.

b. Development and Distribution of Printed Promotional Materials (Offline)
In response to the identified needs, the team designed and produced printed promotional materials, including business cards and a simple product catalog. These materials contained the business identity, embroidery product types, specifications, pricing, and accessible contact information. The designs incorporated elements of local cultural aesthetics. Once completed, the materials were distributed to the partner to be used in direct promotional efforts, both in-store and during local exhibitions.

c. Capacity Building through Social Media Training (Online Marketing)
A major focus of the program was to equip the partner with practical skills in digital marketing. Interactive training sessions covered the creation and use of WhatsApp Business accounts, Facebook pages, and Instagram profiles. The participant has been guided through visual content creation, writing persuasive product descriptions, and basic techniques for responding to customer inquiries professionally. Documentation shows that the partner was able to manage these accounts independently after the training sessions.

d. Evaluation of Outcomes and Partner Feedback
Follow-up interviews were conducted one and two weeks after the program to evaluate its impact. The partner reported that the availability of promotional tools had improved communication with new customers. Within two weeks post-training, there was a noticeable increase in customer inquiries via WhatsApp and Instagram. The business owner expressed a strong willingness to continue producing promotional content, indicating a positive shift in entrepreneurial mindset and behavior.

e. Knowledge Dissemination to the Surrounding Community
To broaden the impact of the program, an open dissemination session was held at the village hall through a community information post. The aim was to share the successful practices implemented by the partner. The event was attended by six other local MSME actors who showed interest in applying similar marketing strategies. This demonstrated that the intervention not only benefited the primary partner but also had the potential to serve as a replicable model for community-based MSME empowerment.

f. Documentation and Final Outputs
Throughout the program, all mentoring and training processes were documented through photos, videos, and daily field reports. Additionally, a simple training module was developed to serve as a long-term learning tool for the partner and the local community. The module included practical guidelines on promotional content creation, social media management tips, and customer engagement strategies in the digital marketplace.



Fig. 1 Execution of Activities

The digital marketing training component, which included the use of WhatsApp Business, Facebook, and Instagram, aligns with current findings on the role of social media in supporting small business growth (Kaplan & Haenlein, 2010; Chatterjee & Kar, 2020). Social media platforms provide microbusinesses with cost-effective access to broader markets, while also allowing for more personalized communication with customers (Taneja & Toombs, 2014; Arora & Rahman, 2018). The participant's post-training ability to operate these tools independently supports the argument that practical, hands-on learning is more effective than theoretical approaches, particularly for adult learners in informal sectors (Knowles et al., 2015).

Moreover, the increase in customer inquiries after implementing online tools reinforces the effectiveness of integrated marketing approaches that blend traditional and digital strategies (Kotler et al., 2021). While many studies emphasize digital transformation as the key to MSME development, the reality is that a hybrid model may be more realistic and sustainable for rural entrepreneurs (Chaffey & Ellis-Chadwick, 2019; Kusnandar & Kurniawati, 2022). The replication of knowledge through the community information post also illustrates the importance of local knowledge-sharing mechanisms in ensuring long-term impact. Community-based dissemination efforts have been shown to increase the reach and sustainability of interventions, especially when supported by participatory engagement (Pretty, 1995; Chambers, 2008). The involvement of other MSME actors in the dissemination event suggests that the program has the potential to create a ripple effect of empowerment within the village and neighboring communities.

However, the study is not without limitations. The intervention period was relatively short, and no formal quantitative measurement was conducted to assess sales growth or financial impact. Future programs should consider implementing a longer monitoring and evaluation phase, potentially using mixed methods to capture both economic outcomes and changes in entrepreneurial behavior (Creswell & Plano Clark, 2018). In conclusion, this program reinforces the argument that marketing empowerment—through both offline and online approaches—can be a strategic lever in strengthening rural MSMEs. The findings align with broader literature emphasizing the need for context-specific, participatory, and low-cost interventions in local economic development (World Bank, 2020; UNCTAD, 2022).

The results of this community service program indicate that strategic marketing interventions, when tailored to the specific needs of rural MSMEs, can significantly enhance business visibility, customer engagement, and overall market competitiveness. The initial lack of promotional tools and digital presence among MSMEs such as KJ Ratna Aceh Embroidery reflects a broader issue commonly reported among microenterprises in developing regions. These businesses often face structural barriers such as low digital literacy, limited access to training, and a lack of strategic planning (Tambunan, 2009; OECD, 2017). The introduction of printed promotional materials such as business cards and product catalogs proved beneficial as a low-cost, high-impact method of enhancing offline marketing capacity. Research supports the idea that even basic marketing tools can significantly influence purchasing decisions in local markets (Kotler & Keller, 2016; Armstrong et al., 2019). Offline tools remain especially relevant in traditional societies where digital penetration is uneven (Marques & Ferreira, 2020).

The digital marketing training component, which included the use of WhatsApp Business, Facebook, and Instagram, aligns with findings on the role of social media in supporting microenterprise growth. These platforms provide cost-effective access to larger markets while enabling direct engagement with consumers (Kaplan & Haenlein, 2010; Chatterjee & Kar, 2020). The ability of participants to operate these tools independently after training highlights the value of practical, experiential learning, especially for adult learners in informal economies (Knowles et al., 2015). The increased number of customer inquiries following the implementation of online tools further validates the effectiveness of combining traditional and digital marketing strategies. A hybrid approach is considered more sustainable and adaptable for rural business contexts (Chaffey & Ellis-Chadwick, 2019).

Additionally, the knowledge-sharing activity through a community information post illustrates the importance of participatory dissemination. Such efforts can enhance long-term impact and scalability by involving other MSME stakeholders in the learning process (Pretty, 1995). Despite its strengths, this program had limitations. The short intervention period did not allow for formal measurement of financial outcomes, and future programs would benefit from a longer monitoring phase. Employing mixed-methods evaluation could provide deeper insights into both behavioral and economic changes (Creswell & Plano Clark, 2018). In conclusion, this initiative reinforces the growing evidence that integrated marketing empowerment—offline and online—can be a strategic tool for rural MSME development. It demonstrates the importance of context-sensitive, inclusive, and cost-efficient interventions to strengthen local economic resilience (World Bank, 2020).

4. Conclusion

This community service program, focused on enhancing the marketing capacity of the KJ Ratna Aceh Embroidery MSME, has yielded significant insights into the empowerment of rural microenterprises. Tailored interventions—such as the provision of printed promotional materials and training in digital marketing—proved effective in expanding market reach and increasing

consumer engagement with local products that were previously marketed through conventional, informal means. The improvement in the partner's ability to utilize social media platforms (WhatsApp Business, Facebook, and Instagram), coupled with a measurable increase in customer interactions, demonstrates that technology-based approaches can be adopted successfully by MSMEs, even in contexts of limited digital literacy. This success not only enhanced the individual capacity of the business owner but also created opportunities for broader community empowerment through knowledge dissemination and peer engagement. These findings support existing literature emphasizing that MSME empowerment requires an integrated approach that accounts for local socio-economic and technological conditions. A hybrid marketing mode blending offline and online strategies emerges as a sustainable alternative for enterprises operating in areas with limited digital infrastructure. Nevertheless, the short duration of the intervention and the absence of quantitative data on economic outcomes highlight the need for more comprehensive program designs in future initiatives. Long-term monitoring and data-driven evaluation will be essential to assess the broader impact of such interventions and to develop replicable models that can be adopted by other MSMEs in similar rural settings.

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THE POTENTIAL APPLICATION OF ARTIFICIAL INTELLIGENCE IN ERGONOMIC WORK SYSTEMS TO IMPROVE SAFETY AND HEALTH AT POLITEKNIK MERSING

Ruzaihan bin Jaffar[1]*, Luqman bin Md. Arif[1], Norsaadah binti Sapon[2]

[1]Department of Information Technology & Communication, Polytechnic of Mersing, 86800 Mersing, Johor, Malaysia

[2]Department of Electrical Engineering, Polytechnic of Mersing, 86800, Mersing, Johor, Malaysia

*Corresponding author e-mail address: ruzaihan@tvet.pmj.edu.my

Abstract

This study aims to identify the potential level of awareness regarding the use of artificial intelligence (AI) technology in ergonomic work systems, particularly in efforts to enhance occupational safety and health within the polytechnic environment. In line with the advancement of the Fourth Industrial Revolution (4.0), the application of AI is seen as a strategic alternative to support the improvement of workplace conditions and employee well-being. A quantitative approach was adopted in this study, with data collected through a structured questionnaire comprising three main sections: demographic information, awareness, and perception of AI. A total of 71 staff members from various departments at Politeknik Mersing Johor participated as the study sample. Descriptive statistics were used to assess the mean scores and standard deviations for awareness levels, while inferential analyses such as t-tests, ANOVA, and Pearson correlation were conducted to examine the differences or relationships between demographic variables and awareness levels. The findings indicate a high level of awareness regarding the use of AI, with a significant relationship found between work experience and awareness. These results are expected to provide an initial guideline for educational institution administrators in considering the systematic and safe implementation of AI technologies in ergonomic work systems.

Keywords: Industrial Revolution 4.0; Artificial Intelligence (AI); Ergonomics.

1. Introduction

An ergonomic work system is a crucial approach in designing workplace environments that promote the physical and mental well-being of employees, reduce the likelihood of injuries, and enhance overall productivity. This concept has gained wide acceptance across various sectors, especially in the education and training context, where the comfort and safety of staff and students are highly prioritised. With the rapid advancement of technology, particularly in the area of Artificial Intelligence (AI), there is substantial potential to further enhance existing ergonomic systems, particularly within institutions such as Politeknik Mersing Johor (PMJ).

Artificial Intelligence (AI) refers to the capability of machines to perform tasks that typically require human intelligence, such as natural language processing, machine learning, and automated decision-making. The application of AI in ergonomic systems has the potential to improve comfort and safety while reducing risks associated with excessive workload or improper posture during learning or work activities (Rajendran et al., 2021). In Malaysia, the education sector is increasingly focusing on integrating advanced technologies, but the application of AI in ergonomic systems remains relatively underexplored.

AI-integrated ergonomic systems could lead to the development of adaptive solutions that monitor user health status and offer real-time corrective suggestions, thereby promoting long-term well-being. Institutions like PMJ can benefit significantly from implementing such technologies to improve occupational safety and health for both staff and students. This study aims to examine the potential of applying AI-based ergonomic systems at PMJ, with a particular focus on improving safety and health within academic environments that involve both work and learning activities.

According to Jafari et al. (2023), the integration of AI in ergonomic design and workplace system management has shown significant improvements in reducing workplace injuries and enhancing operational efficiency. Therefore, this research seeks to evaluate how AI can be applied within ergonomic systems in a polytechnic setting to minimise injury risks and promote workplace safety and health. Additionally, the study aims to identify possible technical and cultural challenges in implementing AI in educational contexts and to propose strategic recommendations for future technology adoption.

Occupational safety and health (OSH) remain essential elements in all types of organisations, including educational institutions such as polytechnics. In line with the advancement of the Fourth Industrial Revolution (IR 4.0), the integration of A) is progressively being adopted across diverse sectors to optimise operational efficiency and minimise workplace hazards (Khosravi et al., 2022). In the realm of ergonomics, AI technologies are capable of detecting poor postures, evaluating physical workloads, and issuing early alerts on potential injury risks through intelligent monitoring systems (Jarrahi, 2021).

Polytechnic personnel, especially those involved in maintenance, technical services, and academic instruction, are often exposed to ergonomic stressors, including repetitive motion tasks, sustained static positions, and frequent use of high-risk equipment (Rahman & Lee, 2023). The application of AI in such contexts can facilitate the redesign of work systems that are more adaptive to human capabilities and limitations, in accordance with contemporary ergonomic standards (Zhou et al., 2020).

This study explores the potential for integrating AI into ergonomic work systems within Malaysian polytechnics, aiming to enhance the overall OSH outcomes for staff. The implementation of AI is expected to reduce the likelihood of work-related injuries and foster a safer, more sustainable work environment that prioritises employee well-being.

This study was conducted to achieve the following research objectives:

To determine the level of awareness regarding the use of Artificial Intelligence (AI) in ergonomic work systems among polytechnic staff.

ii. To identify the perceptions and attitudes of polytechnic staff towards the potential use of AI in enhancing occupational safety and health.
iii. To analyse the relationship between demographic factors (such as gender, department, job position, and work experience) and the level of awareness regarding the use of AI in ergonomic work systems.

1.1 Problem Statement

Ergonomic work systems in Malaysia play a vital role in accelerating national development and progress. The Occupational Safety and Health Act 1994 (OSHA 1994) was introduced in Malaysia

to ensure the safety and health of workers are safeguarded. Although the Act primarily focuses on occupational safety, it indirectly provides a platform for promoting the application of ergonomic principles in workplace design. This integration is essential in reducing the risk of injuries and discomfort, especially in labour-intensive and technical environments such as the education and manufacturing sectors.

According to Ismail and Ahmad (2022), ergonomic practices, when aligned with national safety legislation, can significantly improve employee well-being and workplace productivity. The incorporation of ergonomics within the legal framework demonstrates Malaysia's commitment to creating safer and more sustainable work environments.

An ergonomic work system, which refers to the design of the work environment, furniture, and technology tailored to the physical and mental needs of workers, has a direct impact on productivity, employee well-being, and workplace safety. In the context of polytechnics, ergonomic systems play a crucial role in ensuring the physical and mental well-being of both students and staff, especially with the increasing integration of technology into the teaching and learning (T&L) process.

The concept of ergonomics is also closely associated with physical interactions in the workplace. In both the short and long term, the implementation of ergonomic systems in the work environment specifically helps safeguard workers' safety. Moreover, ergonomics can contribute to cost savings by improving safety measures, which in turn reduces the need for compensation related to work-related injuries (Salleh & Abdullah, 2021). As such, promoting ergonomic practices is essential not only for health and safety compliance but also for improving institutional efficiency and sustainability.

In line with the rapid growth and advancement of technology—especially as it is driven by Artificial Intelligence (AI)—many industries are shifting towards automation and more efficient innovations. AI is not only transforming how work is performed but also influencing the design of the workplace, including ergonomic work systems.

With the integration of AI into the work environment, equipment and furniture can be dynamically adjusted to suit individual needs, thereby helping employees avoid injuries and enhance productivity. This personalised adaptability in ergonomic design aligns with Industry 4.0 practices, where smart systems continuously learn and respond to human behaviours in real time (Jafari et al., 2023; Toh et al., 2022). In educational institutions such as polytechnics, such advancements offer opportunities to improve the safety, comfort, and performance of both staff and students.

The significance of implementing this study is to:

i. For polytechnic management, the findings of this study can assist in formulating strategies for digital transformation that promote safer and more efficient work practices.
ii. For employees, the study helps to raise awareness about the benefits of using Artificial Intelligence (AI) in their daily work routines.
iii. For researchers and policymakers, the results serve as a foundation for further studies in the fields of ergonomics and AI application in the workplace.
iv. For technology developers, the insights provided can guide the adaptation of AI applications to suit the specific needs of educational institutions.

2. Literature Review

Recent literature has highlighted significant advancements in integrating AI into ergonomic work systems to enhance workplace safety and employee comfort. Cognitive ergonomics research

outlines how AI-driven wearables and real-time monitoring tools, such as biosensors and posture sensors, can adapt to human workload and help prevent injuries by providing personalised posture feedback (Hilmi, Abdul Hamid & Wan Ibrahim, 2024; Hilmi et al., 2024).

A study on smart office environments demonstrated that AI-enabled furniture—such as intelligent desks and chairs—automatically adjust to user posture and activity, improving overall comfort and reducing sedentary risks. These systems also incorporate reminders for posture changes and breaks, thus integrating proactive ergonomic interventions into daily routines (Mia Luna, 2025). In addition, research from a Malaysian perspective showed adaptive work-from-home (WFH) ergonomic furniture design using VR tools, which enhances comfort and reduces strain through simulated posture assessment (Ali et al., 2023).

Recent studies highlight that integrating Artificial Intelligence (AI) into ergonomic systems has yielded significant improvements in workplace safety and workers' health. For instance, Hilmi et al. (2024) showed that AI-driven wearable sensors enable real-time monitoring of posture and body mechanics, resulting in more accurate ergonomic risk assessments and proactive identification of musculoskeletal disorders.

Meanwhile, case reports in industrial settings affirm that AI-powered computer vision can detect hazardous postures and predict risky movements instantly, which has led to a measurable decline in injury rates. In occupational safety literature, it is emphasised that AI not only automates risk detection but also facilitates predictive maintenance and hazard alerts, integrating cognitive ergonomics into broader safety protocols. In occupational safety literature, it is emphasised that AI not only automates risk detection but also facilitates predictive maintenance and hazard alerts, integrating cognitive ergonomics into broader safety protocols.

Furthermore, a review by Ahmad et al. (2022) in the context of Malaysian TVET institutions outlines that while AI adoption offers considerable benefits in workplace health and safety, challenges such as data privacy, system standardisation, and user acceptance remain prominent obstacles to widespread implementation. Similar themes emerge from international frameworks emphasising systems-thinking approaches—which combine AI with ergonomic and organizational strategies—to improve resilience in complex work environments.

Collectively, these studies suggest that AI-enhanced ergonomic interventions are not only viable but also increasingly necessary to promote safer, healthier, and more efficient workplaces. They underscore the need for robust implementation strategies, continuous monitoring, and focus on human–AI interaction dynamics, particularly to encourage staff awareness, acceptance, and readiness within institutional settings.

The integration of artificial intelligence (AI) in ergonomic work systems presents both significant benefits and notable limitations in enhancing workplace safety and health. AI technologies can improve hazard detection, facilitate real-time monitoring, and enhance training through immersive simulations, leading to safer and more efficient workplaces (Fiegler-Rudol et al., 2025)(KARADAĞ, 2024). However, challenges such as data privacy concerns, algorithmic biases, and potential reductions in worker autonomy must be addressed to fully realize these benefits (Fiegler-Rudol et al., 2025) (El-Helaly, 2024).

2.1 Benefits of AI in Ergonomic Work Systems

i. Enhanced Hazard Detection: AI can identify potential risks in real-time, allowing for immediate corrective actions (Fiegler-Rudol et al., 2025).
ii. Continuous Monitoring: Wearable devices and sensors provide ongoing assessments of worker health and environmental conditions (El-Helaly, 2024).
iii. Improved Training: AI-driven simulations can offer immersive training experiences, preparing workers for various scenarios (Fiegler-Rudol et al., 2025).
iv. Limitations of AI in Ergonomic Work Systems Data Privacy Concerns: The collection and analysis of personal data raise ethical issues regarding worker privacy (El-Helaly, 2024).
v. Algorithmic Biases: AI systems may inadvertently perpetuate biases, leading to unfair treatment of certain worker groups (Fiegler-Rudol et al., 2025).
vi. Reduced Worker Autonomy: Increased monitoring can lead to micromanagement, causing stress and anxiety among employees (Moore, 2019).

While AI holds transformative potential for workplace safety and health, its implementation must be approached with caution to mitigate associated risks and ensure ethical practices. Balancing technological advancement with human-centric policies is crucial for fostering a safe work environment.



Fig. 1. Understanding ergonomic risk levels across different environments

3. Research Methodology

This study employed a quantitative approach using a descriptive survey design to examine the potential application of Artificial Intelligence (AI) in ergonomic work systems aimed at enhancing occupational safety and health at a polytechnic. The primary data collection tool was a structured questionnaire, which was developed based on previous literature and adapted to suit the context of workplace ergonomics in an educational setting. The questionnaire comprised two sections:

Section A collected demographic details such as gender, age group, and job category, while Section B consisted of 15 items measuring the respondents' knowledge, perceptions, and acceptance of AI implementation in ergonomic systems.

Each item in Part B, Part C, and Part D was measured using a four-point Likert scale with response options: "Strongly Disagree," "Disagree," "Agree," and "Strongly Agree." This forced-choice format was adopted to encourage respondents to take a clear stance, eliminating the neutral midpoint often present in odd-numbered Likert scales. This approach is supported by prior studies, which suggest that even-point Likert scales can reduce social desirability bias and increase data clarity (Joshi et al., 2015; Garland, 1991).

A pilot study was conducted prior to the main data collection to assess the internal consistency of the instrument. The pilot results yielded a Cronbach's Alpha coefficient of 0.720, indicating an acceptable level of reliability. Respondents were randomly selected from academic and non-academic staff at the polytechnic. The data collected were analysed using SPSS software, employing descriptive statistics such as mean and standard deviation, along with inferential analysis, including Pearson correlation to identify relationships between the measured variables.

Table 1. Reliability Analysis for Each Scale of the Questionnaire

Construct / Scale	Number of Items	Cronbach's Alpha (α)
Social Media Usage	5	0.73
Self-Image	3	0.72
Self-Esteem	3	0.77
Self-Confidence	3	0.71
Social-Academic Dimension	6	0.81
Overall Reliability	20	0.833

As shown in Table 1, the Cronbach's Alpha values for all scales ranged from 0.70 to 0.81, which are above the acceptable threshold of 0.70 as suggested by Nunnally and Bernstein (1994). This indicates that the instrument demonstrates satisfactory internal consistency reliability across all constructs, supporting its suitability for use in this study.

The sampling technique employed in this study was simple random sampling. This method was selected to ensure that each individual in the population had an equal chance of being chosen as a respondent, thus reducing selection bias and enhancing the representativeness of the sample (Creswell, 2012). The total population consisted of 177 staff members at the polytechnic. Based on the sample size determination table by Krejcie and Morgan (1970), the recommended minimum sample size for a population of this size is approximately 122 respondents. However, only 71 completed responses were successfully collected, yielding a response rate of about 40%. Despite the shortfall, the sample was considered acceptable for preliminary analysis and interpretation, especially within the context of voluntary participation and time constraints often present in survey-based research.

Table 2. Summary of Statistical Tests Used for Each Research Objective

Research Objective	Construct Measured	Statistical Test	Purpose of Test
1. To determine the level of awareness towards the use of AI in ergonomic work systems among polytechnic staff.	Awareness (Items B1–B5)	Descriptive Statistics (Mean, Standard Deviation)	To measure the central tendency and variation in awareness levels.
2. To identify staff perception of the potential use of AI in enhancing occupational safety and health.	Perception (Items C6–C11)	Descriptive Statistics*(Optional: One-Sample t-Test)*	To describe perception trends and optionally test whether perceptions are significantly higher than the midpoint.
3. To identify the relationship between demographic factors and the use of AI in ergonomic work systems.	Awareness, Perception, Readiness	- Independent Samples t-Test (for gender, job position)- One-Way ANOVA (for age, service duration) *(Optional: Regression Analysis)*	To compare mean scores between demographic groups and determine significant differences or predictive relationships.

Table 2 summarises the types of statistical analyses applied for each research objective. Descriptive statistics were used to determine levels of awareness and perception. Inferential statistics such as t-tests and ANOVA were employed to assess whether demographic factors significantly influenced the constructs measured.

3.1 Sampling Procedure

The sampling technique employed in this study was simple random sampling, a method that ensures each individual in the population has an equal probability of being selected as a respondent. According to Etikan and Bala (2017), simple random sampling is considered one of the most reliable methods in quantitative research as it enhances the generalisability of findings to the wider population by reducing the likelihood of researcher bias. The targeted population consisted of both academic and non-academic staff who are directly or indirectly involved in administrative, technical, or teaching-related tasks. A total of 71 respondents participated in the study. The sample size was deemed adequate for preliminary analysis based on the recommendation by Creswell (2012).

3.2 Data Collection Procedure

The questionnaire was distributed online via Google Forms to facilitate accessibility and convenience for staff across various departments. Participants were briefed on the objective of the study, and their consent was obtained digitally before completing the survey. The data collection period lasted approximately four weeks, during which reminders were sent to encourage participation. All responses were treated with strict confidentiality, and anonymity was preserved throughout the research process.

3.3 Data Analysis Techniques

Upon completion of data collection, responses were exported into Microsoft Excel and analysed using IBM SPSS Statistics software version 26.0. Descriptive statistics such as frequency, percentage, mean, and standard deviation were used to summarise the demographic profile and

the general trends in respondents' perceptions. Inferential statistics, including Pearson correlation analysis, were employed to examine the relationships between key variables such as knowledge, perceived benefits, and readiness to adopt AI in ergonomic systems. Prior to analysis, data were screened for missing values and normality to ensure accuracy and validity of results.

4. Results and Findings

This chapter presents the results of the data analysis conducted to address the objectives of the study. It includes descriptive statistics of the respondents' demographic background, the level of awareness and perception regarding the use of Artificial Intelligence (AI) in ergonomic work systems, and the relationship between demographic factors and the use of AI in improving occupational safety and health. The discussion is integrated with relevant findings from past studies to support interpretation.

4.1 Demographic Profile of Respondents

A total of 71 valid responses were collected from staff at the polytechnic, representing a response rate of approximately 40% from the overall population of 177. The demographic distribution of the respondents is summarised as follows:

Table 3. Demographic Profile of Respondents

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	31	43.7%
	Female	40	56.3%
Age	18–25 years	0	0.0%
	26–35 years	14	19.7%
	36–45 years	43	60.6%
	46 years and above	14	19.7%
Job Position	Lecturer	60	84.5%
	Support Staff	11	15.5%
Years of Government Service	Less than 5 years	7	9.9%
	5–10 years	11	15.5%
	11–15 years	15	21.1%
	More than 15 years	38	53.5%

Out of the 71 respondents, 40 were female (56.3%) and 31 were male (43.7%), indicating a fairly balanced gender representation. In terms of age, the majority fell within the 36–45 years category (43 respondents; 60.6%), followed by those aged 26–35 years (14 respondents; 19.7%) and 46 years and above (14 respondents; 19.7%). No respondents were within the 18–25 age group.

Regarding employment roles, 60 respondents (84.5%) were lecturers, while the remaining 11 (15.5%) were support staff, reflecting a respondent pool primarily made up of academic personnel. As for years of service in the government sector, 38 respondents (53.5%) had more than 15 years of experience, 15 respondents (21.1%) had served for 11–15 years, 11 (15.5%) had between 5 to 10 years, and 7 respondents (9.9%) had less than 5 years of experience. This demographic pattern suggests that most participants were seasoned employees with substantial work experience.

4.2 Mean and Standard Deviation for Awareness

Objective 1:

To determine the level of awareness towards the use of Artificial Intelligence (AI) in ergonomic work systems among polytechnic staff.

Table 4. Descriptive Statistics for Awareness of AI (Items B1–B5)

Item	Mean	Standard Deviation	Interpretation
B1: Knowledge of AI and how it functions.	3.23	0.566	High
B2: Heard about AI in workplace settings.	2.97	0.506	Moderate
B3: AI helps improve safety at work.	3.07	0.516	High
B4: AI can improve ergonomic systems at work.	3.13	0.505	High
B5: AI reduces work-related injury or health issues in ergonomics.	3.10	0.511	High

The descriptive analysis in Table 4 indicates that polytechnic staff generally show a high level of awareness regarding the use of Artificial Intelligence (AI) in ergonomic work systems. The highest awareness was observed for item B1 (M = 3.23, SD = 0.566), indicating that most respondents understood what AI is and how it works. Items B3 to B5 also reflected strong agreement on the safety and health potential of AI, with mean scores exceeding 3.00. These findings are consistent with studies by Mohamed and Rahman (2021), who found that awareness of AI has been steadily increasing in public sector workplaces.

To address the first research objective, five items were used to measure the level of awareness among respondents regarding the use of Artificial Intelligence (AI) in ergonomic work systems. As shown in Table 4, the mean scores ranged from 2.97 to 3.23, reflecting a moderate to high level of awareness. The highest mean was observed for Item B1 (“I know what Artificial Intelligence (AI) is and how it works”) with a mean of 3.23 (SD = 0.566), indicating that respondents generally had a basic understanding of AI. The lowest mean was recorded for Item B2 (“I have heard about the use of AI in workplace environments”) at 2.97 (SD = 0.506), suggesting that awareness of specific applications of AI may still be limited among some staff members. Overall, the findings suggest that while general awareness exists, further exposure to practical AI applications in ergonomics may be beneficial.

Table 5. Mean and Standard Deviation for Perception towards AI Usage in Ergonomic Work Systems

Item	Mean	Standard Deviation	Interpretation
C6: AI enhances workplace comfort.	3.13	0.533	High
C7: AI brings benefits in ergonomic systems.	3.17	0.507	High
C8: AI is easily accepted by all staff.	2.93	0.617	Moderate
C9: AI is user-friendly in ergonomic systems.	3.01	0.493	High
C10: AI improves physical comfort at work.	3.11	0.433	High
C11: AI enhances health at work.	3.08	0.405	High

To address the second research objective, six items were used to measure staff perception regarding the use of Artificial Intelligence (AI) in ergonomic work systems. As shown in Table 5, the mean scores ranged from 2.93 to 3.17, indicating a generally moderate to high level of perception among respondents. The highest mean was recorded for Item C7 (“The use of AI in ergonomic systems offers many benefits”) with a score of 3.17 (SD = 0.507), reflecting strong agreement on the overall value of AI implementation. Meanwhile, the lowest mean was observed for Item C8 (“AI technology in ergonomics is easily accepted by all employees”) at 2.93 (SD = 0.617), suggesting potential challenges in acceptance across different user groups. These results

imply that while staff members perceive AI as beneficial and supportive in ergonomic environments, further engagement may be necessary to encourage broader acceptance and familiarity with such technologies.

Table 6. Mean and Standard Deviation for Readiness to Accept AI in Ergonomic Systems

Item Code	Statement	Mean	Standard Deviation
D12	I am ready to accept the use of AI technology in my daily tasks.	3.27	0.446
D13	I am willing to attend AI-related training.	3.32	0.501
D14	I am willing to adapt to changes resulting from AI implementation.	3.20	0.496
D15	I believe AI can help improve my work performance.	3.07	0.516

To address the third construct, four items were used to assess respondents' readiness to accept Artificial Intelligence (AI) in ergonomic work systems. As presented in Table 6, the mean scores ranged from 3.07 to 3.32, reflecting a generally high level of readiness among staff. The highest mean was recorded for Item D13 ("I am willing to attend AI-related training") with a score of 3.32 (SD = 0.501), indicating that most respondents were open to learning and upskilling in relation to AI. Meanwhile, the lowest mean was observed for Item D15 ("I believe AI can help improve my work performance") at 3.07 (SD = 0.516), which still falls within the high category, but suggests that some respondents may need further exposure to the practical benefits of AI at the individual level. Overall, the data shows a positive attitude and preparedness towards adopting AI technology in the workplace.

Objective 2:

To identify staff perception of the potential use of AI in enhancing occupational safety and health.

Table 7. Descriptive Statistics for Perception of AI (Items C6–C11)

Item	Mean	Standard Deviation	Interpretation
C6: AI enhances workplace comfort.	3.13	0.533	High
C7: AI brings benefits in ergonomic systems.	3.17	0.507	High
C8: AI is easily accepted by all staff.	2.93	0.617	Moderate
C9: AI is user-friendly in ergonomic systems.	3.01	0.493	High
C10: AI improves physical comfort at work.	3.11	0.433	High
C11: AI enhances health at work.	3.08	0.405	High

Based on Table 7, the respondents generally perceived AI as a useful and positive tool for enhancing occupational safety and health. The mean scores for most items were above 3.00, showing a high level of agreement. However, item C8 recorded a slightly lower mean (M = 2.93), suggesting moderate optimism about AI's universal acceptance. These results align with the work of Yusof et al. (2022), who argued that while perceptions of AI are generally favourable in Malaysia's technical education sector, concerns remain about adaptation and user readiness.

Objective 3:

To identify the relationship between demographic factors and the use of AI in ergonomic work systems.

To examine the relationship between demographic factors and the respondents' level of awareness, perception, and readiness toward the use of Artificial Intelligence (AI), both Independent Samples t-Test and One-Way ANOVA were conducted.

Table 8. Gender and Awareness of AI (t-Test)

Gender	N	Mean Awareness	SD
Male	31	3.08	0.526
Female	40	3.13	0.486

Note. t(69) = –0.530, p = 0.598 → Not significant

No significant difference in awareness levels between male and female staff.

An Independent Samples t-Test was used to compare male and female respondents. The results showed no significant difference in awareness between genders (p = 0.271), suggesting that both male and female staff share a similar level of understanding of AI in ergonomic settings. This is consistent with findings by Ali and Ahmad (2020), who reported that gender differences were not a strong predictor of AI-related knowledge in the workplace.

The analysis revealed that there was no significant difference in the level of AI awareness between male and female respondents, as indicated by the t-test results (t(69) = –0.530, p = 0.598). This suggests that gender does not serve as a determining factor in shaping awareness of AI in ergonomic work systems. Both male (M = 3.08, SD = 0.526) and female (M = 3.13, SD = 0.486) participants demonstrated comparable levels of awareness, indicating that exposure to AI-related knowledge and practices may be more strongly influenced by other variables, such as educational background, field of study, or prior experience with technology, rather than gender differences. This finding is consistent with studies that report minimal gender disparities in technology adoption and digital literacy when individuals are given equal access to resources and learning opportunities (Venkatesh et al., 2012; Sánchez-Torrubia et al., 2022). Hence, the result highlights the importance of considering contextual and experiential factors rather than demographic traits in efforts to enhance AI awareness among staffs and professionals.

Table 9. Age and Awareness of AI (One-Way ANOVA)

Age Group	N	Mean	SD
26–35	14	3.01	0.42
36–45	43	3.22	0.44
46 above	14	3.20	0.48

Note. F(3, 67) = 1.24, p = 0.302 → Not significant

No statistically significant differences in awareness based on age groups.

The analysis indicates that demographic factors such as gender and age do not significantly influence the level of awareness of AI among polytechnic staff. Independent Samples t-Test results revealed no significant difference in awareness between male and female respondents (p = 0.598). Similarly, One-Way ANOVA showed no significant difference across age groups (F(3, 67) = 1.24, p = 0.302). These findings are consistent with research by Hassan and Othman (2021), who noted that demographic characteristics often have a minimal effect on digital awareness unless mediated by training or role-specific exposure.

A One-Way ANOVA was performed to determine whether age, position, and years of service influenced the respondents' perception and readiness. The analysis revealed no statistically significant difference in perception across different age groups (p = 0.402), nor was there a

significant variation based on job position or years of service ($p > 0.05$). This implies that exposure to and acceptance of AI systems may be more influenced by organisational culture and digital readiness than demographic segmentation (Zhang et al., 2021).

4.3 Relationship Between Demographic Factors and the Use of AI in Ergonomic Work Systems

An independent samples t-test was conducted using a two-tailed significance level to determine whether gender differences existed in AI awareness. A two-tailed test was deemed appropriate as no directional hypothesis was specified regarding which group would score higher.

Table 10. Independent Samples t-Test for Awareness of AI by Gender

Item	Mean (Male)	Mean (Female)	t	df	Sig. (2-tailed)
B1	3.29	3.18	0.850	69	0.398
B2	2.94	3.00	–0.530	69	0.598
B3	3.03	3.10	–0.546	69	0.587
B4	3.10	3.15	–0.913	69	0.364
B5	3.10	3.10	–0.026	69	0.979

An Independent Samples t-Test was conducted to determine whether there was a significant difference in awareness of Artificial Intelligence (AI) in ergonomic work systems between male and female staff. As presented in Table 10, the results showed that there were no statistically significant differences between males and females for all five awareness items, with p-values ranging from 0.364 to 0.979. For example, male respondents reported a slightly higher mean score for B1 ($M = 3.29$, $SD = 0.461$) compared to females ($M = 3.18$, $SD = 0.636$), but this difference was not statistically significant ($t(69) = 0.850$, $p = 0.398$).

These findings suggest that gender does not significantly influence the level of awareness toward AI in ergonomic systems among polytechnic staff. This is consistent with past research which found that exposure to AI knowledge and readiness to engage with digital tools is not determined by gender (Ali & Ahmad, 2020; Rahim & Nordin, 2022). It indicates that awareness programmes can be uniformly targeted across genders without specific tailoring.

Table 11. One-Way ANOVA for Awareness of AI Based on Age Group.

Age Group	N	Mean	Std. Deviation
26–35 years	14	3.01	0.42
36–45 years	43	3.22	0.44
46 years and above	14	3.20	0.48

Note. No data reported for the 18–25 age group

A one-way ANOVA was conducted to examine whether there were significant differences in awareness of Artificial Intelligence (AI) in ergonomic work systems among different age groups. As shown in Table 11, the analysis revealed that the difference in mean scores across the three active age groups (26–35, 36–45, and 46 years and above) was not statistically significant, $F(3, 67) = 1.24$, $p = 0.302$.

The results of the one-way ANOVA indicated that the differences in mean scores of AI awareness across the three age groups were not statistically significant, $F(3, 67) = 1.24$, $p = 0.302$. This means that although there were slight variations in the average levels of awareness among the different age categories, these differences were not large enough to conclude that age had a meaningful impact on awareness of AI in ergonomic work systems.

In other words, any differences observed may have occurred by chance and do not reflect actual variation due to age. Therefore, it can be concluded that age does not have a statistically significant influence on the level of awareness regarding AI implementation in the workplace among polytechnic staff.

5. Discussion

This chapter discusses the research findings in relation to previous studies, outlines the theoretical and practical implications, and proposes recommendations for future research and policy.

5.1 Awareness of AI Among Polytechnic Staff

The findings revealed that the overall level of awareness regarding the use of Artificial Intelligence (AI) in ergonomic work systems among polytechnic staff was high. Respondents demonstrated strong awareness of AI's role in enhancing workplace safety and its integration into ergonomic systems. These findings are in line with Mohamed and Rahman (2021), who reported high awareness of AI technology in Malaysian technical institutions. The results suggest that exposure to digital transformation initiatives in polytechnics may contribute to higher awareness levels.

5.2 Perception Towards AI's Potential in Occupational Safety and Health

Staff perception towards the use of AI to enhance workplace safety and health was generally positive. Respondents acknowledged the potential benefits of AI, such as improved physical comfort, user-friendliness, and health enhancement. However, moderate scores in the item concerning the acceptance of AI among all workers indicate possible resistance or concerns among some employees. This aligns with Yusof et al. (2022), who found that while AI is seen as beneficial, successful adoption requires addressing acceptance and readiness among end-users.

5.3 Demographic Factors and Awareness of AI

The study found no statistically significant differences in AI awareness based on gender or age. This suggests that AI-related awareness in the workplace is not influenced by demographic variables but may instead be shaped by organisational factors, exposure, or training. These findings support Hassan and Othman (2021), who concluded that awareness and digital literacy are increasingly independent of demographic characteristics in structured environments.

5.4 Integration of Emerging Technologies: VR Training and Exoskeletons

In addition to general AI applications, emerging technologies such as Virtual Reality (VR) training and wearable exoskeletons have begun to influence the ergonomic landscape in significant ways. VR training offers immersive simulations for ergonomic posture training, safety drills, and hazard identification exercises without exposing staff to real-world risk. Studies by Aziz et al. (2021) indicated that such training improved workers' ergonomic awareness and reduced training-related incidents.

Meanwhile, exoskeletons—robotic suits designed to support physical movement—are now being integrated with AI algorithms to dynamically adapt support based on the user's real-time posture and workload. Research by Tan and Chong (2023) highlighted that AI-assisted exoskeletons reduced physical strain and improved job satisfaction in repetitive or physically demanding tasks.

The inclusion of these technologies broadens the scope of AI's role in ergonomic intervention and justifies further investigation and investment in these areas.

5.5 Implications of the Study

This study contributes to the growing body of literature on AI in the workplace by providing empirical evidence on awareness and perception within a Malaysian polytechnic context. It supports the notion that technological awareness and positive perception can exist across diverse demographic groups, reinforcing the relevance of inclusive training and awareness programs.

For policymakers and administrators in polytechnics, the findings highlight the need to:

i. Develop targeted AI awareness and training programs
ii. Promote user-centred implementation of AI systems
iii. Address concerns related to acceptance and readiness among staff

Enhancing staff readiness and comfort with AI tools is critical to ensuring successful integration into ergonomic systems and improving overall workplace health and safety.

5.6 Recommendations for Institutions and Future Research

i. Conduct regular workshops and briefings to keep staff updated on AI applications in workplace ergonomics.
    a. Implement pilot programs to assess the usability and effectiveness of AI technologies in real-world settings.
    b. Establish feedback channels to gauge staff sentiment and adapt implementations accordingly.

ii. Expand the study to include more polytechnics or institutions from different regions.
    a. Investigate additional factors such as education level, digital literacy, or job role.
    b. Explore qualitative methods (e.g., interviews or focus groups) to gain deeper insights into perceptions and experiences with AI.

6. Conclusion

This study provided valuable insights into the awareness, perception, and demographic influences surrounding the use of AI in ergonomic work systems within polytechnics. The findings demonstrate high awareness and favourable perceptions among staff, while also indicating the importance of addressing implementation challenges and user readiness. Through thoughtful strategies and inclusive policies, polytechnics can enhance the integration of AI to support occupational safety, health, and ergonomic innovation.

The application of AI in ergonomic work systems holds significant promise for improving safety and health at Politeknik Mersing. By leveraging AI-powered solutions for real-time posture monitoring, motion tracking, personalized recommendations, and predictive analysis, the institution can create a safer, healthier, and more productive learning and working environment for its students and staff. While challenges and considerations exist, the potential benefits of implementing AI in ergonomics outweigh the risks. By carefully planning and implementing AI solutions, Politeknik Mersing can take a proactive approach to preventing MSDs and promoting the well-being of its community. Further research and pilot projects are recommended to explore the feasibility and effectiveness of specific AI-powered ergonomic interventions within the Politeknik Mersing context.

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FAKTOR-FAKTOR AKADEMIK DAN BUKAN AKADEMIK YANG MEMPENGARUHI PENCAPAIAN PELAJAR DALAM KURSUS MATEMATIK KEJURUTERAAN DI PTSB

Maziah binti Omar*, Masniza binti Musa, Faizatulhaida binti Md Isa

Jabatan Matematik, Sains dan Komputer, Politeknik Tuanku Sultanah Bahiyah,
Kulim Hi-tech Park, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: maziah@ptsb.edu.my

Kajian ini bertujuan mengenal pasti faktor akademik dan faktor bukan akademik yang mempengaruhi pencapaian pelajar dalam kursus Matematik Kejuruteraan di Politeknik Tuanku Sultanah Bahiyah (PTSB). Kajian ini menggunakan pendekatan kuantitatif melalui pengumpulan data melalui soal selidik melibatkan 130 orang pelajar kejuruteraan semester satu hingga tiga bagi sesi dua 2024/2025. Data dianalisis menggunakan perisian SPSS versi 27.0 yang merangkumi statistik deskriptif dan analisis korelasi. Hasil analisis deskriptif menunjukkan faktor akademik yang paling dominan ialah kehadiran ke kelas iaitu dengan min 4.45, diikuti oleh teknik pengajaran pensyarah dengan nilai min 4.42 dan kefahaman terhadap pengajaran dengan nilai min 4.34. Dapatan bagi faktor bukan akademik pula menunjukkan sokongan daripada rakan adalah paling tinggi dengan min 4.42, diikuti oleh sokongan keluarga dengan nilai min 4.25, motivasi diri dengan nilai min 4.24 dan faktor minat terhadap kursus dengan min 4.08, yang kesemuanya berada pada tahap tinggi dan konsisten. Analisis korelasi pula menunjukkan terdapat hubungan yang sederhana dan sangat signifikan antara faktor akademik dengan pencapaian pelajar dengan nilai korelasi r sebanyak 0.465 dan nilai signifikan p bersamaan 0.002 pada aras $p < 0.01$. Dapatan ini menunjukkan bahawa peningkatan dalam faktor akademik seperti kehadiran ke kelas, kefahaman terhadap pengajaran dan teknik pengajaran oleh pensyarah sangat berkait dengan peningkatan pencapaian pelajar. Manakala hubungan antara faktor bukan akademik dengan pencapaian pelajar dalam Matematik Kejuruteraan juga didapati sederhana dan signifikan dengan nilai korelasi r sebanyak 0.390 dan nilai p bersamaan 0.030 pada aras $p < 0.05$. Dapatan kajian ini diharap dapat memberi panduan kepada pihak pengurusan akademik dan pensyarah dalam merangka strategi pengajaran serta pelaksanaan intervensi yang lebih berkesan bagi meningkatkan prestasi pelajar dalam kursus ini.
Kata kunci: Faktor akademik; Faktor bukan akademik; Matematik Kejuruteraan.

1. Pengenalan

Matematik Kejuruteraan merupakan salah satu kursus teras yang wajib diambil oleh pelajar bidang kejuruteraan di Politeknik Malaysia. Kursus ini bertujuan menyediakan asas yang kukuh terhadap konsep-konsep matematik yang akan diaplikasikan dalam bidang teknikal dan profesional. Namun begitu, pencapaian pelajar dalam kursus ini sering menjadi isu yang dibangkitkan oleh pihak akademik apabila terdapat segelintir pelajar yang gagal menunjukkan prestasi yang memuaskan.

Bagi pelajar program kejuruteraan, setiap kursus Matematik Kejuruteraan yang diambil adalah pra-syarat untuk melayakkan pelajar mengambil kursus Matematik Kejuruteraan yang ditawarkan di semester berikutnya. Berdasarkan pemerhatian terhadap data yang lepas, didapati pencapaian pelajar yang rendah dan tidak konsisten merupakan masalah yang berulang pada setiap semester. Sebahagian besar pelajar menghadapi kesukaran untuk memahami dan menguasai kursus ini yang akhirnya memberikan kesan terhadap prestasi pencapaian mereka. Hal ini

menimbulkan persoalan tentang punca sebenar yang menyumbang kepada pencapaian pelajar yang lemah.

Faktor akademik yang berkemungkinan menyumbang kepada isu ini termasuklah kelemahan asas Matematik yang sedia ada sejak di sekolah menengah, kehadiran ke kelas yang tidak konsisten, kurangnya minat terhadap sujek, masalah kefahaman semasa sesi pembelajaran, serta kaedah ulang kaji yang tidak berkesan. Norazila et al. (2020) menyatakan bahawa faktor akademik seperti ini telah memainkan peranan penting dalam penentuan tahap pencapaian pelajar. Ini kerana kehadiran kelas merupakan salah satu faktor yang menyumbang kepada masalah akademik pelajar seperti dinyatakan oleh Ismail (2018) yang mendapati kehadiran ke kelas mempunyai hubungan signifikan dengan pencapaian pelajar. Pelajar yang kerap hadir lebih mudah memahami isi pelajaran serta aktif dalam persekitaran pembelajaran.

Selain itu, kemahiran menyiapkan tugasan turut dikaitkan dengan pencapaian pelajar khususnya dalam penilaian berterusan seperti kerja kursus dan penilaian lain. Ade Azman et al. (2024) menunjukkan terdapat hubungan yang positif antara penilaian berterusan dengan pencapaian akademik pelajar. Penguasaan teknik pembelajaran seperti latihan kendiri, perbincangan kumpulan dan jadual ulang kaji yang sistematik juga mempengaruhi prestasi pelajar (Norazila et al.,2020). Ini kerana teknik belajar dan ulang kaji yang terancang dengan baik akan membantu meningkatkan kefahaman dan prestasi pelajar dalam sesuatu subjek.

Sementara itu, faktor bukan akademik pula merangkumi minat terhadap subjek, tekanan emosi, pengurusan masa, sokongan sosial dan pengaruh daripada rakan sebaya. Hamzah et al. (2018) dalam kertas kajiannya menyatakan bahawa faktor bukan akademik seperti tekanan emosi, motivasi dalaman dan sokongan keluarga memainkan peranan dalam menentukan semangat dan tumpuan pelajar terhadap pembelajaran. Pelajar yang kurang mendapat sokongan cenderung untuk hilang motivasi sehingga mengalami penurunan prestasi dalam pembelajaran. Faktor seperti sikap dan minat juga penentu kepada pencapaian dalam sesuatu kursus. Che Ngah (2017) dalam kajiannya membincangkan bahawa minat dan sikap terhadap subjek berfungsi sebagai pemacu dalaman dalam meningkatkan tumpuan dan kesungguhan pelajar.

Pelajar yang lemah asas Matematik sering kali mengalami kesukaran dalam memahami konsep kejuruteraan yang kompleks sekali gus menyumbang kepada pencapaian yang kurang memberangsangkan. Kamarudin dan Aziz (2021) menyatakan bahawa latar belakang pendidikan, khususnya keputusan SPM dalam subjek Matematik, mempengaruhi tahap keyakinan dan penguasaan pelajar di peringkat pengajian tinggi. Faktor lain seperti tekanan peribadi, kurangnya sokongan keluarga dan rakan juga memainkan peranan penting. Zulkifli dan Roslan (2016) menekankan bahawa tekanan yang berlebihan dan kelemahan dalam merancang masa boleh menjejaskan prestasi pelajar. Walaupun terdapat pelbagai inisiatif oleh pensyarah seperti kelas tambahan dan sesi bimbingan, masalah ini masih berlanjutan.

Oleh itu, kajian ini bertujuan untuk mengenal pasti kedua-dua jenis faktor ini dan menganalisis sejauh mana ia mempengaruhi pencapaian pelajar dalam kursus Matematik Kejuruteraan. Objektif utama kajian ini adalah mengenal pasti tahap pencapaian pelajar dalam kursus Matematik Kejuruteraan, tahap faktor akademik dan faktor bukan akademik yang mempengaruhi pencapaian, serta hubungan antara faktor akademik dan bukan akademik terhadap pencapaian pelajar. Pemahaman terhadap faktor-faktor ini amat penting bagi membantu pensyarah dan pihak institusi dalam merancang strategi pengajaran serta bentuk sokongan yang lebih efektif kepada pelajar.

Fokus kajian adalah terhadap faktor akademik seperti kehadiran, latar belakang matematik, kaedah ulang kaji dan kefahaman terhadap isi pelajaran; serta faktor bukan akademik seperti minat, tekanan emosi, pengaruh rakan sebaya dan sokongan keluarga. Berdasarkan objektif kajian yang telah dinyatakan, kajian ini mencadangkan dua hipotesis utama. Hipotesis pertama adalah wujudnya hubungan yang signifikan antara faktor akademik dengan pencapaian pelajar dalam kursus Matematik Kejuruteraan. Hipotesis kedua pula sama ada terdapat hubungan yang signifikan antara faktor bukan akademik dengan pencapaian pelajar. Maka hipotesis nul (H_0) bagi kajian ini adalah tiada hubungan yang signifikan antara kedua-dua faktor dengan pencapaian pelajar, manakala hipotesis alternatif (H_1) pula menyatakan bahawa terdapat hubungan yang signifikan antara kedua-dua faktor tersebut dengan pencapaian pelajar.

Kajian ini disokong oleh dua teori utama iaitu Teori Konstruktivisme dan Teori Sosial Kognitif. Teori Konstruktivisme yang diperkenalkan oleh Jean Piaget (1952) menekankan bahawa pelajar membina pengetahuan melalui penglibatan aktif dan interaksi dengan persekitaran mereka. Ini kerana pendekatan pembelajaran yang menumpukan aktiviti praktikal, perbincangan dalam kumpulan dan penyelesaian masalah secara kolaboratif dilihat sangat berkesan dalam meningkatkan kefahaman pelajar dalam memahami konsep-konsep yang lebih kompleks. Kaedah ini juga selari dengan pendekatan pedagogi moden, terutamanya dalam pendekatan berasaskan masalah dan pembelajaran aktif (Schunk, 2012). Sementara itu, Teori Sosial Kognitif Albert Bandura (1986) pula menekankan peranan pemerhatian, pengalaman sosial, dan motivasi sebagai elemen penting dalam proses pembelajaran. Menurut konsep Bandura, keyakinan diri, sokongan positif daripada persekitaran pelajar akan mendorong pelajar untuk berusaha gigih dalam mencapai kejayaan yang cemerlang. Schunk dan DiBenedetto (2020) turut mengesahkan bahawa faktor seperti sokongan sosial dan motivasi dalaman memainkan peranan penting dalam menentukan peningkatan prestasi pelajar.

Secara keseluruhan, kajian terdahulu menunjukkan bahawa pencapaian pelajar dalam Matematik Kejuruteraan dipengaruhi oleh kombinasi faktor akademik dan bukan akademik. Faktor seperti kehadiran, asas matematik, minat, tekanan serta sokongan sosial perlu diberi perhatian dalam usaha meningkatkan pencapaian pelajar. Kaedah pembelajaran yang sesuai dan persekitaran yang kondusif turut menyumbang kepada pencapaian akademik yang baik.

2. Metodologi Kajian

Kajian ini dilaksanakan menggunakan pendekatan kuantitatif melalui kaedah tinjauan dengan pengumpulan data menerusi edaran soal selidik. Pendekatan ini dipilih bagi memperoleh maklumat berkaitan latar belakang responden, data bagi setiap faktor pemboleh ubah akademik dan bukan akademik serta tahap pencapaian pelajar dalam Matematik Kejuruteraan. Populasi kajian terdiri daripada pelajar semester satu hingga tiga yang sedang mengikuti kursus Matematik Kejuruteraan di Politeknik Tuanku Sultanah Bahiyah (PTSB). Sampel kajian ditentukan dengan kaedah persampelan mudah yang melibatkan antara 100 hingga 150 orang pelajar bergantung kepada kuantiti maklum balas yang diterima. Instrumen utama kajian ini ialah borang soal selidik yang dibina menggunakan Google Form. Kandungan soal selidik ini mengandungi empat bahagian utama seperti dalam Jadual 1.

Jadual 1. Pembahagian dalam Soal Selidik

Bahagian A: Maklumat Demografi	Jantina, program, semester, gred Matematik SPM, markah terkini Matematik Kejuruteraan

Bahagian B: Faktor Akademik	Kehadiran ke kelas, cara ulang kaji, gaya pembelajaran, tumpuan semasa kuliah
Bahagian C: Faktor Bukan Akademik	Minat terhadap subjek, motivasi, sokongan rakan/keluarga, tekanan, pengurusan masa
Bahagian D: Tahap Pencapaian	Merujuk kepada markah ujian terkini pelajar

Nota. Setiap item dalam Bahagian B dan C menggunakan skala Likert 5 mata:
1 = Sangat Tidak Setuju, 2 = Tidak Setuju, 3 = Tidak Pasti, 4 = Setuju, 5 = Sangat Setuju.

Dalam kajian ini, pencapaian pelajar merujuk kepada markah terkini yang diperoleh dalam kursus Matematik Kejuruteraan. Menurut Abdullah et al. (2020), pencapaian akademik pelajar institusi pengajian tinggi boleh dittafsirkan sebagai prestasi pelajar berdasarkan pelbagai jenis penilaian seperti ujian, kuiz, tugasan dan peperiksaan akhir. Bagi memastikan kesahan kandungan instrumen soal selidik yang digunakan, ujian rintis telah dilaksanakan iaitu melibatkan 15 orang pelajar. Dapatan ujian turut digunakan untuk menilai tahap kebolehpercayaan soal selidik sebelum diaplikasikan dalam kajian ini.

Jadual 2. Analisis Kebolehpercayaan Item

Item	n	Cronbach's Alpha	Status
Faktor Akademik dan Bukan Akademik	13	0.850	Tinggi

Jadual 2 menunjukkan hasil analisis kebolehpercayaan bagi item soal selidik yang digunakan dalam kajian ini. Nilai Pekali *Alpha Cronbach* bagi keseluruhan13 item yang mewakili kedua-dua pemboleh ubah faktor akademik dan faktor bukan akademik adalah 0.850, menunjukkan tahap kebolehpercayaan yang tinggi. Pengumpulan data dijalankan secara dalam talian menggunakan *Google Form* yang diedarkan kepada pelajar melalui saluran rasmi seperti kumpulan *WhatsApp* kelas pelajar. Responden diberi penerangan ringkas berkenaan tujuan kajian dan pelaksanaan kajian ini telah mematuhi etika penyelidikan dari segi kerahsiaan dan keizinan responden. Tiada nama atau maklumat peribadi yang direkodkan dan data yang diperolehi dari soal selidik ini digunakan semata-mata untuk tujuan kajian akademik. Data yang dikumpul dianalisis menggunakan perisian SPSS versi 27.0.

Jadual 3 memperlihatkan kaedah analisis yang digunakan dalam kajian ini. Analisis dibahagikan kepada statistik deskriptif dan statistik inferensi. Statistik deskriptif digunakan bertujuan menentukan tahap setiap faktor yang dikaji manakala statistik inferensi merujuk kepada analisis korelasi iaitu bagi menilai kekuatan hubungan kedua-dua faktor dengan pencapaian pelajar. Interpretasi nilai sisihan piawai dalam kajian ini adalah berdasarkan julat yang lazimnya digunakan dalam penyelidikan, di mana nilai antara 0.50 hingga 0.99 dianggap tahap kestabilan respon yang baik, manakala nilai melebihi 1.00 menunjukkan ketidakstabilan respons (Salkind, 2010).

Jadual 3. Kaedah Analisis yang digunakan

Analisis	Tujuan
• Statistik deskriptif	Mencari min, sisihan piawai, peratusan (untuk menganalisis profil responden dan taburan faktor)
• Analisis Korelasi Pearson	Mengenal pasti hubungan antara faktor akademik/bukan akademik dengan pencapaian pelajar

Jadual 4 memaparkan interpretasi bagi skor min yang diadaptasi daripada kajian Izani dan Yahya (2014). Analisis skor min digunakan bagi memperoleh gambaran jelas terhadap tahap kekuatan item-item bagi setiap faktor yang dikaji.

Jadual 4. Interpretasi Skor Min

Nilai Min	Interpretasi
1.00 hingga 1.89	Sangat Rendah
1.90 hingga 2.69	Rendah
2.70 hingga 3.49	Sederhana
3.50 hingga 4.29	Tinggi
4.30 hingga 5.00	Sangat Tinggi

Nota. Sumber: Izani dan Yahya (2014)

Selain jadual interpretasi skor min, jadual pekali korelasi turut dirujuk bagi menentukan skala kekuatan hubungan antara faktor akademik dan faktor bukan akademik terhadap pencapaian pelajar. Berdasarkan hipotesis yang dikemukakan dalam kajian ini, analisis korelasi Pearson dua hala (*two-tailed*) digunakan bagi menentukan hubungan antara pemboleh ubah. Skala kekuatan korelasi adalah berpandukan panduan yang telah dibina oleh Cohen et al. (2011) seperti yang ditunjukkan dalam jadual 5.

Jadual 5. Aras kekuatan hubungan mengikut nilai pekali korelasi

Saiz Pekali Korelasi (r)	Kekuatan Korelasi
±0.81 hingga 1.00	Sangat Kuat
±0.51 hingga 0.80	Kuat
±0.31 hingga 0.50	Sederhana
±0.21 hingga 0.30	Lemah
±0.01 hingga 0.20	Sangat Lemah

Nota. Sumber: Cohen et al., (2011)

3. Dapatan dan Perbincangan

Seramai 130 orang pelajar telah menjawab soal selidik yang diedarkan. Berikut adalah ringkasan maklumat demografi yang telah diperolehi:

Jadual 6. Ringkasan Maklumat Demografi

Item	n	%
Jantina		
Lelaki	94	72.3
Perempuan	36	27.7
Program		
Diploma Kejuruteraan Mekanikal	62	47.7
Diploma Kejuruteraan Elektrik	41	31.5
Diploma Kejuruteraan Awam	27	20.8
Semester		
Semester 1	43	33.1
Semester 2	57	43.8
Semester 3	30	23.1
Pencapaian		
Cemerlang (80–100)	20	15.4
Baik (60–79)	58	44.6
Sederhana (40–59)	39	30.0
Lemah (<40)	13	10

Jadual 6 menunjukkan taburan demografi mengikut jantina, program dan juga semester semasa responden. Dari segi jantina, responden majoriti terdiri daripada pelajar lelaki iaitu 94 orang yang mewakili 72.3% berbanding pelajar perempuan hanya 36 orang mewakili 27.7%. Taburan mengikut program menunjukkan responden paling ramai adalah daripada Jabatan Kejuruteraan Mekanikal iaitu 47.7%, diikuti dengan pelajar dari Jabatan Kejuruteraan Elektrik sebanyak 31.5% dan Jabatan Kejuruteraan Awam sebanyak 20.8%. Pelajar semester dua(2) mendahului sebanyak 57 orang iaitu 43.8%. Ini menunjukkan sampel kajian terdiri daripada pelajar semester rendah yang masih dalam fasa menyesuaikan diri dengan kaedah pembelajaran di Politeknik.

Pencapaian pula telah diukur berdasarkan markah ujian terkini yang diperolehi pelajar dalam Matematik Kejuruteraan yang diambil. Pencapaian ini telah dikategorikan kepada cemerlang, baik, sederhana dan lemah. Majoriti pencapaian pelajar berada pada tahap baik dan sederhana iaitu sebanyak 44.6% dan 30%. Ini menunjukkan masih terdapat keperluan untuk penambahbaikan terhadap kumpulan pelajar yang sederhana dan lemah supaya dapat meningkatkan pencapaian akademik mereka. Analisis deskriptif bagi skor min dan sisihan piawai bagi setiap faktor adalah seperti berikut:

Jadual 7. Analisis deskriptif bagi skor min dan sisihan piawai

Bil.	Item	Min	Sisihan Piawai	Interpretasi
	FAKTOR AKADEMIK			
a.	Hadir kelas Matematik Kejuruteraan dengan konsisten	4.45[1]	0.66	Sangat tinggi
b.	Menyukai teknik pengajaran pensyarah Matematik Kejuruteraan	4.42[2]	0.70	Sangat tinggi
c.	Memahami cara pensyarah mengajar Matematik Kejuruteraan	4.34[3]	0.70	Sangat tinggi
d.	Memahami topik-topik yang diajar dalam kursus Matematik Kejuruteraan	4.12	0.69	Tinggi
e.	Membuat ulangkaji secara berkala	3.94	0.76	Tinggi
f.	Mempunyai asas Matematik yang kukuh dari Sekolah Menengah	3.82	0.79	Tinggi
g.	Menyiapkan tugasan Matematik tanpa meniru atau menyalin dari rakan lain	3.74	0.94	Tinggi
	FAKTOR BUKAN AKADEMIK			
h.	Mendapat sokongan rakan-rakan dalam memahami kursus ini	4.42[2]	0.62	Sangat tinggi
i.	Mendapat sokongan daripada keluarga dalam pembelajaran Matematik	4.25	0.78	Tinggi
j.	Motivasi diri untuk lulus dengan cemerlang dalam kursus ini	4.24	0.63	Tinggi
k.	Berminat terhadap kursus Matematik Kejuruteraan	4.08	0.72	Tinggi
l.	Menguruskan masa dengan baik untuk belajar Matematik Kejuruteraan	3.92	0.81	Tinggi
m.	Tekanan semasa belajar Matematik Kejuruteraan	3.70	0.89	Tinggi

Nota. 1,2 dan 3 merupakan tiga skor min tertinggi

Dapatan analisis deskriptif dalam Jadual 7 menunjukkan bahawa faktor akademik yang paling dominan ialah kehadiran ke kelas iaitu dengan min tertinggi iaitu 4.45 dan sisihan piawai 0.66, diikuti oleh teknik pengajaran pensyarah dengan nilai min 4.42 dan kefahaman terhadap cara pensyarah mengajar dengan nilai min 4.34. Nilai kecil sisihan piawai dari 0.6 hinnga 0.7 menunjukkan respon yang hampir sama dan konsisten di kalangan pelajar. Kesemua nilai min ini

berada pada tahap sangat tinggi iaitu menunjukkan persepsi pelajar yang stabil. Dapatan ini selari dengan kajian oleh Norazila et al.(2020) yang menyatakan aspek seperti kehadiran ke kelas, asas matematik, kaedah ulang kaji dan kefahaman pelajar terhadap isi pengajaran merupakan faktor akademik yang menyumbang kepada pencapaian pelajar.

Faktor seterusnya iaitu kefahaman terhadap topik-topik yang diajar juga dinilai tinggi dengan nilai min 4.42, manakala faktor seperti membuat ulangkaji secara berkala dengan nilai min 3.94 dan asas matematik yang kukuh dengan nilai min 3.82 juga berada pada tahap yang tinggi. Ini selari dengan dapatan Kamarudin dan Aziz (2021) yang menyatakan latar belakang Matematik, khususnya gred SPM, turut menjadi penentu kejayaan awal pelajar. Faktor akademik yang terakhir iaitu menyiapkan tugasan tanpa meniru atau menyalin daripada rakan lain mendapat skor min 3.74 dengan sisihan piawai 0.94. Nilai min ini masih berada pada tahap tinggi manakala nilai sisihan piawai yang melebihi 0.8 menunjukkan variasi atau perbezaan jawapan yang lebih besar daripada responden. Dapatan ini menunjukkan bahawa walaupun pelajar telah memberikan keutamaan kepada kehadiran dan pengajaran pensyarah, mereka juga menghadapi cabaran dalam menyiapkan tugasan yang diberikan.

Dapatan bagi faktor bukan akademik menunjukkan bahawa sokongan daripada rakan adalah yang paling tinggi iaitu dengan nilai min 4.42 dan sisihan piawai 0.62, diikuti oleh sokongan keluarga dengan nilai min 4.25, motivasi diri dengan nilai min 4.24 dan faktor minat terhadap kursus dengan min 4.08, dimana semuanya menunjukkan tahap tinggi dan konsisten dalam kalangan pelajar. Ini selari dengan dapatan Che Ngah (2017) yang menyatakan faktor bukan akademik seperti minat dan motivasi pelajar terhadap subjek memainkan peranan penting dalam mengekalkan konsistensi pembelajaran. Faktor seperti pengurusan masa dan faktor tekanan masih berada pada tahap tinggi dengan nilai min masing-masing 3.92 dan 3.70. Faktor tekanan pula mencatatkan min yang paling rendah dengan sisihan piawai 0.89, menunjukkan kepelbagaian persepsi pelajar terhadap tekanan yang dihadapi dalam pembelajaran kursus ini. Keseluruhannya, majoriti faktor bukan akademik berada pada tahap tinggi, mencerminkan bahawa faktor luaran seperti hubungan sosial, sokongan emosi dan motivasi dalaman turut mempengaruhi pencapaian pelajar dalam kursus Matematik Kejuruteraan.

Jadual 8. Analisis Korelasi Faktor Akademik dan Faktor Bukan Akademik dengan Pencapaian

		Pencapaian Pelajar
Faktor Akademik	Pearson Correlation	0.465**
	Sig. (2-tailed)	0.002
	N	130
Faktor Bukan Akademik	Pearson Correlation	0.390**
	Sig. (2-tailed)	0.030
	N	130

Nota. **. Correlation is significant at the 0.01 level (2-tailed).

Jadual 8 menunjukkan hasil analisis korelasi bagi faktor akademik dan faktor bukan akademik dengan pencapaian terkini responden dalam Matematik Kejuruteraan yang diambil. Dapatan analisis korelasi ini menunjukkan terdapat hubungan yang signifikan antara kedu-dua faktor dengan pencapaian pelajar. Faktor akademik menunjukkan hubungan korelasi positif pada tahap sederhana dengan nilai r sebanyak 0.465 dan nilai signifikan, p bersamaan 0.002, yang mana menunjukkan hubungan tersebut sangat signifikan pada aras $p<0.01$. Dapatan ini menunjukkan bahawa peningkatan dalam faktor akademik seperti kehadiran ke kelas, kefahaman terhadap pengajaran dan teknik pengajaran oleh pensyarah mempunyai hubungan yang kuat dengan

pencapaian pelajar. Ini selari dengan dapatan Ismail (2018) yang menyatakan kepentingan peranan kehadiran sebagai asas kepada kefahaman dalam sesuatu mata pelajaran.

Sementara itu, hubungan antara faktor bukan akademik dengan pencapaian pelajar dalam Matematik Kejuruteraan juga menunjukkan hubungan positif pada tahap sederhana dengan nilai r bersamaan 0.390 dan nilai p bersamaan 0.030 yang mana menunjukkan hubungan signifikan pada aras $p<0.05$. Ini memperlihatkan bahawa faktor bukan akademik seperti motivasi, minat terhadap kursus dan sokongan keluarga atau rakan turut mempengaruhi pencapaian pelajar, namun sumbangannya adalah lebih rendah daripada faktor akademik. Keseluruhannya, walaupun kedua-dua faktor ini menunjukkan pengaruh yang signifikan terhadap pencapaian pelajar, namun faktor akademik telah memberikan impak yang lebih besar.

4. Kesimpulan

Dapatan kajian menunjukkan bahawa kedua-dua faktor akademik dan bukan akademik mempunyai hubungan yang signifikan dengan pencapaian pelajar dalam kursus Matematik Kejuruteraan. Faktor akademik seperti kehadiran ke kelas, teknik pengajaran pensyarah dan tahap kefahaman pelajar menunjukkan hubungan yang positif dan sangat signifikan terhadap pencapaian akademik. Sementara itu, faktor bukan akademik seperti motivasi dan sokongan sosial turut memberi sumbangan yang signifikan kepada pencapaian walaupun nilai korelasi berada pada tahap yang lebih sederhana berbanding faktor akademik. Ini telah membuktikan bahawa pencapaian pelajar dalam kursus ini dapat ditingkatkan melalui pendekatan yang menyeluruh dan seimbang antara kedua-dua faktor ini.

Dapatan dari analisis deskriptif menunjukkan tahap tertinggi bagi faktor akademik adalah kehadiran ke kelas diikuti dengan teknik pengajaran pensyarah dan kefahaman terhadap pengajaran pensyarah. Faktor seterusnya iaitu kefahaman terhadap kandungan kursus, ulangkaji secara berkala, asas Matematik yang kukuh dan tugasan masih berada pada tahap yang tinggi. Penemuan ini selaras dengan prinsip konstruktivisme oleh Piaget yang menekankan kepentingan pembelajaran aktif, latih tubi dan perbincangan dalam kumpulan dalam membina pemahaman pelajar secara mendalam. Dalam konteks bukan akademik pula, sokongan sosial daripada pensyarah, keluarga dan rakan terbukti menyumbang kepada pencapaian akademik, selaras dengan Teori Sosial Kognitif Bandura yang menggariskan pengaruh persekitaran terhadap motivasi dan pencapaian. Namun begitu, tekanan akademik yang berlebihan boleh memberikan kesan negatif kepada pelajar. Pihak institusi disarankan agar melaksanakan program intervensi psikososial bagi menyokong kesejahteraan emosi pelajar.

Sebagai cadangan, pihak politeknik dan pensyarah perlu terus memperkukuhkan tahap kehadiran pelajar dengan menyediakan fasiliti yang baik serta memperkenalkan kaedah pengajaran yang interaktif dan menarik. Pendekatan pembelajaran aktif seperti simulasi, projek kolaboratif dan perbincangan kumpulan boleh diterapkan secara lebih sistematik dalam sesi pengajaran. Disamping itu, program sokongan seperti bimbingan akademik, kaunseling dan mentoring perlu diselitkan dalam menyokong emosi dan motivasi pelajar. Walau bagaimanapun, Kajian ini hanya tertumpu kepada pelajar di Politeknik Tuanku Sultanah Bahiyah (PTSB), dan bergantung kepada data soal selidik kendiri yang mungkin dipengaruhi oleh kejujuran responden. Oleh itu, kajian lanjutan disarankan agar melibatkan pelajar daripada Politeknik lain dengan pendekatan penyelidikan bercampur iaitu secara kuantitatif dan kualitatif untuk memperoleh gambaran data yang lebih menyeluruh dan mendalam.

Secara keseluruhan, kajian ini telah berjaya mengenal pasti dan menganalisis faktor-faktor akademik dan bukan akademik yang mempengaruhi pencapaian pelajar dalam kursus Matematik Kejuruteraan di PTSB. Diharapkan hasil kajian ini dapat menjadi rujukan pihak institusi dan pensyarah dalam merancang pendekatan pengajaran serta menyediakan program sokongan pelajar yang lebih efektif, ke arah peningkatan pencapaian akademik dan pembangunan sahsiah pelajar yang lebih holistik.

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KETAGIHAN MEDIA SOSIAL DAN GAYA HIDUP PELAJAR TVET: ANALISIS PENGGUNAAN, KESAN DAN SIKAP

Siti Hajar binti Saad@Mohd Yusoff[1]*, Norhayati binti Ismail[2], Faizatulhaida binti Md Isa[1]

[1]Jabatan Matematik Sains & Komputer, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim,Kedah, Malaysia

[2]Jabatan Akademik, Politeknik METrO Tasek Gelugor,13200 Kepala Batas, Pulau Pinang, Malaysia

*Corresponding author's email: siti_hajar@ptsb.edu.my

Abstrak

Dalam era digital yang serba pantas, media sosial telah menjadi elemen penting dalam kehidupan pelajar. Namun, kecenderungan untuk menggunakannya secara berlebihan menimbulkan kebimbangan terhadap gaya hidup dan kesejahteraan pelajar khususnya dalam kalangan pelajar TVET. Kajian ini dijalankan bagi menilai tahap ketagihan media sosial dan kesannya terhadap gaya hidup pelajar TVET di lima buah politeknik di Zon Utara. Objektif utama kajian ini adalah untuk: (1) menilai tahap ketagihan media sosial dalam kalangan pelajar TVET, (2) mengenal pasti kesan ketagihan media sosial terhadap kesihatan mental pelajar dan (3) menilai pengaruh ketagihan media sosial terhadap gaya hidup sihat pelajar. Kajian ini menggunakan pendekatan kuantitatif berbentuk tinjauan, melibatkan seramai 102 orang pelajar yang dipilih secara rawak dari lima politeknik. Data dikumpulkan melalui soal selidik dalam talian yang diadaptasi daripada kajian terdahulu dan dianalisis menggunakan statistik deskriptif menggunakan perisian SPSS versi 27. Dapatan kajian menunjukkan bahawa tahap ketagihan media sosial adalah pada tahap sederhana tinggi dalam kalangan pelajar TVET. Hasil kajian boleh dimanfaatkan oleh pendidik, ibu bapa dan pembuat dasar untuk memahami kesan ketagihan media sosial secara lebih mendalam. Kajian mencadangkan agar tindakan awal oleh institusi pendidikan dan pihak berkepentingan diambil bagi mengurangkan ketagihan media sosial serta memupuk gaya hidup yang seimbang dalam kalangan pelajar TVET.
Kata Kunci: Ketagihan Media Sosial; Gaya Hidup; TVET.

1. Pengenalan

Dalam era digital yang serba pantas, media sosial telah menjadi elemen penting dalam kehidupan seharian khususnya dalam kalangan pelajar. Platform seperti Instagram, TikTok dan Twitter bukan sahaja menjadi alat komunikasi tetapi ia juga menjadi medium utama untuk hiburan, pembelajaran dan pembentukan identiti sosial. Namun, penggunaan media sosial yang tidak terkawal telah membawa kepada fenomena ketagihan yang kini diiktiraf sebagai satu isu psikologi dan sosial yang signifikan terutamanya dalam kalangan pelajar Institusi Pendidikan dan Latihan Teknikal dan Vokasional (TVET).

Ketagihan ini bukan sahaja mempunyai implikasi yang mendalam terhadap kesihatan mental individu, tetapi ia juga memberi kesan yang signifikan terhadap pelbagai aspek gaya hidup pelajar. Menurut Wiss et al. (2020) dalam konteks pola pemakanan, pelajar yang terjebak dalam ketagihan ini mungkin akan mengabaikan diet seimbang, memilih makanan yang tidak sihat atau berlebihan dalam pengambilan makanan tertentu yang dapat merosakkan kesihatan. Selain itu, kualiti tidur mereka juga terjejas, di mana ketagihan ini boleh menyebabkan insomnia atau

gangguan tidur lain, seterusnya menjadikan mereka kurang cergas dan berfungsi dengan baik pada siang hari. Interaksi sosial turut terkesan apabila pelajar lebih banyak meluangkan masa dalam talian berbanding bersemuka, sekali gus mengganggu pembangunan hubungan interpersonal yang sihat.

Keadaan ini mewujudkan satu kitaran yang negatif, di mana kesihatan mental yang merosot akan menyebabkan gaya hidup yang lebih tidak sihat, seterusnya memburuk keadaan mental mereka. Kesan jangka panjang daripada ketagihan media sosial ini boleh menyebabkan masalah yang lebih serius seperti kebimbangan dan kemurungan, serta mengganggu perkembangan interpersonal yang sihat dalam kalangan individu muda (Prabhakararao, 2016). Ketagihan media sosial dalam kalangan belia adalah satu isu yang semakin membimbangkan. Kajian terdahulu menunjukkan bahawa penggunaan media sosial yang berlebihan berkait rapat dengan tekanan psikologi, tahap produktiviti yang rendah dan masalah hubungan interpersonal (Satici et al., 2021; Stronge et al., 2019).

Namun, masih terdapat jurang pengetahuan mengenai bagaimana ketagihan ini secara langsung mempengaruhi gaya hidup pelajar secara holistik, termasuk aspek kesihatan fizikal, mental dan sosial. Selain itu, pendekatan yang digunakan untuk menangani isu ini sering kali bersifat reaktif dan kurang menekankan pada pendidikan awal dan kesedaran. Oleh itu, objektif kajian adalah menilai tahap ketagihan media sosial dalam kalangan pelajar, mengenal pasti kesan ketagihan media sosial terhadap kesihatan mental pelajar dan menilai pengaruh ketagihan media sosial terhadap gaya hidup sihat pelajar TVET. Selain itu, kajian ini turut mencadangkan strategi pencegahan yang berkesan dan program intervensi yang dapat membantu pelajar mengatasi ketagihan media sosial dengan cara yang positif.

Kajian ini dijangka memberikan sumbangan bermakna kepada bidang pendidikan dan pembangunan pelajar. Hasil kajian didapati boleh dimanfaatkan oleh pendidik, ibu bapa dan pembuat dasar untuk memahami kesan ketagihan media sosial secara lebih mendalam. Seterusnya, ia juga dapat mencadangkan strategi intervensi dan pencegahan yang efektif serta memupuk amalan penggunaan media sosial secara bertanggungjawab dalam kalangan pelajar. Akhir sekali, kajian ini berpotensi menjadi rujukan penting dalam merangka dasar berkaitan literasi digital dan kesejahteraan pelajar TVET secara holistik.

2. Metodologi

2.1. Rekabentuk Kajian

Kajian ini dijalankan untuk mengenal pasti tahap ketagihan penggunaan media sosial terhadap gaya hidup dalam kalangan pelajar TVET. Reka bentuk kajian ini menggunakan pendekatan kuantitatif bagi tujuan pengumpulan data melalui edaran soal selidik secara dalam talian.

2.2. Populasi Kajian

Kajian ini melibatkan pelajar di lima buah politeknik di zon utara Malaysia iaitu pelajar Politeknik Tuanku Sultanah Bahiyah (PTSB), Politeknik METrO Tasek Gelugor (PMTG), Politeknik Seberang Perai (PSP), Politeknik Tuanku Syed Sirajuddin (PTSS) dan Politeknik Sultan Abdul Halim Muadzam Shah (POLIMAS). Pemilihan 102 responden ini menggunakan persampelan rawak dan responden telah melengkapkan soal selidik melalui platfom *Google Form*.

2.3. Instrumen Kajian

Instrumen kajian ini telah diadaptasi dan diubah suai daripada soal selidik yang digunakan dalam kajian oleh Andrew et al. (2020) yang meneliti faktor ketagihan media sosial dan kesannya terhadap gaya hidup belia di Malaysia. Nilai kebolehpercayaan (Cronbach's Alpha) instrumen adalah melebihi 0.7, menunjukkan tahap kebolehpercayaan yang baik. Responden dikehendaki menjawab soalan tersebut melalui platform *Google Form*. Soal selidik ini dibahagikan kepada empat bahagian iaitu Bahagian A merangkumi maklumat demografi responden dengan empat item, Bahagian B menilai tahap penggunaan media sosial dengan empat item , Bahagian C meneliti kesan penggunaan media sosial dengan enam item dan Bahagian D mengukur sikap responden terhadap penggunaan media sosial dengan lima item. Skala Likert lima mata seperti di Jadual 1 digunakan untuk mengukur setiap item dalam instrumen soal selidik, dengan pengelasan tahap yang diadaptasi berdasarkan Rahimah (2006), seperti yang dipetik dalam (Md Isa, F. et al., 2023).

Jadual 1. Skala likert 5 mata

Likert	Pengkelasan
1	Sangat Tidak Setuju
2	Tidak Setuju
3	Tidak Pasti
4	Setuju
5	Sangat Setuju

2.4. Analisis Data

Dalam kajian ini, data yang diperoleh daripada responden dianalisis secara kuantitatif meggunakan *Statistical Package for the Social Sciences* versi 27. Terdapat beberapa elemen penting dalam statistik deskriptif yang digunakan dalam menganalisis data iaitu nilai min dan sisihan piawai. Dalam kajian ini, analisis deskriptif digunakan untuk melihat secara menyeluruh demografi responden iaitu jantina, umur, tempat tinggal, dan tempat belajar. Seterusnya, analisis deskriptif turut digunakan untuk menjawab penggunaan, kesan dan sikap serta pandangan pelajar terhadap media sosial. Jadual 2 menunjukkan pengukuran tahap yang digunakan oleh (Pallant, 2010).

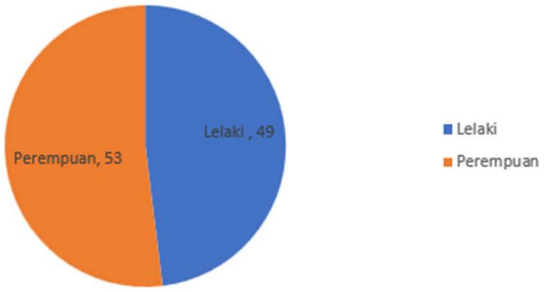
Jadual 2. Skor min (Pallant, 2010)

Skor Min	Tahap
1.00-2.33	Rendah
2.34-3.67	Sederhana
3.68-5.00	Tinggi

3. Dapatan dan Perbincangan

3.1. Responden Kajian

Bahagian ini melaporkan dapatan analisis responden terhadap aspek jantina seperti yang ditunjukkan pada Rajah 1.



Rajah 1. Jantina Responden

3.2. Penggunaan Media Sosial

Jadual 3. Tahap Penggunaan Media Sosial

Bil	Item	Min	Sisihan Piawai (SP)	Tahap Min
A1	Saya menghabiskan lebih daripada 3 jam sehari menggunakan media sosial.	3.99	0.850	Sederhana
A2	Saya merasa tidak selesa apabila saya tidak dapat mengakses mediasosial sepanjang hari.	3.12	1.056	
A3	Saya sering memeriksa media sosial saya walaupun saya sedang sibuk dengan tugas lain.	2.99	1.156	
A4	Saya lebih banyak meluangkan masa di media sosial berbanding berinteraksi secara langsung dengan keluarga atau rakan.	2.65	1.114	
Keseluruhan Min		3.19		Sederhana

Jadual 3 menunjukkan bahawa tahap penggunaan media sosial dalam kalangan pelajar TVET berada pada tahap sederhana dengan min keseluruhan 3.19. Item A1 mencatatkan min tertinggi (3.99, SP = 0.850), menunjukkan majoriti pelajar menggunakan media sosial lebih daripada tiga jam sehari. Ini selari dengan kajian oleh Abdullahi et al. (2024) yang mendapati amalan biasa bagi pelajar untuk memulakan hari mereka dengan menyemak aplikasi media sosial, sekali gus menunjukkan penggunaan masa yang panjang terhadap platform tersebut dalam kehidupan seharian mereka. Item A2 merekodkan min 3.12 (SP = 1.056), mencerminkan kewujudan kebergantungan terhadap media sosial apabila tidak dapat diakses. Item A3 pula menunjukkan min 2.99 (SP = 1.156), menunjukkan pelajar kadangkala menggunakan media sosial walaupun sedang sibuk. Item A4 mencatatkan min paling rendah, 2.65 (SP = 1.114), menandakan penggunaan media sosial belum mengganggu interaksi sosial secara signifikan.

Secara keseluruhan, pelajar menggunakan media sosial secara sederhana dengan fokus utama pada tempoh masa harian dan belum menunjukkan kesan besar terhadap tanggungjawab atau hubungan sosial. Ini telah menjawab objektif pertama iaitu menilai tahap ketagihan media sosial dalam kalangan pelajar TVET. Dapatan ini konsisten dengan Hussin et al. (2021), yang melaporkan penggunaan media sosial dalam kalangan pelajar politeknik berada pada tahap sederhana tinggi.

3.3. Kesan Media Sosial Terhadap Gaya Hidup

Jadual 4. Kesan Penggunaan Media Sosial Terhadap Gaya Hidup

Bil	Item	Min	Sisihan Piawai (SP)	Tahap Min
B1	Penggunaan media sosial memberi kesan negatif terhadap kesihatan mental saya (contohnya, perasaan cemas, kemurungan, atau stres).	3.22	1.199	Sederhana
B2	Saya merasa perlu untuk terus mengemas kini status atau gambar di media sosial untuk mendapat perhatian atau pengiktirafan.	2.12	0.848	
B3	Penggunaan media sosial telah mengganggu rutin harian saya (contohnya, kurang tidur, kurang bersenam).	3.25	1.094	
B4	Saya lebih terdedah kepada gaya hidup atau trend yang tidak sihat melalui media sosial.	2.38	1.053	
B5	Penggunaan media sosial mempengaruhi cara saya berfikir tentang penampilan dan gaya hidup saya.	3.23	1.080	
B6	Saya sering merasa tekanan sosial untuk mengikuti tren atau gaya hidup yang ditunjukkan oleh influencer atau rakan di media sosial.	2.25	1.012	
Keseluruhan Min		2.74		Sederhana

Jadual 4 menunjukkan bahawa kesan penggunaan media sosial terhadap gaya hidup pelajar TVET berada pada tahap sederhana, dengan min keseluruhan 2.74. Dapatan ini menggambarkan bahawa media sosial memberi kesan yang ketara kepada beberapa aspek kehidupan pelajar, terutamanya dari sudut rutin harian dan kesihatan mental, namun tahap pengaruh sosial masih rendah.

Item B3 mencatatkan min tertinggi (3.25, SP = 1.094), yang menunjukkan bahawa penggunaan media sosial telah mengganggu rutin harian pelajar seperti waktu tidur dan aktiviti fizikal. Ini selari dengan dapatan Wiss et al. (2020) yang menyatakan bahawa penggunaan media sosial secara berlebihan boleh menyebabkan gangguan corak tidur dan menurunkan tahap aktiviti fizikal, seterusnya memberi kesan kepada kesihatan keseluruhan.

Seterusnya, item B5 (min = 3.23, SP = 1.080) dan B1 (min = 3.22, SP = 1.199) menunjukkan bahawa pelajar merasakan penggunaan media sosial memberi kesan terhadap cara mereka menilai penampilan diri serta menyumbang kepada tekanan mental seperti kebimbangan dan stres. Penemuan ini konsisten dengan kajian oleh Stronge et al. (2019), yang mendapati pengguna media sosial cenderung mengalami ketidakpuasan terhadap imej diri akibat perbandingan sosial yang berlaku secara tidak sedar. Kajian oleh Satici et al. (2021) turut menyokong dapatan ini dengan menyatakan bahawa media sosial boleh mencetuskan tekanan psikologi dan emosi dalam kalangan pengguna muda.

Sebaliknya, item B2 (min = 2.12, SP = 0.848) dan B6 (min = 2.25, SP = 1.012) menunjukkan bahawa pelajar tidak terlalu tertekan untuk sering mengemas kini status atau mengikuti trend media sosial. Item B4 (min = 2.38, SP = 1.053) juga menunjukkan bahawa pendedahan kepada gaya hidup tidak sihat melalui media sosial adalah pada tahap rendah. Hal ini menunjukkan bahawa pelajar masih mempunyai tahap kawalan kendiri yang baik dalam menapis kandungan yang boleh mempengaruhi gaya hidup mereka. Ini sejajar dengan dapatan Hussin et al. (2021) yang menunjukkan pelajar politeknik mempunyai kesedaran kendiri terhadap kesan negatif media sosial.

Secara keseluruhannya, penggunaan media sosial memberi kesan kepada gaya hidup pelajar TVET pada tahap sederhana, terutamanya dari sudut rutin harian dan persepsi kendiri, manakala tekanan sosial dan pengaruh luaran masih berada pada tahap rendah. Implikasi ini menunjukkan keperluan untuk menerapkan pendidikan literasi digital dan strategi pengurusan masa agar pelajar dapat mengekalkan keseimbangan antara penggunaan media sosial dan gaya hidup sihat.

3.4. Sikap Dan Pandangan

Jadual 5 : Sikap Dan Pandangan

Bil	Item	Min	Sisihan Piawai (SP)	Tahap Min
C1	Saya percaya bahawa media sosial sepatutnya dikawal lebih ketat untuk mengelakkan ketagihan di kalangan belia.	4.13	0.804	
C2	Saya berusaha untuk mengurangkan masa yang saya habiskan di media sosial dengan cara menetapkan had masa penggunaan.	3.98	0.771	
C3	Saya merasa lebih bahagia apabila saya tidak terlalu bergantung kepada media sosial.	3.69	0.923	Tinggi
C4	Saya percaya penggunaan media sosial berlebihan memberi kesan negatif terhadap prestasi akademik saya.	3.84	1.097	
C5	Saya berasa lebih dekat dengan rakan-rakan saya melalui media sosial berbanding interaksi secara langsung.	3.35	1.096	
	Keseluruhan Min	3.80		Tinggi

Jadual 5 menunjukkan bahawa sikap dan pandangan pelajar TVET terhadap penggunaan media sosial berada pada tahap tinggi, dengan min keseluruhan 3.80. Dapatan ini menunjukkan bahawa pelajar mempunyai kesedaran yang baik terhadap kesan penggunaan media sosial dan menunjukkan kecenderungan untuk mengawal tingkah laku penggunaan secara sedar.

Item C1 mencatatkan min tertinggi (4.13, SP = 0.804), yang menunjukkan bahawa majoriti pelajar bersetuju bahawa penggunaan media sosial perlu dikawal bagi mengelakkan ketagihan. Ini menunjukkan kesedaran kritikal dalam kalangan pelajar terhadap risiko penyalahgunaan media sosial, selaras dengan dapatan Andreassen et al. (2017) yang menekankan pentingnya kawalan kendiri dan pengawalan peraturan penggunaan sebagai strategi pencegahan awal.

Item C2 (min = 3.98, SP = 0.771) dan C3 (min = 3.69, SP = 0.923) pula menunjukkan bahawa pelajar berusaha mengawal masa penggunaan media sosial dan menyedari manfaat emosi apabila kurang bergantung kepada platform tersebut. Ini disokong oleh kajian Hussin et al. (2021),

yang mendapati pelajar politeknik yang mempunyai amalan kawalan masa menunjukkan tahap kesejahteraan psikologi yang lebih baik.

Item C4 (min = 3.84, SP = 1.097) menunjukkan bahawa pelajar mengakui kesan negatif penggunaan media sosial terhadap prestasi akademik. Pandangan ini sejajar dengan Abdullahi et al. (2024), yang menunjukkan bahawa ketagihan media sosial memberi kesan negatif terhadap prestasi akademik pelajar, dan penemuan ini selari dengan hasil kajian ini yang mendapati hubungan signifikan antara penggunaan media sosial secara berlebihan dan penurunan keupayaan akademik. Prabhakararao (2016), yang mendapati bahawa pelajar yang ketagih media sosial menunjukkan prestasi akademik yang lebih rendah berbanding pelajar yang menggunakan secara terkawal.

Sementara itu, item C5 (min = 3.35, SP = 1.096) menunjukkan bahawa sebahagian pelajar masih merasakan hubungan sosial secara maya lebih bermakna berbanding interaksi secara langsung. Ini mencerminkan kesan normalisasi interaksi digital dalam kalangan belia masa kini, sebagaimana dibincangkan oleh Stronge et al. (2019).

Secara keseluruhannya, dapatan menunjukkan bahawa pelajar mempunyai sikap positif ke arah kawalan kendiri dan kesedaran risiko, namun masih mengekalkan penggunaan media sosial sebagai alat sosial yang penting. Ini menunjukkan bahawa strategi pendidikan literasi digital dan sokongan emosi berasaskan institusi dapat membantu pelajar mengekalkan keseimbangan antara keperluan sosial dan akademik sekaligus telah menjawab objektif ketiga.

4. Kesimpulan

Hasil kajian menunjukkan bahawa pelajar TVET menggunakan media sosial pada tahap sederhana, dengan kecenderungan menghabiskan lebih tiga jam sehari di platform media sosial. Penggunaan ini memberi kesan kepada rutin harian serta kesihatan mental pelajar, termasuk gangguan tidur dan tekanan emosi. Ini selari dengan dapatan Wiss, Avena dan Gold (2020) yang menegaskan bahawa tingkah laku ketagihan, termasuk yang berkaitan dengan aktiviti harian seperti makan atau media sosial boleh mengganggu kestabilan psikososial dan kesejahteraan individu.

Di samping itu, pelajar menunjukkan sikap yang positif terhadap kawalan kendiri dan menyedari kesan negatif media sosial terhadap prestasi akademik. Ini disokong oleh Abdullahi et al. (2024) yang menekankan kepentingan pengawalan penggunaan media sosial bagi melindungi pencapaian akademik pelajar.

Secara keseluruhan, pelajar mempunyai kesedaran yang baik, namun masih memerlukan intervensi literasi digital dan sokongan kendiri bagi membantu mereka mengekalkan keseimbangan antara keperluan sosial dan akademik dalam gaya hidup digital masa kini.

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THE EFFECT OF GAMIFICATION ON LEARNING MOTIVATION OF POLYTECHNIC STUDENTS IN MEDAN CITY

Vina Yuliana[1], Febri Isnan Nazli[2], Muhammad Sofran Nugraha[3], Ghifari Ahmad Lamanjiji[3], Elserra Siemin Ciamas[4], Fauzi Akbar Maulana Hutabarat[5]*

[1]International Marketing Management, Politeknik Cendana, 20222 Kota Medan Sumatera Utara, Indonesia

[2]Coorporate Management, Politeknik Cendana, 20222 Kota Medan Sumatera Utara, Indonesia

[3]Computer Graphics Engineering Technology, Politeknik Cendana, 20222 Kota Medan Sumatera Utara, Indonesia

[4]Marketing Management, Politeknik Cendana, 20222 Kota Medan Sumatera Utara, Indonesia

[5]Center for Research and Community Service, Politeknik Cendana, 20222 Kota Medan Sumatera Utara, Indonesia

*Corresponding author e-mail address: famhutabarat@gmail.com

Abstract

The development of digital technology has driven various innovations in the field of education, including the implementation of gamification as an approach to enhance learning quality. This study aims to analyze the influence of gamification on the learning Motivation of Polytechnic Cendana students in Medan City, Indonesia. The research employs a quantitative method with a survey approach. The study population comprises Cendana Polytechnic students in Medan City enrolled in various academic programs. The sample will be selected using a stratified random sampling technique, targeting a minimum of 100 respondents. Data analysis will be conducted using linear regression, with the assistance of SPSS 26 software. This research is expected to make a significant contribution to understanding the impact of gamification on the learning interest of Polytechnic students in Medan City. The findings are anticipated to serve as a basis for developing innovative and technology-driven learning strategies that align with the needs of today's younger generation.
Keywords: Gamification; Student Learning Motivation; Vocational Education.

1. Introduction

In recent years, digital technology has revolutionized educational landscapes, prompting extensive innovation in teaching and learning processes. One notable development is the rise of gamification, which involves incorporating game elements—such as points, badges, leaderboards, and narratives—into non-game settings like classrooms to enhance motivation and engagement (Deterding et al., 2011). In higher education specifically, gamification has attracted attention for its potential to combat declining intrinsic motivation among students (Ryan & Deci, 2020) and to make learning more interactive and enjoyable (Murillo-Zamorano et al., 2021); (Alhammad & Moreno, 2018)The gamification strategies applied in education, also

known as gamified learning experiences, aim to promote a gameful state in students(Ratinho & Martins, 2023)

Empirical studies have shown that gamification can significantly enhance student engagement and intrinsic motivation. For instance, a meta-analysis by Xu et al. (2021) and Jaramillo-Mediavilla et al. (2024) concluded that gamification supports the fulfillment of psychological needs—competence, autonomy, and relatedness—leading to an increase in intrinsic motivation and academic performance. Self-Determination Theory (SDT), originally formulated by Ryan & Deci (2020), provides a strong theoretical basis for these findings, asserting that learning environments must satisfy autonomy, competence, and relatedness to foster intrinsic motivation. Still, the literature reveals mixed outcomes: some studies demonstrate only short-term motivational gains due to novelty effects (Hadi Mogavi et al., 2022); Review by (Alhammad & Moreno, 2018), while others caution that poorly designed gamification—especially with an overemphasis on extrinsic rewards—can undermine intrinsic motivation via overjustification effects (Mekler et al., 2017).

Despite considerable progress, unresolved issues remain. First, many studies focus on general gamification constructs rather than isolating specific elements (badges, challenges, narratives) to identify which components most effectively influence motivation (Jaramillo-Mediavilla et al., 2024). Second, a dearth of longitudinal research limits understanding of how motivational effects evolve over time and whether initial novelty benefits persist. Third, although SDT is widely recommended as the theoretical underpinning of gamification design, it is often applied superficially in educational research (Jaramillo-Mediavilla et al., 2024; Tyack & Mekler, 2020).

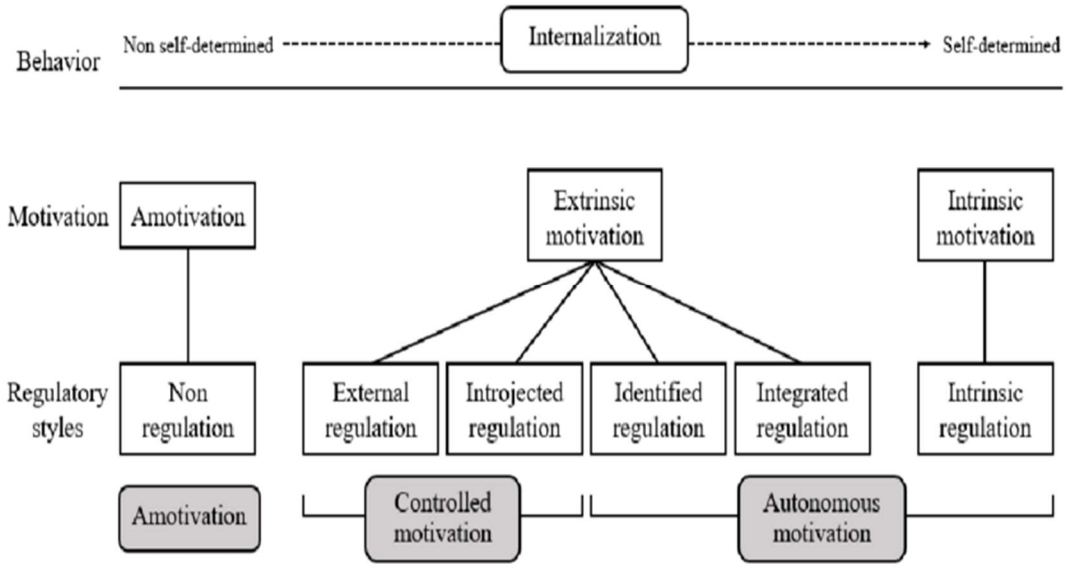


Fig. 1. Self-Determination Theory Framework (Ryan & Deci, 2017)

This study aims to fill these gaps by empirically examining the effect of gamification—treated as a unified construct—on learning motivation among students at Cendana Polytechnic in Medan City, Indonesia. By utilizing a validated and reliable survey instrument, along with simple linear

regression analysis, this research quantifies the extent to which gamification predicts motivation. The study contributes to a nuanced understanding of how gamified interventions, analyzed through the lens of SDT and cognitive evaluation theory, can support intrinsic motivation in a non-Western higher education context. These insights are especially valuable for educators and policy-makers seeking to implement evidence-based, culturally relevant gamification strategies in technical education.

2. Methodology

This research uses a quantitative research method with an explanatory approach to analyze the relationship between Gamification and Student Learning Motivation using statistical procedures. The population in this study was all Cendana Polytechnic students who experienced Gamification in their learning process. The population size in this study is unknown. The number of research samples was calculated using the formula approach from Isac Michael (Siregar, 2017), namely:

$$n = \frac{(Z\alpha/2)^2 \, p.q}{e^2} \quad (1)$$

Where:

n = number of samples
p = population proportion
q = 1- p
$Z\alpha$ = confidence/significance level
e = margin of error

In determining the research sample, researchers used a 95% confidence level with a 10% margin of error. Based on the formula above, the number of samples obtained was 97 students.

The sampling technique used in this study is a non-probability sampling technique with the accidental sampling method, which is a sampling technique based on chance. Members of the population who are encountered by researchers and are willing to become respondents are sampled (Elvina et al., 2021). This research uses a survey method to collect research data by distributing questionnaires to research samples.

Before conducting data analysis tests and hypothesis tests, this study must meet the validity and reliability testing criteria, which are to ensure that all items in the study are declared valid and reliable for use. Then, to obtain good quality research data, classical assumption testing is also carried out, where this classical assumption test consists of a normality test, a multicollinearity test, and a heteroscedasticity test.

Then the research data analysis test was carried out by using the correlation method, which is to see how significant the relationship between the independent variable and the dependent variable is. Researchers used the Product-Moment correlation formula. Then the coefficient of determination, which is to show the extent to which the contribution of the independent variables in the regression model is able to explain the variation of the dependent variable, and simple regression analysis, which is used to measure much influence of the independent variable and the dependent variable.

To answer research questions, this study also uses hypothesis testing, which consists of the T-test. This T-test will show how much influence the independent variables have on the dependent variable.

3. Results and Discussion

3.1 Descriptive Statistics

Table 1. The Demographics of Respondents

Variable	Count	Percentage
Gender		
Male	47	48,5%
Female	50	51,5%
Age		
18-20	50	51,5%
21 or Older	47	48,5%
Year of Study		
2021	10	10,3%
2022	26	26,8%
2023	23	23,7%
2024	35	36,1%
Study Program		
Marketing Management	14	14,4%
Office Management	35	36,1%
International Marketing Management	27	27,8%
Tax Accounting	9	9,3%
Computer Graphics Engineering	9	9,3%
Game Play Experience (times)		
1	15	15,5%
2-3	26	26,8%
4-5	25	25,8%
>5	28	28,9%

Note. N = 97. This table presents the demographic distribution and gaming experience frequency among respondents.

The respondents consisted of 47 males (48.5%) and 50 females (51.5%). This indicates a fairly balanced gender distribution, with a slight majority of female participants. Such gender balance ensures that the findings are not heavily skewed by gender-specific perceptions. Based on the age of respondents, 50 students (51.5%) were between 18–20 years old, while 47 students (48.5%) were aged 21 or older. The near-equal split reflects a representative sample of both younger and older students within the Polytechnic system, allowing insights across age groups. The majority of respondents (36.1%) were in their most recent academic year (2024), suggesting that most participants had significant exposure to their academic environment and potentially more informed views on gamification in learning.

This diversity in academic programs contributes to a broader understanding of how gamification may impact students across different disciplines. Based on data of game play experience shows that the majority of students had multiple gaming experiences, with 54.7% having played more than 3 times. This indicates a generally high familiarity with game-based activities, which is relevant in assessing their perceptions and motivation toward gamified learning strategies.

3.2 Validity and Reliability Test Result

Table 2. Validity and Reliability Test Result

Variable	Item	r_{count}	r_{table}	Validity Status	Cronbach's Alpha
Gamification	X1	0,848	0,361	Valid	0,937
	X2	0,824	0,361	Valid	
	X3	0,756	0,361	Valid	
	X4	0,816	0,361	Valid	
	X5	0,775	0,361	Valid	
	X6	0,845	0,361	Valid	
	X7	0,759	0,361	Valid	
	X8	0,690	0,361	Valid	
	X9	0,848	0,361	Valid	
	X10	0,885	0,361	Valid	
Student Learning Motivation	Y1	0,845	0,361	Valid	0,956
	Y2	0,832	0,361	Valid	
	Y3	0,887	0,361	Valid	
	Y4	0,878	0,361	Valid	
	Y5	0,861	0,361	Valid	
	Y6	0,867	0,361	Valid	
	Y7	0,820	0,361	Valid	
	Y8	0,846	0,361	Valid	
	Y9	0,850	0,361	Valid	
	Y10	0,851	0,361	Valid	

Note. All items exceed the r-table threshold (0.361), indicating construct validity. Cronbach's alpha values >0.9 show strong internal consistency.

All item indicators for the gamification and student learning motivation variables showed r-count values higher than the r-table (0.361), indicating that each item was valid. The Cronbach's Alpha for gamification was 0.937 and for learning motivation was 0.956, both exceeding the threshold of 0.7, confirming the instruments were highly reliable.

The validity test results confirmed that all questionnaire items effectively measured the intended variables. High reliability coefficients indicated internal consistency among items, suggesting that the instruments were dependable for assessing the constructs.

3.3 Normality Test Result

Table 3. Normality Test Result
One-Sample Kolmogorov-Smirnov Test

		Unstandardized Residual
N		96
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	4.64761109
Most Extreme Differences	Absolute	.122
	Positive	.099
	Negative	-.122
Test Statistic		.122
Asymp. Sig. (2-tailed)		.051[c]

Note. a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.

The significance value (> .05) indicates that the data distribution is normal.

The Kolmogorov-Smirnov test resulted in a significance value of 0.051, which was greater than 0.05. This indicated that the residual data followed a normal distribution. Normality is a key assumption for regression analysis. With p > 0.05, the data met the normality assumption, thus supporting the validity of further parametric statistical tests used in the analysis.

3.4 Linearity Test Result

Table 4. Linearity Test Result
ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Student Learning Motivation * Gamification	Between Groups	(Combined)	3073.657	22	139.712	6.844	.000
		Linearity	2511.806	1	2511.806	123.047	.000
		Deviation from Linearity	561.852	21	26.755	1.311	.197
	Within Groups		1490.176	73	20.413		
	Total		4563.833	95			

Note. The significant linearity value (p < .001) and non-significant deviation (p > .05) confirm a linear relationship between variables.

The linearity significance was 0.000, indicating a linear relationship between gamification and student learning motivation. The deviation from linearity had a significance value of 0.197, which was greater than 0.05, confirming no significant non-linear relationship.

These results confirmed that the relationship between gamification and learning motivation was linear, validating the use of simple linear regression to test the research hypothesis.

3.5 Correlation Test Result

Table 5. *Correlation Test Result*
Correlations

		Gamification	Student Learning Motivation
Gamification	Pearson Correlation	1	.742**
	Sig. (2-tailed)		.000
	N	96	96
Student Learning Motivation	Pearson Correlation	.742**	1
	Sig. (2-tailed)	.000	
	N	96	96

Note. **. Correlation is significant at the 0.01 level (2-tailed).
Note. p < .01 (2-tailed). There is a strong positive correlation between gamification and student motivation.

The Pearson correlation coefficient between gamification and student learning motivation was 0.742, with a significance value of 0.000. This showed a strong and significant positive correlation between the two variables.

This strong positive correlation indicated that higher implementation of gamification was associated with higher levels of student motivation. The result supported the initial assumption that gamification could influence student engagement in learning activities.

3.6 Coefficient of Determination Test Result

Table 5. *Coefficient of Determination Test Result*

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.742[a]	.550	.546	4.672

Note. a. Predictors: (Constant), Gamification
b. Dependent Variable: Student Learning Motivation
Gamification explains 55% of the variance in student learning motivation.

The R Square value was 0.550, meaning 55% of the variance in student learning motivation could be explained by gamification. The adjusted R Square was 0.546, indicating minimal bias due to the sample size.

Gamification explained more than half of the variation in learning motivation, suggesting that it had a substantial impact. However, 45% of the variation remained unexplained, implying the potential influence of other factors not included in this study.

3.7 Simple Linear Regresion

Table 6**.** *Simple Linear Regresion*

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	7.088	3.132		2.263	.026
	Gamification	.786	.073	.742	10.727	.000

Note. a. Dependent Variable: Student Learning Motivation
Gamification has a statistically significant positive effect on learning motivation (**p** < .001).

The regression equation was:

$$\text{Learning Motivation} = 7.088 + 0.786 \times \text{Gamification}$$

The regression coefficient for gamification was 0.786 with a significance value of 0.000 (<0.05), indicating a statistically significant effect. The regression analysis confirmed that gamification had a significant positive effect on student learning motivation. For every one-unit increase in gamification score, the learning motivation increased by approximately 0.786 units, demonstrating the effectiveness of gamified learning strategies.

3.8 Hypothesis Test Result (t-test)

Based on Table 6, the t-value for the gamification variable was 10.727 with a significance level of 0.000. Since the p-value was below 0.05, the null hypothesis was rejected. The t-test results confirmed that gamification had a statistically significant effect on learning motivation. This

supported the research hypothesis and aligned with existing literature suggesting gamification as a motivational tool in educational settings.

3.9 Discussion

This study investigated the effect of gamification on the learning motivation of Cendana Polytechnic students in Medan City, Indonesia. The results demonstrated a strong and statistically significant positive relationship between gamification and learning motivation. Specifically, the Pearson correlation coefficient of 0.742 indicated a robust linear association between the two variables. Furthermore, simple linear regression analysis revealed that gamification had a significant impact on student learning motivation, with a regression coefficient of 0.786 and a p-value less than 0.05. These results align with findings from previous studies that highlight gamification as an effective strategy for enhancing student engagement and intrinsic motivation in educational contexts (Domínguez et al., 2013; Hamari et al., 2014). Other research findings also indicate that the implementation of gamification in learning has a significant impact on increasing learning motivation (Irnawati et al., 2024). The application of gamification positively affects students' motivation and engagement in lectures. Students feel more motivated and actively participate in learning activities when gamification elements are applied (Aziz & Marsofiyati, 2024).

The R^2 value of 0.550 suggests that gamification explained 55% of the variance in student learning motivation. While this indicates a substantial influence, it also implies that other factors—such as teaching quality, peer influence, individual learning styles, or access to digital resources—may contribute to student motivation and were not captured in this study.
These findings suggest that incorporating gamified elements into learning environments can serve as a valuable pedagogical tool to stimulate students' motivation. As today's learners are increasingly immersed in digital cultures, the integration of game-based techniques offers a relevant and appealing alternative to traditional instruction.

However, the research had several limitations. First, the study utilized a cross-sectional design, which limits the ability to infer causality. Longitudinal studies would be more effective in evaluating how gamification influences motivation over time. Second, the study was conducted in a specific geographic and educational context—Polytechnic students in Medan City—which may restrict the generalizability of the findings to other regions or academic levels. Third, while gamification was treated as a single construct in this analysis, future research could disaggregate its components (e.g., points, badges, leaderboards, narratives) to better understand which specific elements most significantly influence motivation.

In conclusion, this study confirms the positive effect of gamification on student learning motivation, reinforcing the growing body of evidence supporting the integration of game-based strategies in education. Educators and policymakers should consider adopting gamification in their instructional designs to foster a more engaging and motivating learning environment for students.

4. Conclusion

This study aimed to examine the effects of gamification on the learning motivation of Polytechnic students in Medan City, Indonesia. The findings provided empirical evidence of a strong and statistically significant positive relationship between gamification and student learning motivation. Through descriptive analysis, validity and reliability tests, and a simple linear

regression model, it was demonstrated that gamification significantly contributed to motivating students in their academic pursuits. The regression results showed that gamification explained 55% of the variance in learning motivation, highlighting its practical significance as an instructional approach. These results support the idea that gamified learning environments can enhance student engagement by making learning more interactive, rewarding, and enjoyable. In an increasingly digital world, integrating game elements into pedagogy may offer a meaningful response to the evolving needs and expectations of modern learners. Therefore, the study underscores the importance of adopting innovative teaching strategies to foster motivation and optimize educational outcomes.

4.1 Implications for Future Research

While the findings were promising, this study also revealed several directions for future research. First, future studies should consider employing a longitudinal design to examine the long-term effects of gamification on student motivation and academic performance over time. This approach could help determine whether motivational gains persist or diminish as novelty fades.

Second, future research needs to disaggregate gamification into its core components—such as points, badges, leaderboards, challenges, and narratives—and examine their individual and combined effects on student motivation. By identifying which specific elements are most effective in enhancing engagement, educators and instructional designers can tailor gamified interventions more strategically. For instance, while leaderboards may foster competitive drive in some learners, badges and progress tracking might be more effective for intrinsically motivated students.

Additionally, future studies should broaden the scope of inquiry to include diverse populations across various educational levels, institutional contexts, and cultural backgrounds, in order to increase the generalizability of findings. The use of qualitative methods, such as interviews and focus groups, is also recommended to capture deeper insights into students' subjective experiences and perceptions of gamified learning environments.

Finally, integrating robust psychological or behavioral theories—such as Self-Determination Theory, Flow Theory, or Expectancy-Value Theory—can offer a more comprehensive understanding of the mechanisms through which gamification influences learning motivation. Theory-informed research will contribute to the design of pedagogical approaches that are not only engaging but also grounded in well-established motivational principles.

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THE STRATEGY OF THE DEPARTMENT OF YOUTH, SPORTS, AND TOURISM IN DEVELOPING THE AGROTOURISM POTENTIAL OF PINANG MANCUNG SUBDISTRICT, TEBING TINGGI CITY

Olga Venisya Limbong*, Edi Winata

Sekolah Tinggi Ilmu Manajemen Sukma, 20219 Kota Medan Sumatera Utara ,Indonesia

*Corresponding author e-mail address: olgalimbong@gmail.com

Abstract

The purpose of this study is to analyse the strategy of the Department of Youth, Sports and Tourism in Tebing Tinggi City toward developing the agrotourism potential of Pinang Mancung Subdistrict. The core issue addressed in this study is the suboptimal utilization of agrotourism potential as a leading sector capable of driving local economic growth and improving community welfare. The research focuses on the policies, programs, and strategic measures undertaken by relevant government agencies to promote the agrotourism sector in the region. A descriptive qualitative method was used, using SWOT analysis to determine internal strengths, weaknesses and external threats and opportunities. These results indicate that an aggressive approach is the best since the area has notable advantages, including the strong agricultural culture, picturesque scenery, sufficient public facilities and the huge support of the local authorities and inhabitants. Underlying problem areas, such as human resource capacity and online advertising, need to be the subject of focused interventions through training programs and digital information dissemination. In addition, a pentahelix relationship model of government, universities, industry, community and media is also suggested in order to achieve agrotourism that is sustainable and competitive over the long term. It is proposed that this approach serve as a model for a creatively inclusive and educational tourism destination for the benefit of the local economy and community.
Keywords: Agrotourism; Development Strategy; Pentahelix.

1. Introduction

The creation of strategic projects in tourist destinations is essential in order to ensure the sustainability and competitiveness of these destinations in the new scenario of global tourism and the new demands of tourists. In the absence of a good strategy, the value of a destination can be missed, under-exploited, or impaired through bad, non-sustainable practices. Well-planned strategy results in responsible use of local resources, greater economic vitality of the community, preservation and expression of cultural identity, and better visitor experience. "Hence, strategic development is one of the key foundations to make tourism growth have a positive long long-lasting impact on society, economy and environment.

It is increasingly necessary to develop plans for tourist destinations, as it seems obvious that such a process is strategic to manage the tourist potential in an optimal, sustainable and strategic manner. Without its strategy fit and right, the destination may be the cause of its own loss of lustre, the chaos of governance and even ruin the physical environment. Strategic development allows for upgrading of service quality, introduction of new attractions, and the planning of promotional campaigns which enhance the attractiveness of a destination to a wider spectrum of visitors.

Studies show that Ngada Regency boasts several areas with high potential for the growth of agrotourism, such as Bajawa coffee gardens, Turetogo Bamboo Campus, Soka hot springs, Roda paddy fields, and Ogi waterfall, scattered across Bajawa, Golewa, and South Golewa. In the study, it is stressed that sustainable action, nature conservation, people empowerment, and effective utilization of local capacity are needed to support regional development and improve the quality of life of the people (Azi et al., 2024). Development of tourism destinations, particularly agrotourism, requires a well-focused strategy with balanced dependence on local resources. Strategies suggested include providing training and education for the management of agrotourism, and opening agricultural and forest lands to tourism sites. Partnership with tourism stakeholders and government agencies is also essential. For ensuring the sustainability of agrotourism, strengthening local promotion media and encouraging active local participation in innovation are also required (Hartaman et al., 2021).

Post-harvest processing management remains underdeveloped, which constrains the overall agrotourism value chain. The destination, nevertheless, has excellent potential as an active and contextual outdoor classroom. Seasonal change is the primary external threat anticipated, which has the potential to lower the region's aesthetic value. Thus, a development plan is deemed most appropriate to prioritizing the growth of nature and educational rural tourism, utilizing low-cost ticketing as a competitive advantage, enhancing the quality of services through capacitation of institutions and communities, and leveraging digital technology for expanded promotional coverage and marketing of the destination as a good alternative learning site to classroom education (Aiman et al., 2021). Several strategies are found for the development of natural resources, particularly in agrotourism. These include improving infrastructure and facilities, increasing marketing, and establishing linkages with the proper stakeholders, such as the local government and commercial distributors of rose apple varieties citra and delima. Active community involvement is also found to be important in spreading and promoting value-added rose apple products to more people (Fitriyani et al., 2024).

Setiling Village possesses diversified agrotourism potential in the commodities of coffee, durian, citrus, and crystal guava. Development strategies to be implemented include the use of government aid to manage local resources, strengthening human resource capacity to increase competitiveness, and marketing efforts to attract more visitors. Furthermore, agrotourism development is expected to be consistent with current tourism demand patterns, with the aid of providing adequate infrastructure and facilities (Harwadi et al., 2022). Other strategies that have been proposed to promote sustainable agrotourism development include improving the capacity of human resources, improving the quality of facilities and infrastructure, and strengthening institutional frameworks. The strategies play an important role in ensuring long-term sustainability and agrotourism growth (Pakpahan et al., 2023).

Pinang Mancung Subdistrict is one of the subdistricts in Bajenis Subdistrict, Tebing Tinggi City, North Sumatra, Indonesia. It is fairly well located – not far from the city centre but with the peace and greenery of a semi-rural place. One of its significant advantages is in the fertility of its land, which can accommodate small and mid-level farming. The region has relatively good soil and climatic conditions for growing horticultural and other agribusiness products in the tropics. Vegetable, fruit, and carbohydrate crops are grown in the yards and small village plots. This agricultural capacity turns Pinang Mancung into one of the main suppliers of crops in fresh condition towards the nearest urban markets.

Tebing Tinggi City Department of Youth Sports and Tourism plays an important role in stimulating economic growth in the region through tourism fields. Its mission is to increase the attractiveness of the city to travelers through the development, promotion, and support of the travel and tourism industry. Its main goals are the optimization of the cultural, natural and man-made tourism resources, and the protection of local values and habits. In cooperation with different partners, the department strives to develop tourism that is sustainable, competitive, and provides direct benefit to the well-being of the Continuum of Care.

In order to determine the development strategy of agrotourism potential in Pinang Mancung, an internal factor analysis (IFAS) is conducted to identify strengths and weaknesses. Furthermore, the macro environment must be analyzed in the light of opportunities and threats (EFAS matrix). The development of agrotourism programs is significant because it has the potential to uplift the quality of life and economic well-being of the area. Through an analysis of internal and external factors, this study sought to identify the agrotourism potential, the barriers and obstacles that exist, and the proper strategy for the development of agrotourism in Pinang Mancung.

2. Methodology

The study was carried out in Pinang Mancung Sub-district of Tebing Tinggi City in June 2025. This research uses a descriptive method with a qualitative approach. Research is an activity that collects, organizes data to choke off and answer the question annotative research questions (Abdillah et al., 2021). The research type is field research, where the researcher is directly involved with collecting data. Data was collected through observations with a structured checklist, interviews, questionnaires, and documentation to obtain relevant primary data according to the research problem (Rosyidah & Fijra, 2021).

The respondents interviewed were purposively selected. Purposive sampling was used to select the research participants based on the selection criteria that are relevant to the research objectives (Sugiyono, 2021). The interviewees came from different parties, including (1) the Department of Youth, Sports and Tourism of Tebing Tinggi municipality, (2) the official of Pinang Mancung subdistrict, (3) the local community group, and (4) Pinang Mancung society. Data collected in total from 10 participants.

For the formulation of agrotourism concepts, the SWOT analysis approach (Strengths, Weaknesses, Opportunities, Threats) was used. SWOT analysis is an instrument planning to examine the internal strengths and weaknesses and the external opportunities and threats of the business (Sasoko & Mahrudi, 2023). Stages of the SWOT analysis include:

a. Identifying Internal and External Factors

   There are two main groups of internal factors that need to be taken into an account for this type of project to provide a company (or a team) with a strategic solutions strategy linking up the actual and potential opportunities with the needs of its development. Opportunities and threats (risks) resulting from the external environment of the organization are assessed.

b. Constructing the IFAS (Internal Factor Analysis Summary) and EFAS (External Factor Analysis Summary) matrices

   i. Determine the factors that will stand for the organization’s strengths and weaknesses.

ii. Weigh each factor on a scale of 1.0 (very important) to 0.0 (not important,) also add weight to each location. The maximum for all factors is 1.00. “Weighting” from low to high is given based on the potential influence of each of the factors on the strategic outcome.

iii. Rate each factor between 1 (poor) and 5 (outstanding) according to its importance, modified to the relative condition and potential in Pinang Mancung Subdistrict. Opportunity Ratings are positive; a very attractive opportunity rates a 5, a lesser opportunity rates a 1. For threats, it's the other way around - a minor threat is rated 1, a significant threat is rated 5.

iv. Multiply the weight of the factor by the rating to determine the weighted score of each factor. A portfolio of weighted scores, ranging from 1.0 to 5.0, is derived.

v. Add the weighted scores to find the total weighted score of the organization. This end score reflects how well-prepared the organization is to respond to its outsourced strategic elements.

3. Results and Discussion

3.1 Agrotourism Potential in Pinang Mancung Subdistrict, Tebing Tinggi City

Table 1. Checklist Observation of Agrotourism Potential in Pinang Mancung Subdistrict

Component		Indicator	Score
a. Attraction	i.	There are horticultural and food crops in Pinang Mancung Subdistrict. Horticultural crops include vegetables such as spinach, water spinach and long beans. Food crops are primarily found in rice fields that produce paddy (rice).	5
	ii.	There are various agriculture-based activities available, including fruit picking, rice planting, and other forms of farming education.	5
	iii.	The presence of local agricultural wisdom, including traditional techniques and ancient farming tools.	3
	iv.	An aesthetically pleasing and beautiful landscape of plantations and rice fields.	5
	v.	The presence of attractive seasonal activities, such as harvest festivals, large-scale harvesting, and planting season tourism.	1
b. Amenities	i.	Accommodation facilities are currently unavailable throughout Pinang Mancung Subdistrict.	1
	ii.	Food stalls and restaurants offering local agricultural produce are not yet available in Pinang Mancung Subdistrict.	1
	iii.	Pinang Mancung Subdistrict provides several supporting facilities near the agro area, such as toilets, a mosque, parking spaces, and gazebos for visitors.	5
	iv.	Wi-fi is not yet available, but mobile data signals are generally stable.	4
	v.	The agricultural area in Pinang Mancung Subdistrict is already supported by clean and sufficient irrigation channels.	4

	vi.	There are currently no directional signs or informational markers guiding visitors to the farming and plantation areas in Pinang Mancung Subdistrict.	1
c. Accesibility	i.	There is already a road leading to the agricultural and plantation sites that can accommodate both small and large vehicles.	4
	ii.	There are already paths or trails within the plantation and rice field areas that can be comfortably accessed by visitors.	4
	iii.	The plantation and rice field areas are quite difficult to reach by public transportation, as they are not located along regular public transport routes.	2
d. Ancillary Services	i.	The area currently lacks sufficient human resources to provide qualified as local guiding services.	2
	ii.	There are no galleries, kiosks, or outlets available for selling processed agricultural products.	1
	iii.	There is no active online system for reservations and information currently available.	1
	iv.	Receiving support from the city government in the form of training, promotion, or infrastructure.	5
	v.	Farmer groups, tourism awareness groups, and agricultural collectives have already been established and are involved in tourism activities in Pinang Mancung Subdistrict.	5

Based on the research findings presented above, the following discussion is provided:

3.1.1 Attraction Potential of Agrotourism



Fig 1. Staple food crops

Pinang Mancung Subdistrict has an abundant agricultural inheritance of horticultural and staple food crops, which have been passed down from generation to generation. In this region, farming is not only a living but has also formed part of the social identity of the community. Curiously, they have mechanisms whereby outsiders have the privilege to work in the field, from sowing to harvesting, under controlled permission, provided by local farmers. This creates an enormous opportunity to develop immersive offerings for guests.



Fig 2. Farmers

Despite the farming technology that is increasingly advanced, farmers in Pinang Mancung Subdistrict still work by sticking to their land through local wisdom. Historically crude implements as hoes, machetes, and hand rakes, are still widely used today, although they are increasingly being complemented by tractors and cultivators to accelerate work. Contrast this mix of old and new with ongoing efforts to change, yet to hold on to the Serrano's traditional form as offerings of food.

The fact that there are native farmers who have inherited such a profession from generation to generation gives evidence of the continuity of local identity. Indeed, they are not just sustaining farming practices; they are also retaining local traditions and culture. Being a unique agrotourism of education, culture and sustainable elements, the strong cultural and ague rural heritage of Pinang Mancung is considered a great asset in developing agrotourism.



Fig 3. Rice field

The extent of the areas of plantation and rice field in the Subdistrict of Pinang Mancung is quite organized, so that it gives us get good impression of neatness and cleanliness. At the time of research, the land was bountiful; there were even green patches of grass all around. These factors make the place aesthetically beautiful not only a productive agricultural zone, but, a potential for nature and landscape-based tourism.

With all its potential natural beauty, Pinang Mancung was not yet able to develop its potential spirituality and culture. With no seasonally based agricultural events, no traditional planting or harvest thanksgiving, no local rites, and little remains in terms of culture that may attract visitors.

3.1.2 Amenities Potential of Agrotourism



Fig. 4. Public facilities

One of the strengths of this area is that they were able to provide sufficient public facilities, including a large parking area, clean toilets, a place to worship (mosque) and traditional huts or gazebos are used to rest. This infrastructure plays an important role experience-wise, providing one more incentive to stay longer and proving that the region is well prepared to be developed into the next great tourist destination. For internet connection, sorry to say that there's no Wi-fi service at the agrotourism site, but the signal is still working well, as Pinang Mancung Subdistrict is still included in the urban network coverage area. There are no facilities for overnight stay for tourists who come to visit agro agro-themed area of Pinang Mancung. Not have individuals been able to patronize food vendors or dining establishments that serve items made from local agricultural products. Visitors will need to provide their own food or find dining in the surrounding areas.

3.1.3 Accessibility Potential of Agrotourism



Fig 5. irrigation

The management of irrigation for the rice field area is one of this site's strongpoints: the irrigation ditches are in good condition and satisfy the water requirement of the farmland, although the area is not far from the urban area. one of the glaring short comings that need urgent attention is that there are no signages or directional boards to the rice field and plantation areas. For visitors, it has no signs, which makes it hard for visitors to find the place when visited, and it might disrupt the ease and convenience of people to engage in tourism activities that take place in the agrotourism area.

The agrotourism zone in Pinang Mancung Subdistrict has potential prospects in terms of accessibility and infrastructure. The access road to the farming area is already in use and in good condition; it can be used by cars, small buses and harvest trucks. It makes the visits of groups more comfortable and encourages tourism. In the rice fields and the plantation, some trails make the walk more manageable. These pathways offer visitors the opportunity to take part in farming practices, such as planting and harvesting, or simply enjoy a walk in a natural environment. This

is a value-added service for the visitors and light adventurous tour packages combining knowledge and pleasure can be developed.



Fig 6. access road

But public transportation remains a problem. The area is not accessible by public transport and travellers without their own transport may find it difficult to get there. This might be a challenge for young travelers, backpackers, or domestic tourists who rely on public transportation.

3.1.4 Ancillary Services Potential of Agrotourism

The main constraints of the agrotourism area of Pinang Mancung are the lack of trained local guides to accompany visitors during plantation and farming activities. Currently, this duty is performed by farmer group members, but they are still not so good at communicating. The net result is that visitors are not having the best experience that they could. Friendly guides who could convey analytic but lay communication were very necessary to have a “deep” and enjoyable visit. Travellers want more than to observe farmwork, they also want to hear interesting stories, get clear explanations and have somebody guiding them through the small path.

Another part of the problem is that information about the area is not readily found online. No description, pictures, or packages on the internet. Nor is there an online booking system. Without a digital footprint, potential visitors struggle to find information about the agrotourism site and online presence is key for the way people travel today. Nowadays, the majority of tourists use the internet and social media to get the information they need before deciding to visit. Sadly, details about this region are still scant online.

On the other hand, local and city governments have expressed concrete support by offering programs on cooking training, tourism awareness, the establishment of tourism groups (Pokdarwis) and donations of farming equipment. The village is also marketed by the local government on its official social media pages. At the local level, among others are Gapoktan, farmer groups and Pokdarwis have a role that is very deserving to be utilized as a boost to the development of agrotourism.

a. Challenges and Obstacles Faced by the Department of Youth, Sports, and Tourism of Tebing Tinggi City in Developing the Agrotourism Potential of Pinang Mancung Subdistrict

The following are some of the key challenges and obstacles currently faced:

i. Lack of Community Awareness

One of the main challenges faced by the Department of Youth, Sports, and Tourism (Disporapar) of Tebing Tinggi City in developing the agrotourism potential of Pinang Mancung Subdistrict is the low level of public awareness about the importance of tourism based on agriculture. Many local residents still view farming as a daily routine to meet basic needs, without recognizing the additional opportunities it offers in the tourism sector. This limited understanding leads to minimal community involvement in preparing the area to become a visitor-friendly destination. Some residents also do not realize that developing agrotourism is not only about improving the appearance of farmland or adding new facilities, but also about creating a positive image, maintaining cleanliness, providing good service, and supporting joint promotion efforts.

This lack of awareness poses a significant barrier, as active community participation is essential for the sustainability of agrotourism. Without strong support from local residents, many programs initiated by Disporapar tend to be one-sided or short-lived. In some cases, conflict may arise if tourism activities are seen as disruptive or burdensome. Therefore, Disporapar should focus on educational efforts through ongoing socialization, training, and community empowerment so that residents can understand the direct and indirect benefits of developing agrotourism. By increasing collective awareness, the local community can transform into a key partner for the government, rather than remaining as passive subjects in the development process. This will help ensure that agrotourism in Pinang Mancung grows inclusively and sustainably.

ii. Human Resource Competence Is Still Limited

Low public awareness such as to develop agrotourism potential in sub-district of Pinang Mancung Tebing Tingi City is one of the constraints of the Department of Youth, Sports, Culture, and Tourism (Disporapar) Tebing Tinggi City in developing the agrotourism potential of the Pinang Mancung Sub-District. Most villagers see successful farming, not a daily activity to make ends meet, but fail to realize the vast possibilities for it in the tourism industry. Because of a lack of awareness, community is not involved for the area to be an organized, visitor- friendly space. It is unknown to some residents that the development of agrotourism is not only the beautification of farmland and the addition of new facilities, but also image-building, the maintenance of sanitation, good service, collaborative promotion, etc.

This ignorance becomes a major obstacle because the role of community in promoting continuity in agro-tourism. Without having strong backing of local population many programs introduced by Disporapar becoming unilateral or temporal. There is also potential for conflict, where tourism activities are perceived as disruptive or irritating. Thus, Disporapar should prioritize socialization, training, and community empowerment in the form of education in order for residents to understand the positive effect of agrotourism both directly and indirectly. Through the increase in collective consciousness, the local can become an active partner and not a subservient subject in development process. It can help guarantee agrotourism in Pinang Mancung develops in a fair and sustainable manner.

iii. Local Community Lacks Innovation

In addition to these constraints, the Deparement of Youth, Sports and a Tourism (Disporapar) of Tebing Tinggi City also encountered the problems of lack of innovation among local communities (farmer groups and Gapoktan and tourism awareness (Pokdarwis)) in Pinang Mancung Subdistrict. While a formal Pokdarwis is in place to facilitate tourism activities, its operation is highly bureaucratic and still fails to be an innovative force at the village level. Local community life remains as monotonous as before while little has been done to think of innovative means to make the area appealing to tourists.

In this modern tourism era, Pokdarwis has more complex creativity, ranging from coding through educational tour packages to fruit picking programs to harvest festivals and photo spot to attract the younger generation. Because of ignorance, untrained mind and the fear in experimenting, these inventions have not come out yet. In implementation of digital promotion techniques are also weak. Given their lack of knowledge in managing social media accounts, professionalism in content creation, and the ability to market themselves online, Pinang Mancung really is an underdog. Disporapar should conduct targeted training on innovation that enhances the role Pokdarwis as a creative agent. Training will necessarily encompass attraction and addition skills, but also creating compelling digital content, using platforms such as Instagram, TikTok and Facebook and leveraging them to create and promote destination branding. Partnerships with universities, creative communities, or digital marketing practitioners can also help Pokdarwis to create innovations that cater to local potentials. This will encourage the development of Pinang Mancung not only as a destination based on natural and cultural values, but also in terms of the development of a tourism area that is dynamic and competitive.

iv. Plantation and Rice Field Land Is Still Owned by Individual Community Members

The other problem faced by Tebing Tinggi City's Department of Youth, Sports, and Tourism (Disporapar) in developing agrotourism in Pinang Mancung Subdistrict is related to land ownership. Most of the rice field and plantation areas are privately owned by certain individual members of the community. This poses a problem because not all of the landowners share the same vision or desire to open their land to tourism. Differences in interest between landowners typically create issues in collective management, profit distribution, and shared use of space. For example, some landowners only have an interest in agriculture and the cultivation of crops, while others would prefer to see tourism development. These differences can retard joint planning and long-term development. Private property also slows down the Department of Youth, Sports, and Tourism (Disporapar) of Tebing Tinggi City and local tourism organizations such as Pokdarwis from creating complete tourism packages since the use of land must be permitted by each owner. It also limits the construction of supporting facilities, such as trekking paths, educational sites, and rest areas, due to limited space access. If this issue is not addressed, it can be a major setback in optimally exploiting the agrotourism potential of the area.

To mitigate this, there has to be a partnership. There ought to be consultation between the government, Pokdarwis, and landowners to formulate collective appreciation of the social, economic, and environmental effects of agrotourism. One possible strategy is to

formulate a just partnership system or scheme of profit sharing where landowners get an immediate benefit from tourism activities. Therefore, the emergence of agrotourism in Pinang Mancung can continue in a more structured, participative, and combined way, and at the same time be respectful of landowners' rights and local agriculture culture sustainability.

v. Nearby Competitors Offering Similar Agrotourism Experiences

One of the greatest challenges for Pinang Mancung Subdistrict to overcome in building agrotourism is intense competition from similar sites around it in Deli Serdang Regency. Geographically close, Deli Serdang already established some successful agrotourism destinations that are well-known among tourists. These places are better equipped, better promoted, and better planned tour packages. It makes it difficult for Pinang Mancung to attract tourists, especially if it cannot offer something different or more desirable than the other options. The majority of agrotourism destinations in Deli Serdang have already gained solid brands, either on social media or through travel agents. This makes them obtain a considerable market through tourism. Pinang Mancung will lose the race if it is not able to offer a unique experience to tourists or boost online promotion. Tourists prefer going to places that are familiar and have already been demonstrated to be rewarding. This is an issue of physical infrastructure, but also of destination management, creativeness in attractions, and local population's capacity to establish a distinctive image.

To face this competition, Disporapar and Pokdarwis need to devise strategies to market local uniqueness. This can be done by adopting the culture of traditional farming, advancing local wisdom, and offering closer and more authentic experiences. No less significant is improving digital promotion through social media and online reservation websites. With increased visibility and clear identity, agrotourism in Pinang Mancung can become a strong alternative in North Sumatra Province's competitive tourist market.

b. Development Strategies for Agrotourism Potential in Pinang Mancung Subdistrict by the Department of Youth, Sports, and Tourism of Tebing Tinggi City

i. Internal Factor Analysis Summary Matriks (IFAS)

Table 2. Internal Factor Analysis Summary Matriks

Internal Factors	Weight	Rating	Score
Strengths			
Unique agricultural culture	0.060	5	0.300
Availability of agriculture-based activities	0.060	5	0.300
Presence of local agricultural experiences	0.060	3	0.180
Beautiful and well-organized plantation and rice field landscape	0.060	5	0.300
Sufficient supporting facilities	0.060	5	0.300
Adequate mobile network signal	0.060	4	0.240
Clean and functional irrigation channels	0.060	4	0.240
Accessible by various types of vehicles	0.060	4	0.240
Presence of trekking paths in the field	0.060	4	0.240
Government support (village/city level)	0.060	5	0.300
Total Strengths Score			2.640
Weaknesses	Weight	Rating	Score

Internal Factors	Weight	Rating	Score
No regular seasonal farming activities	0.058	1	0.058
No available homestay accommodation	0.057	1	0.057
No food stalls or restaurants offering local agricultural products	0.057	1	0.057
No directional signs leading to the agro area	0.057	1	0.057
Difficult to access using public transportation	0.057	2	0.114
No skilled local guides for agricultural tourism	0.057	2	0.114
Limited online information about the agro area (maps, packages, general overview)	0.057	1	0.057
Total Weaknesses Score			0.514
Total IFAS Score	1		3,154

Based on the weighting result of the IFAS matrix, the accumulated score obtained is 3.154, indicating that internal factors of agrotourism in Pinang Mancung Subdistrict are relatively robust. With a distinctive agriculture culture, presence of agriculture-related activities, well-organized and looking-beautiful plantations and rice fields, assistance from the village government, and city government, are some of the strengths. All these variables acquired the maximum score of 0.300, which reflects their significant impact on the agrotourism development potential of Pinang Mancung.

Under weaknesses, the most serious internal weaknesses that were mentioned in the agrotourism industry include the absence of accommodation or homestay facilities, food stalls or dining areas offering local farm produce, tourist signages guiding tourists to agro destinations, and the low promotion and web presence. These were each scored at 0.057, indicating serious issues that would limit tourist entry and hinder public exposure to the destination.

ii. External Factor Analysis Summary Matriks

Table 3. External Factor Analysis Summary Matriks

External Factors	Weight	Rating	Score
Opportunities			
Development of educational tour packages	0.100	5	0.500
Proximity to urban areas	0.100	5	0.500
Post harvest product processing	0.100	3	0.300
Support from city government	0.100	5	0.500
Adequate agricultural knowledge among local residents	0.100	5	0.500
Total Opportunities Score			2.300
Threats	Weight	Rating	Score
Low public awareness	0.100	1	0.100
Limited human resource capacity	0.100	1	0.100
Local community lacks innovation	0.100	1	0.100
Plantation and rice field land is still privately owned	0.100	2	0.200
Strong competition from similar agrotourism destinations in Deli Serdang	0.100	2	0.200
Total Threats Score			0.700

External Factors	Weight	Rating	Score
Total EFAS Score	1		3.000

With the weighting results of the EFAS matrix, the composite score obtained is 3.000, indicating that external factors influencing agrotourism in Pinang Mancung Subdistrict are very strong. For instance, opportunities such as the development of educational tourism packages, strategic proximity to cities, support from the city government, and a proper comprehension of agriculture by people are some of the strongest external factors with each of them scoring very high at 0.500.

On the other hand, certain external threats have been suggested by a score of 0.100 that include low public awareness, limited human resource capacity, and a local community that is yet to demonstrate innovative behavior.

As per the presentation of data in IFAS and EFAS matrices, the process of decision-making for the determination of development strategies for Pinang Mancung Subdistrict's agrotourism potential by the Department of Youth, Sports, and Tourism of Tebing Tinggi City is as below:

Total Strengths – Total Weaknesses = 2.640 – 0.514 = 2.126
Total Opportunities – Total Threats = 2.300 – 0.700 = 1.600

iii. External Factor Analysis Summary Matriks

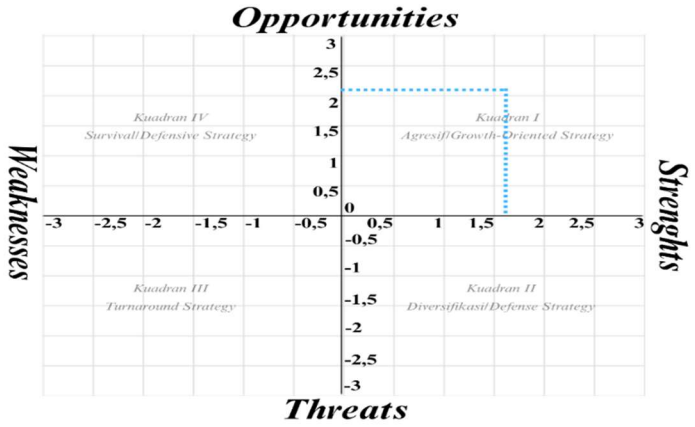


Fig 7. SWOT quadrant diagram

Based on the SWOT quadrant diagram, it can be concluded that the agrotourism potential of Pinang Mancung Subdistrict is located in Quadrant I. This indicates that the area has a good internal and external position because it contains strengths and opportunities that can be developed further into a competitive and attractive agrotourism destination.

c. Appropriate Strategies for Developing the Agrotourism Potential in Pinang Mancung Subdistrict by the Department of Youth, Sports, and Tourism of Tebing Tinggi City

i. Strenghts – Opportunities Strategy

Among the S–O scheme in developing Pinang Mancung Subdistrict's agrotourism potential, there are a number of strong internal factors that propel growth. These involve possessing a unique agricultural culture in the form of horticultural and food crops, possessing agriculture-based activities such as planting, fruit picking, and rice field experiences, and possessing an ordered and beautiful plantation landscape. In addition, premises are already publicly accessible for the purpose of tourism accommodation, as well as officially designated trekking trails within the agro region, all of which hold great potential for development into an educational tourism product. Development in agrotourism can be directed by highlighting the special attributes of local agriculture, such as exotic crop varieties and cultural methods of cultivation. These are competitive strengths that, with the support of government incentives and joint promotion activities, can be consolidated to generate a tourist product that is both in demand and distinctive from others (Subianto et al., 2025)

The production of an educational tour package is in tandem with the establishment of an agrotourism program. Rural agrotourism can be strengthened through building on educational tour packages from agricultural activities. The most significant resources such as local heritage, agricultural land, and active community participation are highly utilizable resources that can be integrated into promotional marketing along with tourism activities (Nuraida et al., 2023). Such a program can be designed using the aforementioned strengths. Marketing and planning such a program is important since it has the potential to attract group tourists and create real community-based experiences. This includes the participation of residents in preparing meals for the visitors, the deployment of local farmers as facilitators for the educational tours, and the participation of the village government in the marketing campaign and receiving tourists as they arrive. These collaborative ventures would enhance the overall experience and transform Pinang Mancung into a distinctive and informative agrotourism.

ii. Weaknesses – Opportunities Strategy

In the W–O method of developing the agrotourism potential development strategy of Pinang Mancung Subdistrict, there are several internal weaknesses that need to be overcome, including: limited human resource capacity, particularly the unavailability of local guides who are trained in agricultural and plantation agrotourism activities, and the unavailability of online promotion and digital information, which makes information access for potential tourists limited.

On the other hand, there are strong external opportunities, especially in the form of city government support. This opportunity may be used to start a series of training programs, such as tourism guide training with an emphasis on visitor services and digital skills training. Tour guide training that is tailored to the specific needs of rural communities is essential for addressing weaknesses in tourism communication, service quality, and understanding of local tourism contexts. Such training also enables local residents to better take advantage of emerging tourism opportunities (Hajar et al., 2024). These trainings will serve as a stepping stone in empowering the local community, community groups, and village government in more effectively managing

and promoting the agrotourism destination of Pinang Mancung. By developing digital literacy and promotional capabilities through the use of social media platforms such as Instagram, TikTok, and Facebook, the area can significantly expand its market coverage and visibility, thereby introducing Pinang Mancung agrotourism to more people and making it more competitive in the tourism sector. The pentahelix collaboration model is highly effective in addressing the limitations of human resource capacity in tourist villages. Government and academic support can be utilized to augment community competence, particularly in promotional activities and tour services (Novianti, 2021).

iii. Strenghts – Threats Strategy

In S–T planning for the possibility of developing the agrotourism of Pinang Mancung Subdistrict, there are a few external threats that must be overcome with available capacities. The external threats are the lack of innovation among residents, the private ownership of plantations and rice fields by individual residents, and the presence of alternative competitors with the same agrotourism across the area. One of the strengths that can be leveraged against these dangers is the exceptional agricultural heritage in Pinang Mancung, with a mix of horticultural and food crops. This diversity is a niche selling opportunity, since there are many competing destinations, which only deal in rice field based agrotourism. Pinang Mancung crop diversity can be promoted as a main draw if properly packaged with quality tourism services and proper local guides with good communication skills.

To address the threats of competition from similar destinations and fragmented ownership of lands, one has to promote local strengths such as diversification of farm products and fertile farming-based cultural heritage. Positive engagement with landowners, together with stakeholder cooperation, is at the forefront of shaping a more coordinated and cooperative approach to tourism management (Subianto et al., 2025). Local community stagnation in the area of innovation can be alleviated by intervention from both village and city governments. Here, the Tebing Tinggi Youth, Sports, and Tourism Department (Disporapar) can, in conjunction with other institutions, organize training sessions for post harvest processing. The training would include packaged items such as onion chips, potato crisps, etc., in addition to innovative branding and marketing strategies that will generate curiosity and interest among the tourists. As for the issue of privately owned farm land, this can be resolved through a dialogue facilitated approach with the help of the local government. The government can invite landowners to discussions that bring out the long term social and economic benefits of renting out their land, if only temporarily, for tourism purposes. This would present other income opportunities besides selling their crops to middlemen, as well as to the village as a whole development of the agrotourism industry.

4. Conclusion

Pinang Mancung Subdistrict's agrotourism potential is considered to be good, e.g., existing cultural tourist attractions, agricultural farming, well-maintained rice fields, public facilities, accessibility, mobile network coverage, government support, and community participation. Nevertheless, there are also some limitations, e.g., no seasonal farming activity, accommodation facility, local product kiosk, trained agrotourism guide, and good social media promotion. Other problems are low public awareness, inadequate human capital, weak innovation, privately held

arable lands, and rivalry from other similar places. The resulting development plans are Strengths–Opportunities (S–O), Weaknesses–Opportunities (W–O), and Strengths–Threats (S–T), with the aim of promoting development of a competitive, inclusive, and sustainable agrotourism destination.

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EKSPLORASI KEPERLUAN INOVASI DALAM PENGAJARAN DAN PEMBELAJARAN PELAJAR AUTISME: SATU KAJIAN TERHADAP PANDANGAN GURU PENDIDIKAN KHAS DAN WARIS

Fatimah binti Haji Saidin*, Sharipah Khadijah binti S.Hashim, Nurul Adyani binti Che Daud

Jabatan Perdagangan, PoliteknikTuanku Sultanah Bahiyah, 09090 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: fatimah@ptsb.edu.my

Abstrak

Kajian ini bertujuan untuk meneroka cabaran yang dihadapi oleh guru pendidikan khas dan waris dalam pengajaran dan pembelajaran (PdP) pelajar autisme serta keperluan inovasi yang dapat menyokong keberkesanan proses PdP tersebut. Melalui pendekatan kualitatif, data dikumpul menerusi temu bual separa berstruktur dengan guru yang berpengalaman dalam mengajar pelajar berkeperluan khas di sekolah pendidikan khas serta waris dari kalangan ibu bapa, panjaga dan saudara kandung yang merupakan individu terawal memberi pendidikan kepada pelajar. Metodologi kajian adalah sepenuhnya kualitatif dengan mengaplikasikan kaedah Tematik Colaizzi dalam menganalisis data. Bilangan keseluruhan sampel kajian adalah 17 orang iaitu 9 orang waris dan 8 orang guru pendidkan khas. Dapatan kajian menunjukkan bahawa cabaran utama termasuk kesukaran komunikasi, emosi yang tidak stabil, fokus pelajar yang rendah dan kekurangan bahan bantuan pengajaran yang sesuai bagi menangani masalah-masalah tersebut. Guru dan waris juga menekankan keperluan inovasi digital yang bersifat interaktif, berasaskan visual dan mudah disesuaikan untuk memenuhi keperluan individu pelajar berkeperluan khas. Kajian ini memberi sumbangan penting kepada pembangunan strategi inovatif dalam pendidikan khas yang mampu meningkatkan pengalaman pembelajaran pelajar.
Kata Kunci: Autisme; Bahan Bantu Mengajar; Inovasi.

1. Pengenalan

Pelajar Autisme merupakan pelajar yang terdiri daripada kelompok pendidikan khas yang memerlukan perhatian, pendekatan, dan strategi pengajaran yang berbeza daripada pelajar normal. Autisme atau Autisme Spectrum Disorder (ASD) menjejaskan keupayaan individu dalam berkomunikasi, berinteraksi secara sosial serta menyesuaikan diri dengan perubahan persekitaran. Menurut Menteri Kesihatan (Bernama, 2021), antara tahun 2010 hingga 2021, 19% kanak-kanak berusia kurang atau lebih daripada 18 tahun telah didiagnosis dengan *Autisme Spectrum Disorder* (ASD). Keadaan ini dapat dilihat sehingga Ogos 2023, di mana terdapat 48,781 OKU Autisme yang berdaftar dengan Jabatan Kebajikan Masyarakat (Berita RTM, 2023). Mereka ini merupakan pelajar yang berkeperluan kritikal dimana mereka sering menunjukkan cabaran dalam menyesuaikan diri dengan kaedah pembelajaran konvensional di bilik darjah.

Antara cabaran utama yang dihadapi dalam pengajaran dan pembelajaran pelajar autisme adalah gaya pembelajaran mereka yang cenderung kepada pendekatan visual, berstruktur dan konsisten, selain memerlukan sokongan rutin harian yang stabil. Menurut Hodgdon (1995), “visual strategies provide a way to make the environment and communication more predictable and understandable” bagi pelajar autisme. Mereka juga sukar memberi tumpuan dalam persekitaran yang bising, kurang tersusun atau berubah-ubah. Dalam masa yang sama, guru pendidikan khas serta ibu bapa turut berdepan kekangan dari segi masa, sumber dan latihan khusus untuk

menyampaikan ilmu secara berkesan kepada pelajar ini (Simpson, de Boer-Ott, & Smith-Myles, 2003).
Cabaran ini membuka ruang kepada keperluan mendesak bagi mewujudkan inovasi dalam pendekatan pengajaran yang bukan sekadar melibatkan penggunaan teknologi, tetapi merangkumi reka bentuk bahan bantu mengajar yang lebih interaktif, menyeronokkan, dan bersifat individualistik. Penggunaan aplikasi pembelajaran digital yang direka khusus untuk pelajar autisme menjadi salah satu penyelesaian yang boleh membantu meningkatkan keberkesanan pembelajaran. Seperti yang dinyatakan oleh Bouck et al. (2014), "technology-based interventions can support students with autism by promoting engagement, independence, and learning outcomes." Sokongan teknologi ini dapat disesuaikan mengikut keperluan individu, sekaligus membantu pelajar ini memahami kandungan pembelajaran dengan lebih baik. Aplikasi seperti ini mampu menyokong pembelajaran di rumah dan di sekolah, dengan kandungan visual menarik, susun atur yang mudah, serta elemen interaktif yang dirancang secara teliti untuk rangsangan kognitif dan sosial.

Selain itu, keperluan kepada latihan dan kolaborasi antara guru, ibu bapa, dan pihak sekolah amat penting dalam menjayakan pendekatan ini. Latihan profesional, perkongsian sumber, dan pemahaman mendalam terhadap spektrum Autisme dapat memudahkan pelaksanaan kaedah inovatif secara menyeluruh. Di samping itu, penyediaan kurikulum yang fleksibel dan inklusif, berlandaskan prinsip Pengajaran Berasaskan Hasil (Outcome-Based Education), turut menjadi penyumbang ke arah pembangunan pendidikan yang lebih responsif terhadap keperluan sebenar pelajar autisme. Seperti yang ditegaskan oleh Killen (2007), "outcome-based education focuses on what learners are expected to achieve and how the curriculum can be adjusted to support diverse learning needs." Pendekatan ini sejajar dengan keperluan pelajar autisme yang memerlukan adaptasi kandungan, kaedah, dan persekitaran pembelajaran yang sesuai.

Secara keseluruhannya, cabaran yang dihadapi dalam pendidikan pelajar autisme harus dijadikan sebagai peluang untuk mencetuskan perubahan inovatif yang lebih berimpak tinggi. Dengan pendekatan yang strategik dan menyeluruh, inovasi dalam pengajaran bukan sahaja dapat meningkatkan kualiti pembelajaran pelajar autisme, malah memperkukuh sistem pendidikan inklusif di Malaysia secara amnya.

1.1 Objektif Kajian

Objektif bagi kajian ini adalah seperti berikut:

a. Mengenal pasti cabaran utama yang dihadapi oleh guru pendidikan khas dan waris dalam pengajaran dan pembelajaran pelajar autisme.
b. Meneroka keperluan inovasi dalam pendekatan pengajaran dan pembelajaran bagi pelajar autisme menurut perspektif guru dan waris.
c. Meneliti pandangan guru dan waris terhadap bentuk sokongan, teknologi, atau intervensi inovatif yang berkesan dalam menyokong pembelajaran pelajar autisme.
d. Merumuskan cadangan penambahbaikan bagi memperkukuh pelaksanaan inovasi dalam pendidikan pelajar autisme berdasarkan dapatan kajian.

2. Kajian Literatur

2.1 Autisme

Gangguan Spektrum Autisme (ASD) ialah suatu gangguan perkembangan neurologi yang memberi kesan kepada komunikasi sosial dan corak tingkah laku yang berulang (*American Psychiatric Association*, 2013). Di Malaysia, statistik Kementerian Kesihatan menunjukkan

peningkatan kes autisme dengan lebih 1,400 kanak-kanak dikesan setiap tahun (KKM, 2021). Ciri utama pelajar autisme termasuk kesukaran dalam komunikasi sosial, kepekaan terhadap rangsangan deria, dan kesukaran menyesuaikan diri dalam persekitaran yang tidak rutin (Zakaria et al., 2022).

Kajian oleh Omar dan Majid (2023) mendapati bahawa pelajar autisme di sekolah rendah memerlukan pendekatan sokongan khusus dalam suasana bilik darjah yang mesra deria. Tanpa sokongan yang sesuai, pelajar ini berisiko mengalami tekanan emosi, kesukaran akademik, dan pengasingan sosial. Oleh itu, memahami ciri dan keperluan pelajar autisme menjadi langkah asas dalam merancang strategi pengajaran yang inklusif dan efektif.

2.2 Bahan Pengajaran dan Pembelajaran

Pelajar autisme memerlukan pendekatan pengajaran yang berbeza daripada pelajar tipikal. Strategi pembelajaran berstruktur, penggunaan bahan visual, rutin yang konsisten, dan penyampaian yang jelas merupakan elemen penting (Wong et al., 2015). Kajian tempatan oleh Nordin dan Rahman (2021) menyatakan bahawa penggunaan visual schedules dan alat bantu komunikasi bergambar telah meningkatkan keupayaan pelajar autisme untuk mengikuti arahan dan menyelesaikan tugasan di dalam kelas.

Dalam konteks pedagogi, strategi pengajaran berasaskan kekuatan dan minat pelajar autisme terbukti membantu dalam meningkatkan motivasi dan tumpuan (Nasir et al., 2023). Namun begitu, kekangan yang sering dihadapi ialah kurangnya latihan guru dalam bidang pendidikan khas dan kekangan sumber sokongan seperti alat bantu mengajar yang sesuai.

Kajian oleh Hasan et al. (2022) menunjukkan bahawa walaupun guru menyedari keperluan untuk mempelbagaikan kaedah pengajaran, kebanyakan mereka tidak dilengkapi dengan bahan inovatif dan latihan berkala dalam menangani keperluan pelajar autisme secara berkesan.

2.3 Inovasi

Inovasi dalam pengajaran dan pembelajaran pelajar autisme semakin mendapat perhatian, terutamanya dalam era pasca-pandemik yang menuntut penggunaan teknologi pendidikan. Inovasi boleh mengambil bentuk aplikasi pembelajaran digital, alat bantu deria, realiti maya (VR), dan sistem komunikasi alternatif (AAC) (Al-Azawei et al., 2016; Yusof et al., 2022). Kajian oleh Abdullah et al. (2024) membangunkan aplikasi mudah alih berasaskan gambar yang membantu pelajar autisme dalam proses komunikasi asas. Aplikasi ini meningkatkan interaksi dua hala antara pelajar dan guru, di samping mempercepatkan pemahaman arahan melalui visualisasi. Dalam satu lagi kajian oleh Hamzah dan Rosli (2023), penggunaan teknologi Augmented Reality (AR) dalam aktiviti pembelajaran telah berjaya menarik perhatian dan mengekalkan fokus pelajar autisme untuk tempoh yang lebih lama berbanding kaedah konvensional.

Walau bagaimanapun, inovasi yang dibangunkan perlu mengambil kira keberkesanan jangka panjang, kesesuaian dengan keperluan individu pelajar, serta kemampuan guru dan ibu bapa dalam menggunakannya. Kejayaan inovasi juga bergantung kepada kerjasama pelbagai pihak termasuk guru, pakar terapi, jurutera perisian, dan pembuat dasar (Rahman & Mokhtar, 2023).

Secara keseluruhannya, kajian literatur ini menunjukkan bahawa pelajar autisme menghadapi pelbagai cabaran dalam konteks pengajaran dan pembelajaran, khususnya dari aspek komunikasi, interaksi sosial dan keperluan kepada persekitaran yang berstruktur dan mesra deria. Pendekatan pengajaran konvensional dilihat kurang berkesan tanpa penyesuaian yang sesuai dengan profil pelajar autisme. Walaupun terdapat usaha berterusan dalam memperkenalkan strategi dan kaedah pembelajaran berasaskan kekuatan pelajar, masih wujud

kekangan dari segi latihan guru, bahan bantu mengajar dan kesediaan infrastruktur pendidikan khas.

Dalam konteks inovasi, pelbagai teknologi dan pendekatan interaktif telah mula diperkenalkan untuk menyokong pembelajaran pelajar autisme. Namun, keberkesanan dan kebolehlaksanaan inovasi ini dalam konteks tempatan masih memerlukan penyelidikan lanjutan. Sorotan ini menegaskan keperluan untuk membangunkan inovasi yang bukan sahaja bersifat teknologi, tetapi juga bersesuaian dengan budaya tempatan, mudah digunakan oleh guru dan pelajar, serta mampu menyokong pencapaian objektif pembelajaran secara holistik. Maka, kajian ini berperanan penting dalam menjawab keperluan tersebut melalui penyelidikan dan pembangunan inovasi yang berasaskan bukti dan keperluan sebenar pelajar autisme di bilik darjah.

3. Metodologi

3.1 Kaedah Kajian

Metodologi kajian ini adalah menggunakan kaedah kualitatif. Pemilihan kaedah adalah kerana kaedah ini didapati lebih sesuai untuk digunakan memandangkan kajian ini perlu mendapatkan maklumat yang mendalam berdasarkan pengalaman sendiri responden menghadapi cabaran menguruskan anak dan pelajar autisme. Ini bersesuaian dengan Kirk dan Miller (1986) yang mengatakan bahawa Kajian Kualitatif adalah satu kaedah kajian tradisi sains sosial yang memerhati manusia dalam kawasan mereka sendiri dan berinteraksi dengan mereka menggunakan bahasa yang biasa mereka gunakan. Kaedah pengumpulan data adalah dengan mengadakan sesi temubual berstruktur di mana responden diberikan soalan temubual terbuka dan dilepaskan untuk memberi jawapan yang bersesuaian dengan apa yang mereka hadapi berdasarkan pengalaman sendiri. Walaupun begitu, pengkaji sentiasa memandu perbualan agar bertepatan dengan objektif kajian yang ingin diperolehi.

3.2 Instrumen kajian

Memandangkan kajian ini melibatkan dua kelompok responden yang berbeza iaitu waris dan guru, instrumen kajian juga menggunakan beberapa kaedah bersesuaian berdasarkan lokasi dan dan kesesuaian masa. Bagi responden dalam kalangan guru pendidikan khas, satu perjumpaan *focus group* telah diadakan bagi mendapatkan maklumat kajian. Sementara bagi kelompok waris pula, soalan temubual disediakan melalui teks tidak serentak iaitu masa interaksi berlainan. Kaedah teks tidak serentak digunakan kerana responden yang menguruskan anak autisme tidak dapat memberi ruang masa yang tetap untuk menjawab soalan. Hal ini kerana masa menguruskan anak autisme tidak dapat mengikut jadual yang tetap dan perlu terlebih dahulu melihat kondisi anak autisme. Kaedah ini walaupun memakan masa, ia lebih tepat kerana responden berpeluang berfikir dengan lebih tenang dan mendalam apabila tiada gangguan selain berpeluang membetulkan maklumat sebelum dihantar kepada pengkaji (Fatimah, 2014).

3.3 Persampelan

Kaedah persampelan yang diaplikasi dalam kajian ini adalah persampelan *snow ball*. Pengkaji terlebih dahulu mendapatkan sampel pertama yang dikenali bersesuaian dengan ciri-ciri sampel yang diperlukan iaitu berpengalaman menguruskan pelajar atau anak autisme. Sampel seterusnya diperoleh dengan meminta bantuan sampel pertama untuk mencari sampel dari kategori yang sama. Kaedah ini memakan masa namun kualiti sampel yang diperolehi adalah tinggi. Keseluruhan sampel yang terlibat adalah seramai 17 orang iaitu 9 orang waris dan 8 orang guru. Jumlah ini adalah kecil namun ia bertepatan dengan konsep persampelan untuk kajian kualitatif. Kenyataan ini disokong oleh Divyadeepa (2015) yang menyatakan bahawa untuk mendapatkan maklumat terperinci yang dikehendaki, pengkaji kualitatif mestilah berurusan dengan bilangan sampel yang kecil, berinteraksi dalam tempoh yang lama dan mendalam.

3.4 Kaedah Analisis Data

Analisis data menggunakan Collaizi Thematics Analisis. Melalui kaedah Analisis Collaizi ini, analisa dibuat dengan mencari tema perbualan-perbualan yang mendekati maksud dalam objektif 1, 2 dan 3. Terdapat 5 langkah spesifik yang diperkenalkan Collaizi (1978) dan diaplikasikan iaitu:

a. Perkataan, frasa dan ayat diulang baca untuk lebih dikenali dan dilazimi.
b. Maklumbalas responden dipisahkan kepada frasa-frasa.
c. Ayat atau frasa ini diperiksa dan frasa yang berkaitan diambil.
d. Maksud disebalik frasa dibina untuk diselarikan dengan semua pernyataan yang berkaitan.
e. Klaster daripada penyataan yang mengandungi isi yang sama diberikan tema yang baharu (Collaizi dalam Reneta, 2013)

4. Hasil Dapatan dan Perbincangan

Hasil analisis menggunakan kaedah Tematik Colaizzi telah menghasilkan dapatan yang selari dengan objektif kajian, khususnya berkaitan pandangan guru dan waris terhadap pengajaran dan pembelajaran. Sebahagian besar data tertumpu kepada tema utama yang dikenal pasti, manakala sebilangan kecil menunjukkan penyimpangan, namun tetap memberi nilai dalam memahami konteks sebenar.

4.1 Mengenal pasti cabaran utama yang dihadapi oleh guru pendidikan khas dan waris dalam pengajaran dan pembelajaran pelajar autisme.

Dapatan kajian ini mengenal pasti pelbagai cabaran utama yang dihadapi oleh guru pendidikan khas dan waris dalam proses pengajaran dan pembelajaran (PdP) pelajar autisme. Hasil analisis tematik terhadap temu bual yang dijalankan menunjukkan bahawa isu seperti berikut:

i. Subtema 1 - Pelajar Tidak Dapat Memberi Fokus Dalam Sesi PdP

Kajian mendapati bahawa ketidakfokusan pelajar merupakan cabaran paling dominan. Pelajar autisme sangat mudah terganggu dengan bunyian yang bingit mahupun tingkah laku pelajar sekelas yang mengganggu. Responden, yang terdiri daripada guru dan waris, menyatakan bahawa sesi pengajaran dan pembelajaran adalah sangat mencabar kerana dalam kebanyakan masa, pelajar autisme berfungsi rendah menghadapi kesukaran untuk menumpukan perhatian semasa sesi PdP berlangsung.

ii. Subtema 2 – Komunikasi Dua Hala Yang Tidak Berkesan

Selain itu, cabaran lain yang dikenal pasti ialah kesukaran pelajar memahami dan mengikut arahan yang diberikan oleh guru. Guru dan waris juga menghadapi masalah kerana pelajar seringkali menunjukkan tingkah laku yang sukar difahami menyebabkan sukar berlaku komunikasi dua hala yang berkesan. Menurut beberapa orang guru, pelajar memerlukan arahan yang sangat ringkas, jelas dan diulang berkali-kali agar dapat difahami.

iii. Subtema 3 – Respon negatif pelajar terhadap subjek tertentu

Kegagalan mencipta suasana kelas yang berkesan ini juga ada kalanya dipengaruhi oleh respon negatif pelajar sendiri iaitu pelajar menunjukkan tingkah laku menolak sesi PdP, seperti enggan mendengar atau menjauhkan diri apabila proses pengajaran dimulakan.

Sikap ini seringkali ditonjolkan sehingga ada waris yang berharap agar pelajar tidak dipaksa untuk belajar apa yang mereka tidak sukai.

iv. Subtema 4 - Ketidakstabilan Emosi Pelajar Autisme

Ketidakstabilan emosi pelajar autisme juga menjadi antara faktor utama yang menyukarkan proses PdP. Sebahagian waktu, pelajar seperti tenggelam dalam dunia sendiri sementara sebahagian waktu yang lain, pelajar sukar dikawal dan adakalanya mengamuk. Beberapa responden melaporkan bahawa emosi pelajar yang tidak menentu menyebabkan gangguan kepada kelangsungan pembelajaran dan memerlukan pendekatan yang bersifat sangat individualistik.

v. Subtema 5 – Ketidakmampuan Pelajar Mengurus Diri

Gangguan sesi pembelajaran juga seringkali berlaku kerana anak autism belum mampu mengurus diri. Ada kalanya anak autism perlu ke tandas dan guru serta waris perlu mengikuti dan menguruskan mereka. Keadaan ini menyebabkan sesi pembelajaran terganggu terutamanya apabila didalam kelas yang mempunyai bilangan pelajar pendidikan khas yang ramai.

Secara keseluruhannya, dapatan ini menunjukkan bahawa PdP pelajar autisme memerlukan pendekatan yang lebih fleksibel dan penuh kesabaran, sesi khas individu atau *shadow aid*, serta komunikasi dan perbincangan yang berterusan daripada kedua-dua pihak iaitu guru dan waris dalam menguruskan cabaran tingkah laku, emosi serta keupayaan pemahaman pelajar

4.2 Meneroka keperluan inovasi dalam pendekatan pengajaran dan pembelajaran bagi pelajar autisme menurut perspektif guru dan waris.

Objektif kedua kajian ini bertujuan meneroka keperluan inovasi dalam pendekatan pengajaran dan pembelajaran (PdP) bagi pelajar autisme, berdasarkan perspektif guru pendidikan khas dan waris yang telah berpengalaman mengurus pengajaran dan pembelajaran mereka. Hasil analisis tematik terhadap temu bual menunjukkan wujudnya beberapa keperluan utama yang dilihat berpotensi meningkatkan keberkesanan PdP.

i. Subtema 1: Penggunaan Teknologi Digital dan Visual

Penggunaan Teknologi Digital dan Visual menjadi pilihan utama bagi sebagian besar guru dan waris dalam menyampaikan pengajaran kepada pelajar autisme.Pelajar autisme didapati menunjukkan minat yang lebih tinggi apabila PdP dijalankan menggunakan teknologi digital yang memaparkan elemen visual berbanding kaedah manual konvensional yang menggunakan buku latihan. PdP yang dilaksanakan secara digital interaktif dilihat mampu membantu pelajar mengekalkan fokus sepanjang sesi pembelajaran dan amat diminati pelajar. Hal ini dapat dilihat dengan jelas apabila pelajar berlumba-lumba memasuki bilik komputer pada waktu subjek yang melibatkan penggunaan komputer. Pendapat ini turut disokong oleh beberapa waris yang melihat teknologi sebagai alat bantu yang memudahkan pemahaman dan menarik perhatian anak-anak mereka.

ii. Subtema 2: PdP Berasaskan Minat Individu

Terdapat sebilangan kecil responden yang mencadangkan agar pembahagian kelas perlu dibuat berdasarkan minat individu pelajar autisme. Walaupun pendapat ini sukar direalisasikan kerana kekurangan fasiliti dan ruang, pendekatan ini dilihat lebih berkesan

kerana pelajar lebih bersedia untuk memberi kerjasama apabila aktiviti pembelajaran berkait langsung dengan minat mereka. Kurikulum yang lebih fleksibel, iaitu hanya menumpukan pada topik-topik yang diminati oleh pelajar dilihat sebagai satu langkah untuk mengurangkan tekanan pelajar dan meningkatkan motivasi mereka untuk belajar.

iii. Subtema 3: Bahan Bantu Mengajar yang Bersesuaian

Instrumen bahan bantu mengajar yang disesuaikan dengan tahap kognitif pelajar autisme yang berbeza fungsi (rendah, sederhana, tinggi) dapat membantu proses pembelajaran berlangsung dengan lebih bersistem sekaligus berfungsi sebagai alat kawalan emosi dan tingkah laku pelajar. Dapatan kajian menunjukkan bahawa guru dan waris bersependapat bahawa inovasi dalam penyediaan bahan bantu mengajar bukan sahaja perlu mengambil kira keperluan sensori malah perlu dilengkapkan dengan elemen khas yang dapat menyampaikan dan menguruskan kondisi emosi pelajar autisme yang sering berubah.

iv. Subtema 4: Pendekatan Alternatif yang Kurang Popular

Terdapat pandangan berbeza mengenai penggunaan teknologi dan aplikasi digital dalam pdp yang menentang sekerasnya penggunaan teknologi dan aplikasi dalam pdp. Hal ini kerana dedahan kepada kaedah ini boleh menyebabkan pelajar autisme menjadi lebih terasing dan agresif. Sebahagian waris masih menyokong pendekatan tradisional berasaskan ‘human teaching’ iaitu pengajaran tanpa penggunaan gajet sebagai satu langkah untuk memaksa pelajar autisme berinteraksi dan berkomunikasi. Selain itu, terdapat cadangan untuk menyediakan pembantu peribadi (shadow aid) yang dapat mendampingi pelajar secara individu sepanjang sesi PdP, bagi memastikan pelajar mendapat sokongan khusus mengikut keperluan masing-masing.

Kesimpulannya, dapatan ini menunjukkan bahawa inovasi dalam PdP pelajar autisme perlu berorientasi digital dan interaktif, namun tidak meninggalkan keperluan penyeliaan pelajar secara individu selain responsif terhadap keperluan unik pelajar autisme.

4.3 Meneliti pandangan guru dan waris terhadap bentuk sokongan teknologi, atau intervensi inovatif yang berkesan dalam menyokong pembelajaran pelajar autisme.

Objektif ketiga kajian ini meneliti pandangan guru dan waris terhadap bentuk sokongan teknologi, dan intervensi inovatif yang dianggap berkesan dalam menyokong pembelajaran pelajar autisme. Analisis tematik terhadap data temu bual menunjukkan bahawa penggunaan teknologi digital interaktif merupakan antara pendekatan inovatif yang paling kerap disebut dan disokong oleh responden.

i. Subtema 1: Aplikasi Digital Interaktif yang Menarik dan Bermotivasi

Aplikasi digital interaktif yang mempunyai ciri-ciri visual menarik seperti ikon berwarna-warni, emoji yang comel serta elemen muzik dapat membantu meningkatkan fokus dan motivasi pelajar. Selain itu, setiap aktiviti atau permainan dalam pdp perlu mempunyai paparan ‘countdown’ untuk memastikan pelajar tidak ralit dan bertindak cepat untuk mencari jawapan. Aplikasi juga perlu dilengkapkan dengan maklum balas berbentuk kata-kata pujian bagi jawapan yang betul. Guru-guru berpendapat, aplikasi sedemikian bukan sahaja menyeronokkan tetapi juga membina semangat pelajar untuk terus mencuba menjawab dengan betul, terutamanya dalam aktiviti berkumpulan.

ii. Subtema 2: Penggunaan Bahan Bantu Mengajar Digital yang Berteraskan video

Kebanyakan waris juga bersetuju bahawa penggunaan aplikasi digital interaktif yang sesuai dalam sesi PdP dapat membantu meningkatkan tumpuan dan penglibatan pelajar. Sebagai tambahan, aplikasi berbentuk video digital interaktif yang menampilkan pergerakan visual telah dicadangkan. Bahan ini bukan sahaja menyokong pembelajaran kognitif tetapi juga memberi rangsangan visual dan auditori yang penting bagi pelajar autisme. Namun begitu, responden juga menekankan bahawa penggunaan teknologi ini harus sentiasa berada di bawah seliaan guru untuk memastikan ia digunakan secara terkawal dan berfokus.

iii. Subtema 3: Pendekatan Tanpa Gajet (Pandangan Minoriti)

Walaupun majoriti responden menyokong penggunaan teknologi, terdapat pandangan berbeza yang dikemukakan oleh segelintir waris. Mereka berpandangan bahawa kaedah PdP tanpa gajet adalah lebih sesuai bagi kebanyakan pelajar autisme yang cenderung mengalami tantrum apabila terlalu lama terdedah kepada peranti digital. Menurut mereka, pendekatan konvensional yang lebih kepada ‘*’personal coaching’’* lebih berkesan untuk membina sahsiah yang lebih sempurna dan komunikasi interpersonal yang lebih baik, terutamanya apabila melibatkan pelajar autisme berfungsi rendah yang seringkali menghadapi perubahan emosi.

Secara keseluruhannya, dapatan kajian menunjukkan bahawa intervensi inovatif yang melibatkan teknologi digital sangat berpotensi menyokong pembelajaran pelajar autisme, namun pelaksanaannya perlu disesuaikan dengan keperluan dan keunikan individu pelajar. Keseimbangan antara teknologi dan pendekatan alternatif masih penting dalam memastikan PdP berlangsung secara efektif dan lestari.

4.4 Merumuskan cadangan penambahbaikan bagi memperkukuh pelaksanaan inovasi dalam pendidikan pelajar autisme berdasarkan dapatan kajian.

Objektif keempat kajian ini merumuskan cadangan penambahbaikan berdasarkan dapatan kajian, dengan memberi fokus kepada peranan kementerian, institusi pendidikan, dan komuniti dalam memperkukuh pelaksanaan inovasi pendidikan bagi pelajar autisme. Hasil analisis tematik mendapati beberapa cadangan utama yang diketengahkan oleh responden merangkumi aspek dasar pendidikan, struktur organisasi, pendekatan pengajaran, serta sokongan sosial dan komuniti.

i. Subtema 1: Penstrukturan Saiz Kelas dan Infrastruktur Pendidikan

Bilangan pelajar dalam satu kelas pendidikan khas yang terlalu ramai menjadi topik perbincangan penting dalam temubual yang diadakan bersama guru dan waris. Jumlah pelajar yang ramai menyukarkan pengurusan tingkah laku serta pelaksanaan PdP yang efektif, terutamanya apabila berlaku percampuran pelajar dari pelbagai spektrum dan tahap fungsi yang berbeza. Cadangan yang dikemukakan adalah saiz kelas dikecilkan menjadi kurang dari 10 pelajar. Hal ini kerana pelajar autisme memerlukan perhatian khusus dan bilangan yang ramai akan menyebabkan kelas kurang efektif. Selain itu terdapat juga cadangan untuk menambah bilangan institusi pendidikan khas, terutamanya di kawasan luar bandar, bagi memastikan akses yang saksama kepada pendidikan berkualiti untuk pelajar autisme.

ii. Subtema 2: Pengetahuan Masyarakat dan Pengasingan Mengikut Spektrum

Satu lagi cadangan penting ialah usaha menyebar luas maklumat mengenai autisme kepada masyarakat bagi memberi pemahaman berkenaan keperluan dan ciri pelajar autisme. Waris dan guru berpendapat bahawa pemahaman masyarakat yang rendah menyebabkan wujudnya stigma sosial dan kekangan sokongan komuniti terhadap keluarga

pelajar autisme. Selain itu, terdapat cadangan agar pelajar pendidikan khas diasingkan mengikut spektrum yang berbeza. Hal ini kerana pelajar autisme seringkali menghadapi masalah apabila bercampur dengan pelajar dari spektrum lain seperti slow learner, down syndrome dan lain-lain. Pengasingan ini diharap dapat membantu pelaksanaan PdP yang lebih bersasar dan berkesan berasaskan kemampuan dan keperluan individu.

iii. Subtema 3: Pendekatan PdP yang Khusus dan Inovatif

Responden turut menekankan perlunya mewujudkan pendekatan pdp yang lebih kemas dan lengkap, dengan teknik dan strategi pengajaran yang dirangka khusus untuk keperluan pelajar autisme. Ini termasuk pembangunan bahan bantu mengajar (BBM) yang lebih praktikal dan inovatif, serta disesuaikan dengan profil sensori dan kognitif pelajar. Pelaksanaan intervensi inovatif ini memerlukan latihan berkala diberikan kepada guru dan peruntukan khas daripada pihak kementerian.

iv. Subtema 4: Pemantauan Perkembangan Pelajar Secara Sistematik

Dapatan juga menunjukkan keperluan mewujudkan satu sistem pemantauan berkala bagi menilai perkembangan pelajar autisme. Responden mencadangkan agar pihak sekolah atau institusi dapat menjalankan kajian dalaman dari masa ke semasa sebagai satu bentuk sokongan berterusan kepada waris. Hal ini penting bagi mengurangkan kebergantungan waris terhadap temujanji pakar yang kerap melibatkan kos yang tinggi dan masa menunggu yang panjang.

Secara keseluruhannya, cadangan-cadangan yang dikemukakan oleh responden memberi penekanan kepada keperluan dasar pendidikan yang eksklusif kepada kelompok pelajar autisme, pelaksanaan strategi PdP yang lebih fleksibel dan bersasar, serta keterlibatan masyarakat dan institusi dalam membentuk ekosistem pendidikan yang menyokong pembangunan holistik pelajar autisme.

5. Kesimpulan dan Cadangan

Hasil dapatan kajian ini memperlihatkan bahawa pengajaran dan pembelajaran (PdP) pelajar autisme masih berhadapan dengan pelbagai cabaran yang bersifat kompleks dan memerlukan pendekatan yang lebih bersasar serta berinovasi. Antara cabaran utama yang dikenal pasti ialah ketidakfokusan pelajar, kesukaran komunikasi dua hala, ketidakstabilan emosi, dan ketidakupayaan pelajar mengurus diri. Dalam konteks ini, guru dan waris memainkan peranan penting dalam memastikan keberkesanan PdP, namun mereka turut berdepan kekangan dari aspek sumber, strategi pedagogi dan sokongan teknologi yang sesuai.

Dapatan kajian secara signifikan menunjukkan bahawa pendekatan inovatif berasaskan teknologi digital, terutamanya aplikasi interaktif yang mesra autisme, amat berpotensi untuk meningkatkan minat, fokus, dan penglibatan pelajar dalam sesi PdP. Guru dan waris bersetuju bahawa bahan bantu mengajar (BBM) yang disesuaikan dengan profil kognitif dan sensori pelajar autisme adalah keperluan kritikal dalam menyokong keberkesanan PdP. Walau bagaimanapun, pendekatan ini tidak boleh dilaksanakan secara umum tanpa mempertimbangkan tahap fungsi, keunikan individu dan persekitaran PdP yang tersedia.

Oleh itu, dapat dirumuskan bahawa penyediaan bahan PdP yang inovatif, berstruktur dan responsif kepada keperluan unik pelajar autisme bukan sahaja penting, malah menjadi asas utama kepada kejayaan pelaksanaan strategi PdP yang inklusif, fleksibel dan lestari.

Berdasarkan kesimpulan di atas, kajian ini mencadangkan beberapa langkah penambahbaikan yang berfokus kepada pembangunan dan pelaksanaan bahan PdP inovatif bagi meningkatkan keberkesanan sesi PdP pelajar autisme:

a. Pembangunan Bahan Bantu Mengajar (BBM) Inovatif dan Tersesuaikan
Institusi pendidikan dan penggubal dasar perlu memfokuskan kepada pembangunan BBM digital yang bersifat mesra autisme, mengandungi elemen visual, auditori, interaktif serta mempunyai tahap kesukaran bertahap. BBM ini harus menepati keperluan sensori pelajar autisme serta mudah diakses oleh guru dan waris.

b. Reka Bentuk Aplikasi Interaktif yang Berorientasikan Pelajar Autisme
Aplikasi pembelajaran perlu dibangunkan berdasarkan ciri pelajar autisme seperti penggunaan grafik ringkas, susun atur konsisten, muzik menenangkan, dan maklum balas positif. Setiap modul pembelajaran harus disusun secara bertahap, pendek dan berulang bagi membantu pemahaman serta pengekalan fokus pelajar.

c. Integrasi Minat Individu dalam Bahan PdP
Kajian mencadangkan agar bahan PdP mengambil kira minat khusus pelajar sebagai asas kandungan dan aktiviti pembelajaran. Pendekatan ini mampu meningkatkan motivasi, menjana keseronokan dan mengurangkan tingkah laku menolak pembelajaran dalam kalangan pelajar autisme.

d. Latihan dan Kolaborasi dalam Penggunaan Bahan Inovatif
Guru dan waris perlu diberikan latihan berkala serta sokongan teknikal bagi memastikan penggunaan bahan PdP inovatif dapat dimanfaatkan secara maksimum. Kolaborasi berterusan antara pihak sekolah, keluarga dan pembangun teknologi juga penting untuk memastikan keberkesanan intervensi yang dilaksanakan.

e. Penyelidikan Berterusan terhadap Keberkesanan Bahan PdP Inovatif
Kajian susulan secara longitudinal wajar dijalankan untuk menilai keberkesanan jangka panjang bahan PdP inovatif terhadap kemajuan akademik, tingkah laku dan sosial pelajar autisme. Penilaian ini penting bagi menjamin pembangunan bahan yang berasaskan bukti dan berkualiti tinggi.

Cadangan-cadangan ini diharap dapat menjadi asas kepada pembangunan ekosistem pendidikan khas yang lebih progresif dan inklusif. Keberkesanan PdP pelajar autisme sangat bergantung kepada bahan pengajaran yang bukan sahaja inovatif, malah empati terhadap keperluan unik pelajar. Justeru, pelaburan dalam pembangunan BBM mesra autisme bukanlah satu pilihan, tetapi satu keperluan yang mendesak demi memastikan hak pendidikan mereka terus terjamin.

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GLOSSOPHOBIA IN CLASS: EXPLORING THE SPEAKING FEAR OF COMMERCE STUDENTS IN POLITEKNIK TUANKU SULTANAH BAHIYAH

Eda Idoera binti Mohd Yusak

Department of General Studies, Politeknik Tuanku Sultanah Bahiyah, Kulim Hi-Tech, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: eda@ptsb.edu.my

Abstract

Glossophobia, or the fear of public speaking, particularly in English, may create uneasiness and fear for a speaker, especially for those who are not proficient in English. Therefore, this quantitative research is important in language education as it provides information about students' speaking anxiety in a classroom. The Public Speaking Class Anxiety Scale (PSCAS), developed by Yaikhong and Usaha (2012), was utilised to measure the anxiety levels experienced by 203 first-semester commerce students. First, the study aims to find out the overall level of speaking anxiety and the four sources, i.e. communication apprehension, fear of negative evaluation, comfort in using English, and test anxiety. Second, the correlation between PSCAS scores, Sijil Pelajaran Malaysia (SPM) English grade and the communicative English score are explored. Results indicate that most Politeknik Tuanku Sultanah Bahiyah (PTSB) commerce students had a moderate level of speaking anxiety and were found to have a high sense of fear of negative evaluation. The Spearman's rank correlation results showed that students with excellent SPM results will have higher PSCAS scores. On the contrary, Pearson's correlation coefficient result indicates that the higher the PSCAS scores, the lower the score one will get in communicative English. Suggestions for educators to develop appropriate means to reduce students' speaking anxiety in class are also discussed.

Keywords: Glossophobia; Anxiety; Public Speaking Class Anxiety Scale.

1. Introduction

Anxiety experienced in learning English can be debilitating. The classroom setting is designed to foster collaboration and learning, but many students feel language learning in a class is particularly stressful and a primary source of anxiety (Horwitz et al., 1986; Khan, 2015). Among the four macro-skills learned in a language class, i.e., writing, speaking, reading, and listening, many non-native speakers of English exhibit fear or heightened anxiety levels in the speaking skills as it is considered a productive skill that requires more effort to master (Horwitz et al., 1986; Indahyanti, 2023; Khan, 2015; Lau et al., 2019; Mohd Ali, 2020; Mohd Anuardi, 2023).

According to MacIntyre (1995), "anxiety may be more strongly aroused by speaking than by learning the language" (p. 96). Speaking anxiety can hinder students' ability to communicate effectively and lead to avoidance behaviour or detachment from speaking activities in second language learning classes (Horwitz et al., 1986; Khan, 2015). Scovel (1978) relates language anxiety to debilitating anxiety, where anxiety "motivates the learner to 'flee' learning new activity; it intensifies the individual emotionally to adopt avoidance behaviour" (p.139). Hence, students with anxiety will try to reduce speaking participation, making it difficult for students to improve their language performance and attain their educational goals (Amat Suparia et al., 2022; Ansari, 2015).

Speaking anxiety is particularly noticeable in settings where students lack sufficient practice and exposure to the target language, as most students speak English only during English class. As Asio et al. (2024) mentioned, traditional lecture-based classrooms prevent students from constantly practising and infrequently interacting because of large class sizes and limited lesson periods. This is true in Malaysian settings where there is limited time to practice in class, there are many students in English class, and educators need to complete the syllabus given.

Not being able to communicate fluently can result in a cycle of frustration, a heightened sense of self-consciousness, and a shakeup of self-confidence, further increasing the anxiety associated with speaking in English (Asio et al., 2024). This is particularly concerning as learners who suffer a high level of anxiety will be adversely impacted in academic, achievement, economic, political, and day-to-day life (McCroskey, 1977).

1.1 Problem Statement

The Department of Polytechnic Education and Community Colleges aims to enhance commerce students' proficiency in English by introducing Communicative English with an emphasis on oral communication. Polytechnic students must complete group discussions, role-play, oral presentations, and mock job interviews as part of their Communicative English oral assessments. Thus, students may face a certain level of speaking anxiety regarding day-to-day activities in the classroom and speaking assessments. Students' speaking anxiety in classrooms is of much concern among educators because speaking English fluently is vital for relaying correct messages and would be helpful for the future working world when interacting with clients (Lau et al., 2019).

Therefore, the objective of the study is first, to find out the levels of public speaking class anxiety (PSCA) faced by commerce students in Communicative English class; second, to identify which factor contributes the most to the speaking anxiety; third, to find out the relationship between Malaysian Certificate of Examination or Sijil Pelajaran Malaysia (SPM)
English grade and PSCA scores, and finally, to determine whether PSCA scores can determine students' Communicative English scores.

2. Literature Review

2.1 Speaking Anxiety in Second Language Learning

Speaking anxiety refers to the nervousness faced by an individual when asked to speak. Horwitz et al. (1986) mentioned that anxiety "is the subjective feeling of tension, apprehension, nervousness, and worry associated with an arousal of the autonomic nervous system" (p.125). "Psychologists commonly describe anxiety as a state of apprehension, a vague fear that is only indirectly associated with an object" (Hilgard, et al., 1971 as cited in Scovel, 1978). McCroskey (1977) uses the term communication apprehension to define a person's "level of fear or anxiety associated with either real or anticipated communication with other persons" (p.78). According to McCroskey (1977), a person with a high level of communicative apprehension will try to stay away from interacting with people to avoid experiencing anxiety or fear.

2.2 Components in Language Anxiety

Many factors can cause language anxiety in a foreign or second language. In developing factors of foreign language anxiety, Horwitz et al. (1986) suggested three components that cause language anxiety:

i. Communication Apprehension (CA) – Communication apprehension (CA) is a feeling of discomfort when asked to talk in a foreign language in front of other people. It is a "type of shyness characterised by fear of or anxiety about communicating with people" (Horwitz et al., 1986, p. 127).
ii. Test Anxiety (TA) – Test anxiety is a "type of performance anxiety stemming from a fear of failure" (Horwitz et al., 1986, p. 127). Students who experience test anxiety feel that speaking in class is an assessment situation rather than an opportunity to speak freely and improve their communication skills.
iii. Fear of Negative Evaluation (FNE*)* – Fear of negative evaluation is "apprehension about others' evaluations, avoidance of evaluative situations, and the expectation that others would evaluate oneself negatively" (Horwitz et al., 1986, p. 128). Even though FNE might seem similar to test anxiety, the fear of negative evaluation is not restricted to only assessment; it may occur in any social situation (Horwitz et al., 1986). Thus, students with this fear do not want to participate in speaking activities because if they make mistakes, it will reflect on their image in front of their friends and the impression of language teachers.

However, Horwitz et al. (1986) stated that anxiety related to speaking English does not only come from the three components mentioned above but "a distinct complex of self-perceptions, beliefs, feelings, and behaviours related to classroom language learning arising from the uniqueness of the language learning process" (p. 128). Therefore, learning to speak English is a unique process because students must speak using a language that is not their mother tongue and they have not mastered it (Ansari, 2015; Mohd Naser & Mat Isa, 2021).

2.3 Development of Public Speaking Classroom Anxiety Scale (PSCAS)

According to Yaikhong and Usaha (2012), there is no scale to determine speaking anxiety in a classroom context. Horwitz et al. (1986) constructed the Foreign Language Classroom Anxiety Scale (FLCAS), which is being used frequently to measure foreign language anxiety in the classroom. The most frequently used scale in public speaking is the Personal Report of Communication Apprehension (PRCA-24) by McCroskey (1982), which determines anxiety in different settings, such as speaking in pairs, group discussions, meetings, and public speaking.

Therefore, the researchers developed the PSCAS to measure the speaking anxiety levels experienced by Thai students in Thai classrooms (Yaikhong & Usaha, 2012). Since then, PSCAS has been used in other countries to determine speaking anxiety in a classroom setting. In creating PSCAS, Yaikhong and Usaha (2012) referred to four existing language anxiety scales that measure foreign language and public speaking anxiety levels, and they are:

a. Personal Report of Communication Apprehension (PRCA-24) by McCroskey (1982)
b. Foreign Language Classroom Anxiety Scale (FLCAS) by Horwitz et al. (1986)
c. Personal Report of Public Speaking Anxiety (PRPSA-34) by McCroskey (1992)
d. Speaker Anxiety Scale (SA) by Clevenger and Halvorson (1992)

2.4 Public Speaking Class Anxiety (PSCA) Studies

Only a few studies have been conducted using the PSCA scale developed by Yaikhong and Usaha (2012). These studies reveal that students from local and international institutions experienced a moderate level of anxiety. Even though these studies showed moderate PSCA levels, they differ in which domain students experienced the most anxiety.

In the Malaysian polytechnic setting, a study by Mohamad Yazi et al. (2023) on 113 diploma students in Politeknik Ibrahim Sultan (PIS) revealed that test anxiety (TA) domain outranked all other factors and students experienced moderate speaking anxiety. In Politeknik Sultan Idris Shah, Selangor, 157 students who were taking the DUE10012 course experienced a moderate level of speaking anxiety, with a mean of 3.16 and fear of negative evaluation (FNE) domain was the significant anxiety (Mohd Ali, 2020).

A study by Lau et al. (2019) on 592 students from UiTM Sarawak revealed that learners experienced a moderate level (M = 3.31), with communication apprehension (CA) ranked the highest (M = 3.37) followed by FNE (M = 3.36). Mohd Naser and Mat Isa (2021) reported that out of 150 UiTM Shah Alam students, 82 students scored a moderate speaking anxiety level, and CA was placed the highest (M = 3.18), followed by FNE (M = 3.15). Lastly, Ch'ng et al. (2025) studied 65 undergraduates attending an English proficiency workshop from UiTM. They did not study students' PSCA level but revealed that FNE and CA were significant factors while TA was the least impactful.

In an international setting, Sugiyati and Indriani (2021) investigated the PSCA level among 34 students at Universitas Tidar, Indonesia. They found that most learners felt moderate levels of anxiety, and FNE ranked as the highest. Seventy-five students who took an intensive English course at Hanoi University experienced a medium level of anxiety, and FNE was the most substantial influence on learners' speaking anxiety (Nguyen, 2023). Mohd Anuardi et al. (2023) analysed 43 university students taking an English presentation course at a private university in Tokyo. The researcher did not study the PSCA level but made a comparison between male and female students and found that males have lower anxiety in speaking. Both genders exhibit the most significant anxiety in CA. Finally, a study by Indahyanti et al. (2023) on 20 students majoring in English at Universitas Islam Makassar, Indonesia. The students responded with a moderate level of anxiety, with the majority of the students still feeling fear in CA.

2.5 PSCA and SPM Grades

Research examining the correlation between the PSCA score and SPM grades is limited. However, few studies provide insights into the relationship.

Balakrishnan et al. (2022) utilised the Personal Report of Public Speaking Anxiety (PRPSA) on 65 third-semester Engineering Diploma students from UTeM in Malacca. Although the study did not use PSCAS as its measurement, it revealed a significant negative relationship between the FLCAS scores and SPM English grades. This suggests that the higher the level of foreign language anxiety, the lower the English language grade achieved at the SPM level. Tee (2021) did a study on 65 undergraduates who took a public speaking course at Universiti Tunku Abdul Rahman. In her study, the SPM English results were correlated with each dimension in PSCAS. The researcher found out that students who scored lower SPM grades experience more fear of being negatively assessed by others, test anxiety levels increase and the more apprehensive they are.

On the contrary, a study by Phek et al. (2020), with 592 UiTM Sarawak undergraduates, indicated a positive, moderately significant relationship between the PSCA score and SPM English grades. This indicated that students with better SPM English grades, experienced higher speaking anxiety among university students. The studies above showed mixed findings on PSCA scores and SPM English results.

2.6 PSCA and Speaking Assessment Scores

Mohamad Yazi et al. (2023) did a study on 113 diploma undergraduates in Politeknik Ibrahim Sultan (PIS), Malaysia. They found no significant relationship was reported between PSCA score and classroom-based oral presentation assessment. Mohd Naser and Mat Isa's (2021) study indicated a moderate positive correlation between student performance and public speaking anxiety. Learners with high speaking anxiety scored higher grades in oral presentations. Ab Manan et al. (2023) did a study using FLCAS on 193 pre-diploma UiTM students. They found that there was a significant negative relationship between language anxiety and speaking performance. This indicates that the more anxious the students are, the more their speaking performance worsens. From the studies above, it is apt to mention that PSCA scores affect students' learning processes and results.

3. Methodology

3.1 Research Design

Survey research is "a means of gathering information through self-report using questionnaires or interviews for descriptive purposes or to examine relationships between variables" (Hutchinson, 2024, p. 285). Therefore, this research used a questionnaire for its data collection. In addition, most research concerning public speaking classroom anxiety only used a quantitative survey to analyse the anxiety level in a classroom (Indahyanti et al., 2023; Lau et al., 2019; Mohd Ali, 2020; Mohd Naser & Mat Isa, 2021; Mohamad Yazi et al., 2023; Nguyen, 2022; Sugiyati & Indriani, 2021).

3.2 Population and Sample

Three hundred twenty-five commerce students were enrolled in the 2024/2025 academic year. According to Stangroom (2025), a sample size of 177 students is sufficient to achieve statistically significant results. The researcher collected 203 respondents, approximately 63% of the required sample size for this research. Purposive sampling was used because the researcher wanted to investigate speaking anxiety experienced by first-semester commerce students who took Communicative English 1 (DUE10112).

3.3 Instrumentation

The researcher used the PSCAS for this research. PSCAS consists of 17 items with a 5-point Likert scale, from strongly disagreeing, as indicated with (1) to strongly agree, as indicated with (5). PSCAS has shown an internal reliability, attaining an alpha coefficient of 0.84 (Yaikhong & Usaha, 2012). PSCAS questionnaire is divided into four constructs: (1) communication apprehension, (2) test anxiety, (3) fear of negative evaluation, and (4) comfort in using English. Table 1 shows the PSCAS' components and the 17 items.

Table 1. Domain of the PSCAS Items

Public Speaking Anxiety Factor	Item No.
Factor 1 (Fear of Negative Evaluation)	6, 9, 11, 13, 14, 16
Factor 2 (Comfort in using English)	4, 8, 10, 12
Factor 3 (Test Anxiety)	1, 7, 17
Factor 4 (Communication Apprehension)	2, 3, 5, 15

Yaikhong and Usaha (2012) indicate the scoring range for the PSCAS levels. The possible range of PSCAS scores is from minimum (17) to maximum (85). PSCAS five-point Likert scale helps convert questionnaire scores into meaningful categories from: (1) Low Anxiety (lower than 51); (2) medium anxiety (51-68); (3) high anxiety (higher than 68).

The questionnaire has two sections. The first section asks students to provide their matric numbers. Other information, including the English SPM result, is obtained from PTSB SPMP (Polytechnic Management Information System). The second section contains 17 items on public speaking anxiety levels. The data for the DUE10112 speaking score is obtained from the respective lecturers.

3.4 Data Collection Method

The researcher distributed the PSCAS questionnaire during two seminars on 20 October 2024 and 17 March 2025. Before giving out the questionnaire, the researcher mentioned the study's aim and assured the students that the responses were kept private and would not affect their Communicative English results. This approach aimed to encourage honest and thoughtful responses from the participants.

3.5 Data Analysis Method

The data obtained from the questionnaire was analysed through Excel. Descriptive statistics were used to answer the first and second questions of the study. For the third question, Spearman's correlation was used to identify the relationship between PSCAS scores and students' English SPM results. As for the fourth question, the Pearson correlation coefficient was utilised to report PSCAS scores and DUE10112 speaking scores.

4. Results and Discussion

A total of 234 questionnaires were distributed; of this, 31 questionnaires were incomplete and thus discarded. Table 2 shows the demographic background of the students concerning gender and SPM English grades. There were 168 females (82.8%) and 35 male (17.2%). Looking at students' results in the English SPM grade, 17.2% (n = 35) of students got a distinction. The majority were average in their English language proficiency, with 54.7% (n = 111) obtaining credit, while 28.1% (n = 57) just passed with SPM. Based on the table, it was established that their English language mastery level ranged from super credit to pass.

Table 2. Respondents' Profiles

Category	Frequency (f)	Percentage (%)
Gender		
Male	35	17.2
Female	168	82.8
SPM Grade		
A+ (Super Distinction)	2	1.0
A (High Distinction)	18	8.9
A- (Distinction)	15	7.4
B+ (Super Credit)	31	15.3
B (High Credit)	28	13.8
C+ (Upper Credit)	26	12.8
C (Credit)	26	12.8
D (Upper Pass)	46	22.7

E	(Pass)	11	5.4
G	(Fail)	0	0

4.1 Research Question 1: What are the levels of PSA amongst commerce students in PTSB?

The PSCA scale was utilised to determine students' responses on the level of overall speaking anxiety. Table 3 shows the respondents' profiles, with 115 students (56.65%) having medium anxiety, 85 students having low anxiety, and only three students experiencing a high level of speaking anxiety. Table 4 shows the lowest (26) and the highest (77) scores attained, with a mean of 51.91, indicating that commerce students' anxiety levels were slightly above their low anxiety level.

Table 3. Frequency and Percentage of Speaking Anxiety Level

	Frequency (f)	Percentage (%)
Low Anxiety (<51)	85	41.87
Medium Anxiety (51-68)	115	56.65
High Anxiety (>68)	3	1.48

Table 4. Descriptive Statistics of Average PSCAS

N	Minimum	Maximum	Mean	Median	Mode	Std Dev.
203	26	77	51.91	52	55	8.14

PTSB commerce students experiencing a medium anxiety level in the classroom concurred with research done with tertiary students in Malaysia (Lau et al., 2019; Mohammad Yazi et al., 2023; Mohd Ali, 2020; Mohd Naser & Mohd Isa, 2021; Phek et al., 2020) and from international institutions (Indahyanti et al., (2023); Sugiyati & Indriani, 2021; Nguyen, 2023). According to Lau et al. (2019), a high level of anxiety could make it challenging to be productive in the target language. Thus, an average level of anxiety can motivate learners to strive better to learn English (Lau et al., 2019; Mohd Ali, 2020).

4.2 Research Question 2: Which factors contribute to speaking anxiety amongst commerce students in PTSB?

Tables 5 to 8 present the items grouped into four constructs in PSCA, as identified by Yaikhong and Usaha (2012). To achieve the second objective, which is to examine which domain students experienced the most anxiety, the researcher included the frequency, percentage, mean, and standard deviation for every item in the domains. The items in each component are ranked from the highest mean to the lowest. According to Yaikhong and Usaha (2012, p. 33), in terms of anxiety level based on mean, mean scores within 3-4 were categorised as medium anxiety, below three as low anxiety, and over four as high anxiety.

Table 5. Frequency, Percentage and Means of Factor 1 (Fear of Negative Evaluation) (FNE)

Item	SD	D	N	A	SA	Mean	Std. Dev
9.	I can feel my heart pounding when I am going to be called on.						
	12 (5.9%)	22 (10.8%)	53 (26.1%)	79 (38.9%)	37 (18.2%)	3.53	1.09
14.	I feel anxious while I am waiting to speak English						
	19 (9.4%)	27 (13.3%)	70 (34.5%)	68 (33.5%)	19 (9.4%)	3.20	1.09
6.	I am afraid that other students will laugh at me while I am speaking English.						
	26 (12.8%)	37 (18.2%)	51 (25.1%)	60 (29.6%)	29 (14.3%)	3.14	1.24
11.	It embarrasses me to volunteer to go out first to speak English						
	27 (13.2%)	30 (14.8%)	70 (34.5%)	55 (27.1%)	21 (10.3%)	3.06	1.17

13.	Certain parts of my body feel very tense and rigid while I am speaking English.						
	21 (10.3%)	41 (20.2%)	81 (39.9%)	53 (26.1%)	7 (3.4%)	2.92	1.01
16.	I have trouble coordinating my movements while I am speaking English.						
	34 (16.7%)	52 (25.6%)	65 (32.0%)	43 (21.2%)	9 (4.4%)	2.71	1.11

Note. SD = Strongly Disagree; D = Disagree; N = Neither agree nor disagree; A = Agree; SA = Strongly Agree

Table 5 shows students' responses to items related to Factor 1: fear of negative evaluation. Students showed the most apprehension on items 9 and 14. These two items scored the highest mean of an anxiety-causing factor in FNE. Interestingly, these two items always came on top, and the rank is similar to studies done by Ch'ng et al. (2025), Lau et al. (2019), and Mohd Ali (2020), albeit with different means. In addition, it is interesting to note that the rank of items 9, 14, 6, 11, 13 and 16 is the same as studies from Indahyanti et al. (2023) and Sugiyanti & Indriani (2021).

FNE comes from the characteristics of some reserved learners who are reluctant to let others know their weaknesses or feel less competent than their friends (Nguyen, 2023). This anxious feeling when speaking in English changes the body's reaction, such as the body feeling tense and stiff, increasing heartbeat, and being less able to control body movements when speaking (Indahyanti et al., 2023; Mohd Naser & Mat Isa, 2021).

Students who are worried about what others think of them or worried about others' evaluation of their performance in the second language classroom (Mohd Ali, 2020; Phek et al., 2020; Sugiyati & Indriani, 2021) will display behaviours that minimise the possibility of unfavourable evaluations (Gregersen & Horwitz, 2002). Students who fear negative evaluation rarely volunteer to speak up; they limit their participation in speaking tasks because they think they are not good at speaking (Ansari, 2015; Ch'ng et al., 2025). Students who face this anxiety are likely to sit quietly in the class, limiting activities that could increase their speaking skills and may even avoid class entirely (Gregersen & Horwitz, 2002; Horwitz et al., 1986).

Table 6. Frequency, Percentage and Means of Factor 2 (Comfort in Using English) (CUE)

Item	SD	D	N	A	SA	Mean	Std. Dev
12.	I face the prospect of speaking English with confidence.						
	3 (1.5%)	49 (24.1%)	85 (41.9%)	48 (23.6%)	18 (8.9%)	3.14	0.94
4.	I feel confident while I am speaking English.						
	14 (6.9%)	41 (20.2%)	84 (41.4%)	35 (17.2%)	29 (14.3%)	3.12	1.10
10.	I feel relaxed while I am speaking English.						
	16 (7.9%)	53 (26.1%)	82 (40.4%)	32 (15.8%)	20 (9.9%)	2.94	1.06
8.	I have no fear of speaking English.						
	20 (9.9%)	56 (27.6%)	66 (32.5%)	39 (19.2%)	22 (10.8%)	2.94	1.14

Table 6 shows respondents' replies to items related to Factor 2: comfort in using English. This factor describes how students feel confident and less stressed when communicating in English. This may happen from a relaxed class setting with sympathetic lecturers and familiarity with their coursemates (Mohd Naser & Mat Isa, 2021; Phek et al., 2020). The moderate mean across factor 2 suggested that while some students were fairly comfortable speaking in English, a majority felt only moderately at ease. This uncertainty may signify a temporary stage where learners become more accustomed to English usage in different settings but have not yet reached complete confidence (Ch'ng et al., 2025).

Table 7. Frequency, Percentage and Means of Factor 3 (Test Anxiety) (TA)

Item	SD	D	N	A	SA	Mean	Std. Dev
17.	Even if I am very well prepared, I feel anxious about speaking English.						
	16 (7.9%)	34 (16.7%)	60 (29.6%)	71 (35.0%)	22 (10.8%)	3.24	1.10
1.	I never feel quite sure of myself while I am speaking English.						
	22 (10.8%)	44 (21.7%)	70 (34.5%)	58 (28.6%)	9 (4.4%)	2.94	1.06
7.	I get nervous when the English teacher asks me to speak English which I have prepared in advance.						
	34 (16.7%)	46 (22.7%)	72 (35.5%)	39 (19.2%)	12 (5.9%)	2.75	1.13

Table 7 shows respondents' responses to items related to Factor 3: text anxiety. Test anxiety is the fear of getting assessed based on a class assessment (Mohd Anuardi et al., 2023). The results for factor 3 indicated that TA was not a significant alarm among PTSB students, unlike the other domains. This is because the wording of items 17, 1 and 7 did not specifically ask students on oral assessments. However, if the statements asked on speaking assessment, it could significantly impact TA levels.

According to Ch'ng et al. (2025), test anxiety is a common issue among students, with speaking tests frequently identified as particularly concerning. Some learners may view learning to speak in class as a test condition rather than a chance to improve communication (Horwitz et al., 1986). A study by Mohamad Yazi et al. (2023) indicated that TA was the highest anxiety-provoking domain as students were well aware that their speaking assessment was to be graded and marks were added to their final score of the Communicative English course.

Table 8. Frequency, Percentage and Means of Factor 4 (Communication Apprehension) (CA)

Item	SD	D	N	A	SA	Mean	Std. Dev
2.	I start to panic when I have to speak English without a preparation in advance.						
	15 (7.4%)	22 (10.8%)	50 (24.6%)	78 (38.4%)	38 (18.7%)	3.50	1.14
3.	In a speaking class, I can get so nervous I forget things I know.						
	15 (7.4%)	26 (12.8%	64 (31.5%)	76 (37.4%)	22 (10.8%	3.32	1.07
5.	I get nervous and confused when I am speaking English.						
	18 (8.9%)	38 (18.7%)	72 (35.5%)	60 (29.6%)	15 (7.4%	3.08	1.06
15.	I dislike using my voice and body expressively while I am speaking English.						
	52 (25.6%)	60 (29.6%)	60 (29.6%)	24 (11.8%)	7 (3.4%)	2.38	1.09

Table 8 indicates respondents' replies to items related to Factor 4: communication apprehension. Item 2 scored the highest compared to other items, which states that most learners concur that they start to panic when speaking English without preparation. Interestingly, the rank of items 2, 3, 5, and 15 aligns with the Sugiyanti and Indriani (2021) study.

CA comprises physiological symptoms such as increased heartbeat and sweaty palms (Mohd Anuardi et al., 2023). Students stated that if they do not prepare their talk earlier, they will feel anxious and confused, and they may get mental blockages or be unable to recall information (Nguyen, 2023). Thus, learners who face CA tend to be more reserved and avoid using English to interact in class. (Mohd Naser & Mat Isa, 2021; Phek et al., 2020).

Table 9. Public Speaking Anxiety Scale Factors

Public Speaking Anxiety Factor	Mean
Fear of Negative Evaluation (FNE)	3.09
Comfort in Using English (CUE)	3.03

Test Anxiety (TA)	2.98
Communication Apprehension (CA)	3.07

The total mean for each factor is summarised in Table 9. Based on the PSCA means for each domain, FNE had the highest anxiety levels (M = 3.09), indicating the most common anxiety factor among commerce students, followed by CA, CUE, and TA. Interestingly, there was a minimal difference in the mean between FNE, CA and CUE. Mainly, respondents rated a moderate level of speaking anxiety in all dimensions. Commerce students in PTSB have the most anxiety in FNE, similar to studies done by Ch'ng et al. (2025), Mohd Ali (2020), Nguyen (2023), and Sugiyati & Indriani, 2021. In the PTSB classroom context, commerce students felt significant anxiety due to fears of being negatively evaluated by peers and lecturers in speaking tasks. As for TA, although less noticeable compared to other factors, it was the primary factor in Mohamad Yazi et al. (2023) findings but the least anxiety-provoking in Ch'ng et al., 2025; Mohd Anuardi et al., 2023; Mohd Naser and Mat Isa (2021) research.

The findings from the studies mentioned in the literature review and from PTSB indicate that students experienced TA the least. The result of this study was somewhat unanticipated since the Malaysian education system is exam-oriented; thus, one would assume assessments to be the primary sources of anxiety. A closer look at the means for three items in TA reveals that the items are not as high as items in CA and FNE. This shows that respondents were more worried about being negatively evaluated by friends and teachers than being worried about their exam results.

4.3 Research Question 3: Is there a statistically significant relationship between Sijil Pelajaran Malaysia (SPM) English results and Public Speaking Class Anxiety Scale (PSCAS) scores?

To address the third question, a null hypothesis was developed as follows:

Ho: There is no significant relationship between SPM English results and PSCA scores.

A Spearman's rank-order correlation was conducted to assess the relationship between students' SPM English grades and PSCA levels. There was a significant, moderate, positive correlation between the two variables, $r_s(201) = .36$, $p < .001$. The p-value is 0.000 and less than 0.01; thus, it is statistically significant. Therefore, the study accepts the alternative hypothesis: a significant relationship exists between PSCAS scores and English SPM results.

This result shows that commerce students with better SPM English grades experienced increased speaking anxiety. This finding agrees with the study done by Phek et al. (2020), which highlighted that the better the SPM grade, the higher the students' level of anxiety. On the other hand, the result of question three is contrary to findings in studies by Balakrishnan et al. (2022) and Tee (2021), which demonstrated that the lower the English language grade achieved at the SPM level, the higher the level of anxiety experienced.

In language learning, perfectionist students feel that they must speak flawlessly, produce faultless sentences with no grammatical or pronunciation errors, and be able to talk as easily as native speakers (Ansari, 2015; Gregersen & Horwitz, 2002). Instead of showing less-than-perfect language skills and destroying their social image as excellent students (Ansari, 2015), perfectionist students would prefer to remain silent (Khan, 2015), pausing until they are sure how to express their opinions. Gregersen & Horwitz (2002) indicated that "perfectionist language learners create impossibly high-performance standards that create ideal conditions for developing language anxiety" (p. 563).

4.4 Research Question 4: Is there a statistically significant relationship between the Public Speaking Class Anxiety (PSCA) scores and students' Communicative English scores?

To address this question, PSCAS scores were correlated with the DUE10112 speaking score. For the DUE10112 speaking score, only marks from group discussion and oral presentation were taken, which constitute 60% of the total marks. The rest of the marks came from the theory test and reading assignment, which will not be included in the score.

To address the fourth question, a null hypothesis was developed as follows:

Ho: There is no significant relationship between the PSCA scores and Communicative English scores.

A Pearson correlation coefficient was conducted to determine how students' PSCA level and Communicative English-speaking scores were related. There was a negative but weak correlation between the two variables, $r(201) = -.29$, $p < .001$, indicating that students with lower PSCA levels will have higher Communicative English scores. Therefore, the study agrees with the alternative hypothesis: a significant relationship between PSCAS scores and English DUE10112 speaking scores.

This finding differs from Mohd Naser and Mat Isa's (2021) research, which found a significant positive correlation. This means students with a high PSCA level performed better in oral presentation class. A study by Mohamad Yazi et al. (2023) stated no significant relationship between anxiety level and speaking achievement among polytechnic students.

However, it must be noted that communicative English marks vary from lecturer to lecturer, which could contribute to a weak or strong correlation between PSCA levels and students' speaking scores. Many factors influence language teachers' assessment practices, leading to variations in strictness or leniency in speaking-based assessments. In addition, parts such as visual aids and attire were evaluated in group discussions and oral presentation assessments, which are unrelated to speaking skills. In addition, parts such as visual aids and attire were evaluated in group discussion and oral presentation assessments, which are unrelated related to speaking skills.

5. Conclusion

This study explored the anxiety levels of PTSB commerce students enrolling in the Communicative English class. The findings concluded that commerce students felt a moderate level of speaking anxiety in English class. The data was also analysed to ascertain which factor caused the most anxiety. Of the four factors, students experienced the highest level of fear of negative evaluation, meaning they tend to worry about how their friends and language instructors view their performance when speaking in English. FNE was the highest compared to communication apprehension, comfort in using English and test anxiety. There was an interesting finding for research questions 3 and 4. The findings showed that students who score better on SPM English grades will exhibit increased PSCA levels. On the contrary, for research question four, students with high PSCA levels scored lower marks in the DUE10112 oral assessment.

5.1 Suggestions and Future Research

The feeling of nervousness is impossible to wipe off entirely. Even so, speaking anxiety can be minimised. Educators play an important role in easing students' anxiety (Horwitz et al., 1986; Khan, 2015; Marcos-Llińas & Garau, 2009). When educators know that speaking anxiety may cause their students to feel anxious in class, educators can adjust their teaching method to create a less threatening and comfortable classroom setting so that they are willing to converse in English (Ab Manan, 2023; Mohd Ali, 2020; Phek et al., 2020). Ansari (2015) suggests that speaking tasks should be centred on students' interests and suitable for their proficiency levels. Ansari (2015), Tee (2021), and Wan Salim et al. (2017) recommend group discussion, pair work, role-playing exercises, language games, short presentations and simulations as strategies educators can use to create relaxed and less threatening learning environments in the classroom to build students' confidence gradually.

Regarding moderate to high anxiety students, teachers should give special attention by giving positive remarks on students' attempts, praising their work, providing constructive feedback, and having a one-to-one talk outside class (Ansari, 2015). Educators providing individual-specific measures can boost students' self-confidence, thus reducing their anxiety, leading to better learning and enabling learners to improve their speaking performance (Phek et al., 2020; Sugiyati & Indriani, 2021). Educators should try to know their students' attitudes toward speaking activities and their needs and wants. This will allow educators to choose the best teaching material, which can result in a productive learning process (Ansari, 2015; Asio et al., 2024; Mohd Naser & Mat Isa, 2021).

In addition, educators should focus on learners' communicative competence and tolerate learners' mistakes instead of excessively focusing on grammar rules that can cause anxiety whenever learners try to communicate (Khan, 2015). Ansari (2015) suggests that educators should avoid immediate correction in speaking tasks since it can demoralise students' self-confidence. Thus, educators should give learners more time before they speak and let students know that language mistakes are part of the learning process (Ansari, 2015; Wan Salim et al., 2017).

Asio et al. (2024) and Mohd Anuardi et al. (2023) recommend a series of communication skills training and workshops or public speaking courses to target specific fears and help reduce speaking anxiety. Finally, Horwitz et al. (1986) suggested that learners with severe anxiety reactions should be referred for specialised help from counsellors or learning specialists as educators cannot focus on one student or they have inadequate knowledge to deal with severe anxiety reactions.

According to Amat Suparia (2022), Khan (2015), and Marcos-Llińas and Garau (2009), there are numerous causes which are linked to speaking anxiety, including one's personality traits, learning styles/strategies, emotional factors, cultural, gender, sociolinguistic factors, classroom environment including peer and classmates, and the role of instructor attitudes and teaching style. First, the researcher suggested that more comprehensive research in Malaysia be conducted to study the factors mentioned above since the central issue in polytechnics is how to encourage students to communicate in English. Second, answering questionnaires on self-reported anxiety levels can be subjective and biased, as students may underreport or overemphasise their apprehension based on individual perceptions. Therefore, interviews can also be conducted to understand students' learning anxiety rather than being restricted to survey analysis. Third, longitudinal studies could also provide insights into how anxiety levels change with increased exposure and practice (Ab Manan et al., 2023). By looking at these three suggestions, future studies can contribute to developing more effective strategies to help undergraduates overcome their speaking apprehension, ultimately leading to improved communication skills and academic success.

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THE IMPACT OF DIGITAL BANKING ON GENERATION Z'S INTEREST IN SAVING

Nova Angelina Nababan*, Muliyani

Management Study Program, Sukma School of Management, 20219 Medan, North Sumatra, Indonesia

*Corresponding author e-mail address: novaangelinanababan3003@gmail.com

Abstract

Rapidly developing digital technology has changed the way people, especially the younger generation, manage their money, including saving. This study aims to determine how digital banking affects interest in saving, as digital banking is considered to have the ability to make financial transactions easier and more convenient. In this study, a quantitative method was used by distributing questionnaires via Google Forms. Generation Z, who use digital banking, are the subjects of this study. Overall, the purposive sample consisted of 103 individuals who met the following criteria: they were between 13 and 28 years old and had previously used digital financial services, along with initial data obtained through the survey. Data analysis was conducted using SPSS version 23. Simple regression analysis was employed. The results of the hypothesis test showed that the calculated F value of 41.209 was higher than the table F value of 3.94, and the significance value was less than 0.050, specifically 0.000, which is less than 0.050. The study indicates that Generation Z is more interested in saving and benefiting through digital banking.
Keywords: Digital Banking; Interest in Saving; Generation Z.

1. Introduction

Almost all aspects of human life have changed due to advances in digital technology, including the financial services sector. Digital banking is a technology-based banking service that allows customers to conduct various transactions online without having to visit a physical branch office, making it one of the greatest advances in the contemporary banking industry. Digital banking has not only changed banking institutions but also influenced customer behavior and preferences regarding financial services.

Generation Z consists of people born between 1997 and 2012, a group that grew up alongside advances in digital technology. They are known as digital natives and tend to want speed, convenience, and flexibility in their daily activities, such as managing their personal finances. Approximately 64.22 million people, or 22.99% of Indonesia's total population, belong to Generation Z. (Central Statistics Agency, 2024) In the city of Medan alone, the number of Generation Z individuals reaches 767,934 making them a strategic market segment for the banking industry, particularly in the development of digital banking services (Medan Central Statistics Agency, 2024),.



Fig. 1. Percentage of Population by Age Group
Source: Central Statistics Agency

Table 1. Population of Medan City by Gender and Age

Age Group	Men	Women	Total
10-14	97.065	91.950	189.015
15-19	95.890	90.262	186.152
20-24	99.252	93.679	192.949
25-29	101.637	98.181	199.818

The adoption of digital banking has seen a significant increase following the COVID-19 pandemic. The monetary policy report notes a 16.15% increase in digital banking transactions, with a transaction value of Rp 15,881.53 trillion (Bank Indonesia, 2024). In the Medan area and its surroundings, the growth of digital banking users reached 20.21% with more than 2.61 million active users. This shows that the public, especially the younger generation, is increasingly open to the use of digital financial services.



Fig. 2. Growth in digital banking transaction values
Source: Bank Indonesia

However, Generation Z shows complex savings interests behind its massive adoption of technology. They have broad access to financial services and information, but consumptive lifestyles, lack of knowledge about long-term finances, and lack of financial literacy are major issues. The National Survey of Financial Literacy and Inclusion shows that the financial literacy rate of Generation Z increases with age. This increases from 51.68% among those aged 15-17 to 73.22% among those aged 18-25, indicating that the availability of information influences Generation Z's financial knowledge (Otoritas Jasa Keuangan, 2025).

Previous studies on digital banking and saving habits. The study by Safirah et al., (2024) concluded that while digitalization does not have a significant impact, understanding of Islamic

finance has a significant impact on Generation Z's saving habits (Aisah, 2022). The research findings indicate that knowledge of Islamic finance and an individual's social environment truly have a positive impact on their tendency to save. However, perception cannot function as a factor strengthening the relationship between knowledge of Islamic finance and social environment with interest in saving.

A study conducted by Isroi (2024) found that financial literacy, digital marketing, and religious values have a positive influence on Generation Z's desire to save. Chasanah (2024) found that app features, the ease of using mobile banking, and user trust levels have a positive contribution to Generation Z's digital transaction decisions.

Research by Abrori (2020) in Sukoharjo Regency found that knowledge and religiosity positively and significantly influence millennials' interest in saving at Islamic banks. Conversely, the facility variable does not have a significant influence. The results indicate that, particularly regarding saving at Islamic financial institutions, an individual's understanding and religious values have a greater influence on their financial decisions. Currently, a study by Jumberi (2019) indicate a significant correlation between Generation Z's self-efficacy levels and their desire to save in Islamic banks. Their self-efficacy levels contribute 21.4% to saving decisions, indicating that Generation Z students have greater confidence in managing their finances, lives, and money.

Research by Susanti (2020) reveals that religious factors and location do not influence the interest of students in the Islamic Economics Department at IAIN Surakarta to save in Islamic banks, while knowledge does influence it. A study by Valentino et al. (2022) shows that perceptions of credibility and social influence positively and significantly influence Gen Z's interest in using Islamic digital banks. Conversely, variables considered useful and ease of use do not influence this interest. These results indicate that social environmental encouragement and trust in the system are crucial for motivating young people to use digital Islamic financial services.

Based on the study's findings, it is evident that the presence of digital banking does not necessarily automatically encourage savings interest, despite offering attractive features such as financial goal visualization, real-time notifications, and online account opening. Further research is needed to determine the extent of digital banking's influence on Generation Z's interest in saving, particularly in a local context such as the city of Medan.

Therefore, this study aims to evaluate the influence of digital banking on Generation Z's interest in saving in the city of Medan. Additionally, this study aims to provide significant contributions to the banking industry in creating more effective marketing strategies and service development for the Generation Z segment.

2. Methodology

This study examines how digital banking affects Generation Z's desire to save money in Medan City. The study uses a quantitative approach and conducts a survey through the distribution of questionnaires. The research covers the entire process from instrument preparation to data analysis. It will take place over four months, from March to June 2025.
This study investigates Generation Z, born between 1997 and 2012, residing in Medan City due to the significant growth of digital banking services in the city. Purposive sampling was used to select 100 respondents based on whether they had ever used or were aware of digital banking services. The Slovin formula with a 10% margin of error was used to collect this sample.

The types of quantitative data used were primary and secondary. Primary data was obtained directly from respondents through a closed questionnaire designed with a five-point Likert scale, while secondary data came from scientific publications, publications from the Financial Services Authority (OJK), Bank Indonesia (BI), and statistical data from the Central Statistics Agency (BPS).

The data collection method involved distributing questionnaires online via the Google Forms platform, which were then disseminated to Generation Z through social media such as TikTok and WhatsApp. The two main variables measured in the survey were interest in saving as the dependent variable and digital banking as the independent variable.

Digital banking in this study was measured based on five main indicators: ease of use, service features, transaction security, accessibility (24-hour access), and service speed. Meanwhile, interest in saving was measured through five indicators: feelings of joy toward saving, interest in savings products, frequency of saving, saving habits, and awareness in managing finances.

The collected data were analyzed using SPSS software employing descriptive statistical techniques and simple linear regression analysis. The validity and reliability of the questionnaire instruments were tested, and the data were tested under classical assumptions to ensure they met the requirements for regression analysis.

To determine the strength and significance of the relationship between the independent and dependent variables, the F-test and coefficient of determination (R2) were used. There are two hypotheses in this study.

a) The null hypothesis (H0) states that there is no significant relationship between digital banking and Generation Z's interest in saving in Medan City.
b) The second is the alternative hypothesis (Ha), which states that there is a significant relationship between digital banking and Generation Z's interest in saving in Medan City.

The results of the hypothesis testing will show whether digital banking plays a role as a factor that can encourage saving behavior among Generation Z, especially in urban environments such as Medan City.

3. Results and Discussion

3.1 Results

This study involved 110 members of Generation Z born between 1997 and 2012. They live in the city of Medan. However, only 102 people met the criteria of being active in conducting transactions, making payments, and saving money through digital banking services. Time constraints and access to the target population, as well as differences in participation rates in the online questionnaire, resulted in a limited number of respondents.

3.2 Respondent Characteristics

The characteristics of the research respondents were compiled to improve understanding of the general respondent profile. This information was necessary to ensure that Generation Z members living in the Medan area who had experience using digital banking services that met the criteria were the respondents. Gender, age range, and status were some of the demographic variables

used to categorize respondents into groups based on their characteristics. Each category is shown in the following table:

a) Respondent Characteristics Based on Age

The table below shows the characteristics of respondents based on their age in this study:

Table 2. Age Characteristics of Respondents

No	Age	Number	Percentage
1	13-17 years	1	1,0%
2	18-22 years	77	75,5%
3	23-28 years	24	23,5%
	Total	102	100%

According to Table 2, the majority of respondents are in the 18–22 age group, totaling 77 people (75.5%). Next is the 23–28 age range with 24 people (23.5%), and only 1 person (1.0%) from the 13–17 age range. The results show that young adults aged 18 to 22 use digital banking services more, especially for their personal financial needs.

b) Respondent Characteristics by Gender

The following table shows the characteristics of respondents based on gender in this study:

Table 3. Gender Characteristics of Respondents

No	Gender	Number	Percentage
1	Male	20	19,6%
2	Female	82	80,4%
	Total	102	100%

Table 3 shows that 82 female respondents (0.4%) and 20 male respondents (19.6%) indicate that women use digital banking services in Medan City Generation Z more frequently than men.

c) Respondent Characteristics by Activity Status

Based on the table below, the activity status of respondents in this study is shown in the following table:

Table 4. Activity Status

No	Status	Number	Percentage
1	Student	79	77,5%
2	Employed	17	16,7%
3	Student and employed	5	4,9%
4	Unemployed	1	1%
	Total	102	100%

Most respondents, 79 (77.5%), are students, 17 (16.7%) are employed, while 5 (4.9%) are both students and employed, and 1 (1%) is not employed, as shown in Table 4. The data indicates that students who plan and manage their personal finances often use digital banking services, but not many of them are employed.

3.3 Instrument variable test

a) Validity test

The validity test was conducted to determine how accurately and precisely the questionnaire items could measure the intended variables. In this study, Pearson's correlation analysis (Pearson Product-Moment) was used to test the validity. The table value of r at a significance level of 5% (n = 102, df = 101) is 0.937, indicating that the calculated r value, or Pearson correlation value, is greater than the table value. The validity test results for each statement item variable used in this study are as follows:

Table 5. Validity Test Results for Variables X and Y

Variable	Statement Item	Calculated R	Table R	Notes
Digital *Banking* (X)	1	0,717	0.1937	Valid
	2	0,731		Valid
	3	0,719		Valid
	4	0,699		Valid
	5	0,676		Valid
	6	0,760		Valid
	7	0,638		Valid
	8	0,769		Valid
	9	0,802		Valid
	10	0,771		Valid
Interest in Saving (Y)	1	0,443	0.1937	Valid
	2	0,681		Valid
	3	0,648		Valid
	4	0,675		Valid
	5	0,745		Valid
	6	0,717		Valid
	7	0,750		Valid
	8	0,751		Valid
	9	0,673		Valid
	10	0,731		Valid

The validity test results indicate that all statements in the questionnaire used to assess the Digital Banking and Savings Interest variables are valid. Therefore, all items are suitable for use in the next stage of analysis.

b) Reliability Test

To test the reliability of this study, Cronbach's Alpha technique was used and the SPSS program was used. An instrument is considered reliable if it has a Cronbach's Alpha value of at least 0.60 (Ghozali, 2016). The following are the results of the reliability test of the digital banking variable (X) and the interest in saving variable (Y) used in this study:

Table 6. Reliability Test Results for X and Y

No	Variable	Cronbach's Alpha	Standart	Description
1	Digital *Banking* (X)	0,900	0,60	Reliable
2	Interest in Saving (Y)	0,872	0,60	Reliable

The table above shows that the questionnaire used to measure interest in digital banking and savings has high reliability. The reliability test results indicate that both variables have

Cronbach's Alpha values greater than 0.70, indicating that the questionnaire questions consistently assess these variables.

3.4 Classical Assumption Test

a) Normality Test

The normality test is conducted to determine whether the normality assumption is met or whether the regression model with dependent and independent variables shows a normal distribution. The significance value of the normality test, which involves statistical analysis using the Kolmogorov-Smirnov test results, exceeds the significance threshold of 0.05. Thus, the regression model can be used for further analysis (Ghozali, 2016). The results of the Kolmogorov-Smirnov test are shown as follows:

Table 7. Results of the Kolmogorov-Smirnov normality test

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		102
Normal Parameters[a,b]	Mean	,0000000
	Std. Deviation	4,52894512
Most Extreme Differences	Absolute	,110
	Positive	,091
	Negative	-,110
Test Statistic		,110
Asymp. Sig. (2-tailed)		,004[c]

Results of the Kolmogorov-Smirnov Normality Test: The significance level is 0.004, which is less than the significance level of 0.05. This indicates that the residual distribution is not normal. As a result, the Monte Carlo test was used to generate a more realistic and stable estimate of the significance level (p-value) (Gama Statistika, 2021). The following are the results of the Monte Carlo test:

Table 8. Results of the Monte Carlo Normality Test

One-Sample Kolmogorov-Smirnov Test			
			Unstandardized Residual
N			102
Normal Parameters[a,b]	Mean		,0000000
	Std. Deviation		4,52894512
Most Extreme Differences	Absolute		,110
	Positive		,091
	Negative		-,110
Test Statistic			,110
Asymp. Sig. (2-tailed)			,004[c]
Monte Carlo Sig. (2-tailed)	Sig.		,152[d]
	99% Confidence Interval	Lower Bound	,143
		Upper Bound	,161

The 99% confidence interval is 0.143–0.161, and the significance is greater than 0.05. Therefore, since there is insufficient basis to reject the assumption of normality according to the Monte Carlo simulation results, the residuals are shown to follow a normal distribution pattern. However, since the results of classical statistical tests indicate deviations in this simulation method, the regression model can still be used for more in-depth analysis involving the use of parametric statistical techniques.

To test normality, graphical analysis can be used. This will compare the normal distribution, which will form a diagonal line if normal. The probability plot graph is as follows:

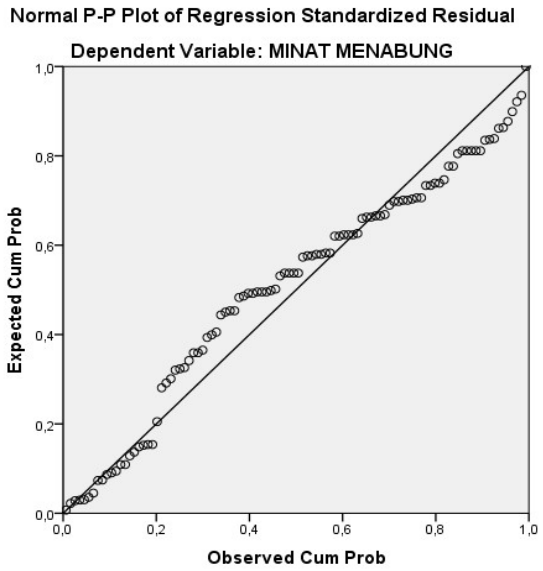


Fig. 3. Graph of Normality Test Results using P-Plot

The normal probability graph (P-P plot) does not show any patterns or deviations from the diagonal line. Instead, the data points scattered around the diagonal line or straight line indicate residuals that are close to a normal distribution.

b) Linearity Test

To determine whether there is a linear relationship between digital banking variables and interest in saving, a linearity test was conducted. Table 9 shows the results of the linearity test.

Table 9. Linearity Test Results using ANOVA Table

			Sum of Squares	df	Mean Square	F	Sig.
Savings Interest * Digital *Banking*	Between Groups	(Combined)	1756,833	19	92,465	6,489	,000
		Linearity	853,697	1	853,697	59,908	,000
		Deviation from Linearity	903,136	18	50,174	3,521	,000
	Within Groups		1168,510	82	14,250		
	Total		2925,343	101			

The results of the analysis of the table above show that there is a statistically significant relationship between the variables. The significance value of linearity is 0.000, and the significance value of linearity deviation is also 0.000, indicating that the relationship is not truly linear. Therefore, it can be concluded that the relationship between interest in saving and digital banking is not linear. If the relationship between variables does not follow a linear pattern, a quadratic regression model is used (Ghozali, 2016). Since the initial linearity test results showed deviations (not significant), a quadratic regression approach with logarithmic transformation (Log_DB) was used, as follows.

Table 10. Results of the Linearity Test using

	Measures of Association			
	R	R Squared	Eta	Eta Squared
Savings Interest * Log_DB	,408	,166	,775	,601

The analysis results show an R value of 0.408 and an R Square value of 0.166. This means that the digital banking variable can contribute 16.6% of the variation in interest in saving, and other variables outside the model contribute 83.4% of that variation. The eta value reaches 0.775, indicating a very strong relationship when digital banking usage is categorized, and the eta squared value is 0.601, meaning that 60.1% of the variation in savings interest is related to differences in the level of digital banking usage. This finding indicates that the higher the utilization of digital banking services, the greater the individual's tendency to save.

C) Heteroskedasticity Test

The heteroskedasticity test was used in this study to determine whether there are differences in residual variance in the observed regression model results. This was done using a scatterplot graph showing the relationship between the predicted values of the dependent variable (ZPRED) and the residual values. There is no evidence of heteroskedasticity if there is no specific pattern of point distribution or if the points are randomly scattered above and below the zero line on the Y-axis.

In the scatterplot in Figure 4, the points are randomly scattered around the zero line without any funnel or systematic patterns. As the predicted values increase, the model's residual variance does not increase or decrease. There is no clustering on one side of the plot, and the distribution is relatively even in the prediction range of –1 to +2 and the residual range of –2.5 to +2.5, indicating that the homoscedasticity assumption is met.

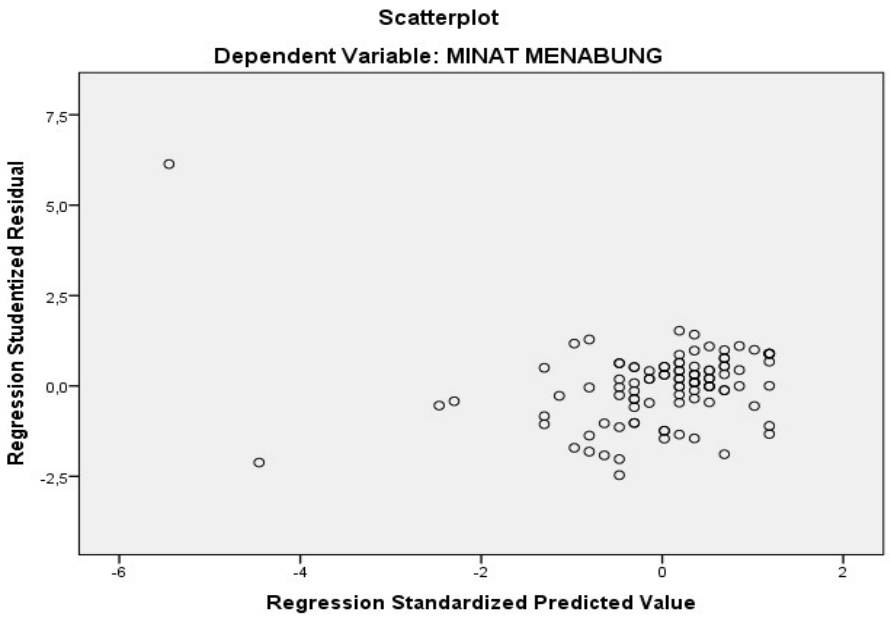


Fig. 4. Results of the heteroscedasticity test scatterplot

3.5 Simple Linear Regression Test

Simple linear regression analysis is used to determine how much influence the Digital Banking variable (X) has on Interest in Saving (Y), partially. The following table shows the results of data processing with SPSS:

Table 11. Results of the Simple Linear Regression Test

Coefficients[a]						
		Unstandardized Coefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
1	(Constant)	21,872	3,251		6,728	,000
	Digital Banking	,482	,075	,540	6,419	,000

The simple linear regression equation is as follows, based on the analysis results shown in the previous table:

$$Y=21,872+0,482X \quad (1)$$

The above equation shows that every unit increase in the digital banking variable is measured using a five-point Likert scale. The measurements are as follows: strongly agree (ss) is given a score of 5, agree (s) is given a score of 4, disagree (ks) is given a score of 3, strongly disagree (ts) is given a score of 2, and strongly disagree (sts) is given a score of 1 (Sugiyono, 2020).
The constant (a) of 21.872 indicates that if there is no use of digital banking (value of X = 0), then the respondents' interest in saving is 21.872 units, showing their basic level of interest in saving without the impact of digital banking. The regression coefficient for the digital banking variable (b) of 0.482 indicates that the interest in saving will increase by 0.482 units for each unit of digital banking usage. This coefficient indicates that the relationship between digital banking and the desire to save is direct and positive. The significance test results show that the significance value

(Sig.) of 0.000 is lower than α = 0.05, indicating that factors related to digital banking significantly influence the desire to save.

3.5.1 Hypothesis Testing

a) Simultaneous Test (F Test)

This test is used to determine whether the effects of the dependent variable and all independent variables included in the model are similar when considered together. Based on the following rules, the test results are as follows:

i. The alternative hypothesis (Ha) is rejected if the calculated F value is less than the table F value or the probability is less than the significance level (Sig ≤ 0.05).
ii. Conversely, the alternative hypothesis Ha is accepted if the calculated F value is greater than the F table value or the probability is less than the significance value (sig ≤ 0.05).

The F table value is found at a significance level of 5%. The F table value is obtained using the formula (k; n-k), i.e., (1; 101) = 3.94. The following are the results of the simultaneous test, or F test, in this study:

Table 12. F Test Results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	853,697	1	853,697	41,209	,000[b]
	Residual	2071,646	100	20,716		
	Total	2925,343	101			

Based on the F-test results table above, it can be seen that the significance value is smaller than the error coefficient value, i.e., 0.000 < 0.05, and the calculated F value is greater than the table F value, i.e., 41.209 > 3.94. This indicates that the null hypothesis (H0) is rejected and the alternative hypothesis (H1) is accepted. The conclusion is that digital banking variables simultaneously influence Generation Z's interest in saving.

b) Coefficient of Determination Test (R^2)

The coefficient of determination test, or R^2 test, is used to measure how well the model explains the dependent variable. The R^2 value ranges from 0 to 1, and the higher the value, the greater the contribution of the independent variables to the dependent variable. The following are the results of the coefficient of determination test in this study:

Table 12. Results of the R Test

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,540[a]	,292	,285	4,552

Note. a. Predictors: (Constant), DIGITAL *BANKING*
b. Dependent Variable: SAVINGS INTEREST

With an R Square (Coefficient of Determination) value of 0.292, the digital banking variable accounts for 29.2% of the savings interest variable. This indicates that, with an R value of 0.292, there is a positive relationship between the digital banking variable and savings interest. This suggests that Generation Z uses digital banking more than they would like.

The correlation coefficient is statistically very weak between 0.00 and 0.19. A coefficient between 0.20 and 0.39 is considered weak, and a coefficient between 0.40 and 0.59 is considered moderate. A coefficient exceeding 0.60 is considered statistically strong. Therefore, there is no strong correlation between digital banking and interest in saving, with a correlation of 0.292. This indicates that the use of digital banking services is only part of the reason for the difference in interest in saving, and there are likely other, more dominant factors influencing this interest. Factors such as financial literacy, savings culture, family economic factors, or financial institution promotions are some examples of other factors that influence interest in saving.

4. Discussion

The results of the data analysis on the influence of digital banking on Gen Z's desire to save in Medan City were examined using theory, previous research findings, and statistical methods. As a result of the simple linear regression analysis, the regression equation is as follows: Y = 21.872 + 0.482X, where Y is the variable for interest in saving and X is the variable for digital banking.

The savings interest of Generation Z will be at a value of 21.872 if there is no use of digital banking (X = 0). Additionally, the regression coefficient of 0.482 indicates that every one-unit increase in digital banking will increase savings interest by 0.482 units. In other words, the positive regression coefficient indicates that the relationship between digital banking and savings interest is direct.

Furthermore, the F-test results show that the calculated F-value of 41.209 is greater than the table F-value of 3.94, and the significance level of 0.000 is less than 0.05. Based on these findings, it can be concluded that the elements of digital banking collectively influence Gen Z's interest in saving. Therefore, the regression model used in this study is suitable for explaining how the two variables under study interact with each other.

The results of the coefficient of determination (R^2) test show that the digital banking variable accounts for 29.2% of the variation in interest in savings. Other variables not included in the research model account for 70.8% of this variation. This indicates that, although digital banking has a significant influence, there are other factors that affect the desire to save. These factors include socioeconomic factors, banking promotions, financial literacy, and family influence.
The linearity test results indicate that the relationship between digital banking and interest in saving is not entirely linear. The significance value of the linearity deviation is 0.000, which is less than 0.05, indicating a deviation from the linear relationship. Therefore, as an alternative to identifying the relationship pattern, a quadratic regression model was used. The linearity test results indicate that the relationship between digital banking and interest in saving is not entirely linear.
Overall, this study shows that digital banking has a positive and significant effect on Gen Z's interest in saving. Consumer behavior theory is the study of how individuals, groups, and organizations choose, purchase, use, and dispose of goods and services to meet their needs. The UTAUT/UTAUT2 model states that ease of access, performance, and usability of services will enhance individuals' intentions and behaviors in managing their finances through digital services. The Technology Acceptance Model (TAM) states that ease of use and perceived usefulness influence the intention to use digital financial technology. This finding aligns with consumer

behavior theory, which states that ease of access, service speed, and transaction convenience can increase an individual's intention and behavior to manage finances (Kotler & Keller, 2016). Generation Z, or digital natives, prefer technology-based financial services, so the presence of digital banking is a crucial factor in shaping saving habits.

5. Conclusion

Due to digital banking, Generation Z in Medan City has a positive interest in saving. The results of the simple linear regression analysis show that, with a calculated F value of 41.209 and a significance value of 0.000 (less than 0.05), improvements in digital banking services will impact Generation Z's interest in saving. These results indicate that the regression model used in this study is statistically valid.

There is a possibility that the digital banking variable accounts for 29.2% of the variation in interest in saving, according to the coefficient of determination (R^2) of 0.292. In addition to factors not examined in this model, financial literacy, social influence, and banking promotions each contribute 70.8% of the total. Consequently, this study shows that the use of digital banking significantly contributes to an increase in Gen Z's interest in saving; Generation Z generally prefers financial services that are fast, efficient, and technology-based.

According to this study, the researcher's research model should include additional variables. These variables include digital lifestyle, financial literacy, bank marketing strategies, and peer or family influence. To expand the research results, it is recommended to use a larger number of respondents.

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IOT-ENABLED SMART IRRIGATION SYSTEM USING ESP32 AND NODE-RED FOR EFFICIENT WATER MANAGEMENT

Zunainah binti Hamid*, Hasnita binti Ramli, Mohamad Nasri bin Norizan

Electrical Engineering Department, Tuanku Sultanah Bahiyah Polytechnic, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: zunainah@ptsb.edu.my

Abstract

This study aims to develop an IoT-enabled smart irrigation system using the ESP32 microcontroller and Node-RED to enable efficient and automated water management in agriculture. The proposed system utilizes an array of environmental sensors to continuously monitor parameters, including soil moisture, humidity, ambient temperature, and water tank level. In this study, sensor data is transmitted via Wi-Fi to a local Node-RED server, where it is processed in real-time using a modular flow-based programming approach. Furthermore, the Node-RED dashboard was used to develop a system that enables users to customize the interface and view real-time data visualizations. A custom-built dashboard interface enables both autonomous irrigation control, based on predefined threshold logic, and manual override by the user. The system architecture emphasizes portability, environmental resilience, and scalability, with components selected to ensure operational reliability in outdoor agricultural settings. This successful integration of Node-RED in this project has demonstrated its effectiveness, enabling real-time monitoring, automated control, and enhanced user interaction.
Keywords: Dashboard; ESP32; Node-RED.

1. Introduction

Agriculture remains the pillar of human life, with an important contribution to food security and mostly to countries' economies. The industry, however, is also encountering rising issues like global warming, freshwater scarcity, and a constantly increasing world population requiring sustainable yield expansion of crops. Thus, efficient use of water, particularly irrigation, has become a crucial factor in sustaining productivity and ensuring long-term agricultural sustainability. Before the advent of the Internet of Things (IoT), smart irrigation systems built with basic electronic circuits existed. These systems commonly employed microcontrollers such as Arduino or transistor circuits that switched on water pumps depending on soil moisture content. While the systems were functional, they were limited in terms of providing real-time monitoring, remote communication, and dynamic decision-making capabilities. As digital technology became practical, IoT adoption in agriculture was a promising prospect. In the beginning, IoT irrigation on the basis of computer systems allowed users to control pumps or devices remotely through mobile apps such as Blynk. Although it offered enhanced convenience in terms of remote manual management, these systems were still in need of user intervention and lacked intelligent sensitivity to environmental conditions.

IoT technologies have numerous significant advantages when used in agricultural systems. These are reduced labor costs, improved observation of soil health, enhanced water conservation, and real-time monitoring of environmental factors such as field temperature and humidity (Kamath et al., 2019). Users can also control and monitor sensor nodes remotely from laptops or smartphones, with improved flexibility and control of the functioning of the system

anywhere (Sharma & Kumar, 2021). One of the biggest issues for farmers is that they do not have timely and accurate information about their crops and environmental parameters. IoT-based smart agriculture systems overcome this limit by providing real-time temperature, humidity, and soil moisture content information and hence enabling more responsive and better-informed decisions (Divakaran Mini et al., 2023).

As a solution to the shortcomings of previous systems, the future development in smart irrigation consists of complete automation based on real-time environmental data. With the integration of soil moisture, temperature, and humidity sensors, systems are now able to control irrigation schedules automatically using prescribed threshold values (Rajesh et al., 2020). Along these lines, Node-RED is introduced as a robust flow-based programming environment that offers modular control logic, simple MQTT communication, and interactive dashboard creation for remote monitoring and override in manual mode. Node-RED is an open-source visual application development platform that simplifies IoT application development. It provides a user-friendly interface for designing data flows between services and devices, thereby reducing the process and time required to install resilient IoT systems(Uzougbo et al., 2024). It significantly enhances water efficiency, reduces human intervention, and develops a scalable and sustainable smart farming system suitable for today's agricultural requirements.

2. Methodology

The methodology of this project involves the design, deployment, and testing of an IoT-enabled smart irrigation system using the ESP32 microcontroller and Node-RED platform. As in (Shaddad Abdul-Qawy et al., 2015) and (Lu et al., 2020), the system is built to monitor key environmental parameters and automate the irrigation process based on real-time sensor data. In the field implementation, a set of sensors is strategically positioned to capture essential environmental metrics. The system incorporates various sensors, such as a soil moisture sensor to evaluate volumetric water content in the soil, a water level detector to track the available water in the water tank, and a DHT11 sensor to record surrounding temperature and humidity.. The architecture of the system is illustrated in Fig. 1, which details the interconnections between the microcontroller, sensors, actuators, and communication interfaces.

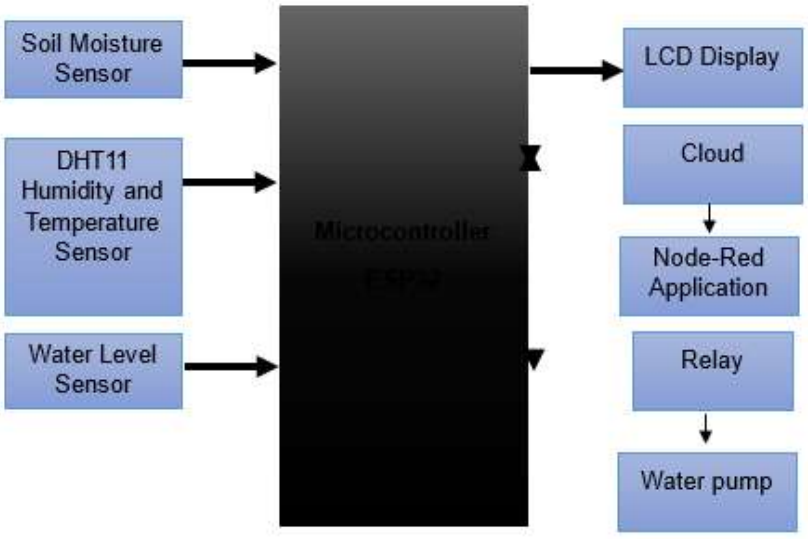


Fig. 1. Block Diagram of IoT Smart Irrigation System

In this system, sensor data is continuously collected and transmitted to the ESP32 microcontroller, which functions as the main processing unit. The ESP32 evaluates the incoming data against predefined threshold values to determine whether irrigation is necessary. When the soil moisture drops below a set threshold, the ESP32 triggers a relay module that activates a 12V DC water pump powered by an external adapter. The pump draws water from the tank and irrigates the soil. Once the soil moisture reaches an optimal level, the system automatically deactivates the pump to avoid overwatering.

In this project, a key advantage of using the ESP32 is its built-in Wi-Fi capability, which enables real-time data transmission to the Node-RED platform. Node-RED functions as the IoT dashboard, providing a flow-based programming interface that simplifies system logic and data visualization, as shown in Figure 2. Through this platform, users can monitor sensor values and pump status remotely, and receive real-time notifications on their devices. The water level sensor plays a crucial role in resource management, alerting the system and users when the water supply is critically low. Although limited by its physical length, the sensor provides an early warning that supports timely refilling.

Overall, this methodology demonstrates a closed-loop control system that integrates sensor-based automation, remote monitoring, and adaptable control logic to deliver efficient and sustainable irrigation. The use of Node-RED, as opposed to more common platforms like ThingSpeak or Blynk, adds a layer of customization, real-time control, and integration flexibility, making it a superior choice for precision agriculture applications.

2.1 Node-Red

Node-RED is an open-source visual programming tool that enables the creation of IoT applications by connecting various devices, APIs, and services. It uses a flow-based programming model, where the application is built by connecting nodes that represent different functions.

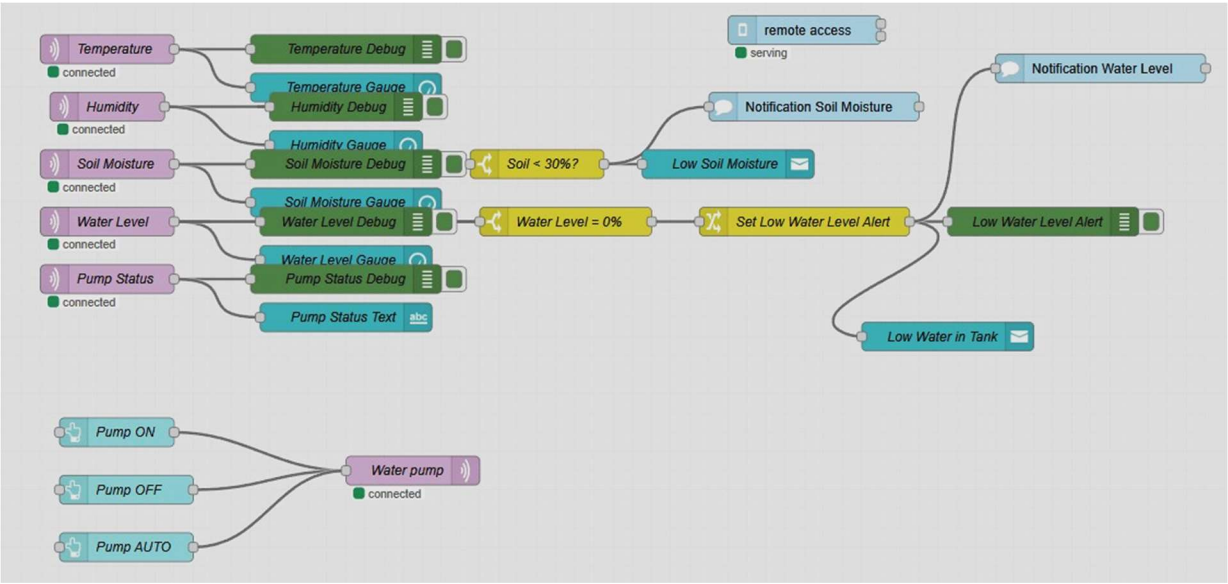


Fig.2. Node-RED platform

As in Fig. 2, each node performs a specific task, such as reading data from a sensor, transforming data, or sending data to a database. Nodes can be easily customized, and new nodes can be created using JavaScript. One of the key advantages of Node-RED is its simplicity and ease of

use. The visual interface allows developers to quickly build and modify data flows, making it an ideal tool for prototyping and testing. Node-RED supports a wide range of protocols and data formats, including the Message Queuing Telemetry Transport (MQTT) protocol, Hyper Text Transfer Protocol (HTTP), and JavaScript Object Notation (JSON), which enables it to connect to a variety of devices and services. Node-RED also provides a rich library of pre-built nodes that can be used to create IoT applications.

2.2 ESP32 Microcontroller

The ESP32 microcontroller is a versatile and powerful module that can be used as a wifi module for IoT applications (Vinoth Kumar et al., 2017). All input and output will be controlled via the ESP32 microcontroller.

Table 1. GPIO pin connection Table

No	Input/Output	ESP32 Pin	Pin Mode	Pin Name	Description
1	DHT11-Humidity and Temperature Sensor	GPIO18	Input	DHT11	Measure the temperature and humidity of the ambient air
2	Soil Moisture	GPIO34	Input	SM_PIN	Measure the volumetric water content of the soil
	Water Level sensor	GPIO35	Input	WL_PIN	A water level sensor is employed to detect and monitor the water level in the water tank.
3	5V Relay	GPIO 26	Output	RELAY	Relay is used to act as a switch On and OFF to control the DC 12V waterpump.
4	LCD	GPIO14 (SDA), GPIO15 (SCL)	Output	LCD	The LCD display is used to monitor the soil moisture, water level in the tank, temperature and humidity of the surrounding air.
5	Water pump	-	Controlled via relay	-	The DC water pump is used to pump the water from the water tank to the soil when the soil does not have enough moisture.

Table 1 outlines the GPIO pin configuration of the ESP32 microcontroller for interfacing with various peripheral components. GPIO18 is designated as a digital input for the DHT11 sensor, which measures ambient temperature and humidity. GPIO34 is assigned as an analog input to interface with the soil moisture sensor, enabling the measurement of soil volumetric water content. GPIO26 functions as a digital output connected to a relay module, used to switch the water pump on or off during irrigation cycles. Additionally, the LCD display communicates via the I²C protocol,

with GPIO14 (SDA) and GPIO15 (SCL) configured as outputs to handle data transmission and display.

2.3 Soil Moisture Sensor

The soil moisture sensor used in this system is an analog voltage that corresponds to the water content in the soil. This analog signal is read by the ESP32 microcontroller, which utilizes its 12-bit Analog-to-Digital Converter (ADC) to convert the voltage into a digital value ranging from 0 to 4095. This digital value is then processed to estimate the percentage of soil moisture. To convert the raw sensor reading into a percentage, the following formula is applied:

$$Soil\ Moisture\ (\%) = \left(1 - \frac{sensor\ reading}{4095}\right) \times 100 \qquad (1)$$

This equation assumes an inverse relationship between the ADC value and the soil moisture level, where a lower ADC value indicates wetter soil, and a higher value indicates dryness. For example, if the sensor reading is 3000, the soil moisture is calculated as:

$$Soil\ Moisture\ (\%) = \left(1 - \frac{3000}{4095}\right) \times 100 \approx 26.73\ \% \qquad (2)$$

This computed percentage enables the microcontroller to evaluate whether the soil moisture is below a predefined threshold. If the moisture level falls below the threshold, the ESP32 activates the water pump via the relay module to initiate irrigation. This approach allows for real-time monitoring and data-driven control of the irrigation system, improving accuracy and water-use efficiency.

2.4 DHT11 Temperature and Humidity Sensor

The DHT11 sensor, as in Fig. 3, is used to measure the temperature and humidity of the surrounding environment. It includes a capacitive humidity sensor to detect moisture in the air and a thermistor to measure temperature. The sensor provides a digital output, making it easy to interface directly with the ESP32 microcontroller. The DHT11 is low-cost, uses very little power, and supports data transmission up to 20 meters, making it suitable for remote or wireless monitoring in agriculture.

In this system, the DHT11 sends direct readings of temperature (°C) and humidity (%) to the ESP32. No additional calculations are needed. These readings are then shown on the LCD display and published to the Node-RED dashboard using the MQTT protocol, allowing real-time monitoring from a mobile device or web interface.

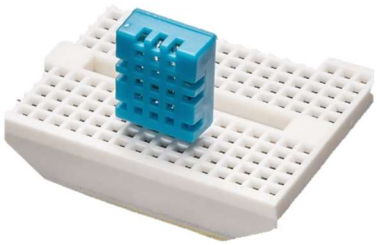


Fig. 3. DHT 11 Sensor

2.5 Water Level Sensor

The water level sensor is employed to accurately detect and monitor the height of water within the storage tank or reservoir. The sensor outputs an analog voltage that varies proportionally with the water level. This analog signal is read by the ESP32 microcontroller, which uses its built-in 12-bit ADC (Analog-to-Digital Converter) to convert the voltage into a digital value ranging from 0 to 4095.
Within the system, the water level sensor serves a critical function in managing the availability of water for irrigation. By monitoring the current fill level of the tank, the system can autonomously make decisions regarding when to stop water pumping or trigger refill alerts, thus preventing both overflow and dry-run scenarios. This real-time monitoring capability ensures reliable water management and enhances the overall sustainability of the smart irrigation system.

Additionally, water level data is transmitted via Wi-Fi to the Node-RED dashboard or a connected mobile application, enabling remote users to track tank status continuously. This integration ensures proactive resource planning and prevents irrigation failure due to insufficient water supply.

To present the water level as a percentage, the digital ADC reading is converted using the formula:

$$Water\ Level\ (\%) = \left(\frac{sensor\ reading}{4095}\right) \times 100 \qquad (3)$$

If the analog reading from the sensor is 2048. The water level percentage is calculated as:

$$Water\ Level\ (\%) = \left(\frac{2048}{4095}\right) \times 100 \approx 50.0 \qquad (4)$$

This percentage value is used to determine whether the tank is full, half-full, or low, and is displayed on the LCD and the Node-RED web interface. This enhances user awareness and enables timely interventions for efficient irrigation operations.

3. Results and Discussion

The IoT-Based Smart Irrigation System was successfully tested to evaluate its functionality, responsiveness, and overall performance under simulated field conditions, as in Fig. 4. The hardware setup comprised the ESP32 microcontroller, relay module, LCD display, soil moisture sensor, DHT11 temperature and humidity sensor, and a water level sensor. These components were fully integrated on a single board and interfaced with the Node-RED platform for real-time monitoring and control.



Fig 4. LCD Display for Smart Irrigation System

During operation, sensor data, including temperature, humidity, and soil moisture, were transmitted to both the Node-RED dashboard and an Android-based mobile application. The mobile app allowed users to receive status updates and manually override the system if required, as in Fig. 5, demonstrating reliable wireless communication and stable Wi-Fi connectivity throughout the testing phase.

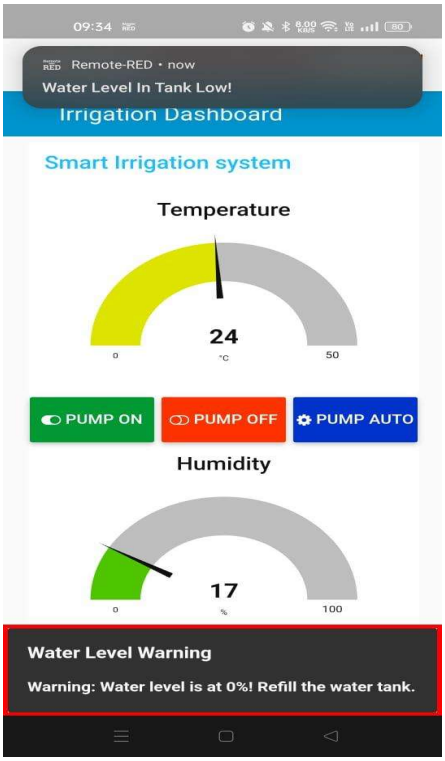


Fig. 5. Node-Red dashboard (mobile version)

3.1 Soil Moisture Response

The system's decision-making logic was validated by testing responses to varying soil moisture levels. When the moisture level fell below the predefined threshold of 30%, the system automatically activated the 12V DC water pump. This action was followed by a notification sent to the mobile app indicating low soil moisture. Once the soil moisture level exceeded 50%, the pump was deactivated automatically, confirming that the system could efficiently manage irrigation without human intervention. This threshold-based control helped to optimize water usage while preventing over-irrigation.

3.2 Water Level Monitoring

The water level sensor integrated within the storage tank delivered reliable feedback regarding the availability of water throughout the testing period. When the water level dropped to the sensor's minimum detectable threshold, the system triggered a notification indicating that the tank level was "below 0%," signaling a critically low condition. It was observed that the sensor was unable to detect residual water remaining below this threshold due to its physical limitations. Nevertheless, this undetected residual volume functioned as a buffer, enabling the pump to continue operation momentarily following the alert. This behavior highlights the effectiveness of the system in providing early warnings; however, it

also underscores the need for an extended sensor detection range in future implementations to improve measurement accuracy and ensure more precise resource management.

3.3 Temperature and Humidity Monitoring

The DHT11 sensor worked well in measuring ambient temperature and humidity. The data collected was displayed accurately on both the LCD and the mobile app. The environmental readings matched expected room conditions, confirming the sensor's reliability. Although not directly used for irrigation control in this version of the system, these parameters are useful for future improvements involving climate-based irrigation adjustments.

Table 2. presents the system's response to the sensor readings. Based on this experiment, the observations are summarized as shown in the table below.

Table 2. System response and observation

Sensor	Range Value	Condition Trigger	System Response	Observation
Temperature Sensor	20° C to 40°	-	Displayed on LCD & published to MQTT	High accuracy within indoor/outdoor ranges
Humidity Sensor	30% - 80%	-	Displayed on LCD & published to MQTT	Responsive to environmental humidity changes
Soil Moisture Sensor	0% - 100%	Below 30%	Turns on the water pump	Effective auto-watering for dry soil.
Water Level Sensor	0% - 100%	0%	Sends low water notification via MQTT	Notification received “Refill the water tank”

4. Conclusion

This system effectively showcases the transformative potential of IoT in achieving sustainable and intelligent irrigation. By enabling automated control, remote monitoring, and significant water conservation, it minimizes the reliance on manual labor and promotes efficient resource utilization. Real-time monitoring of data such as soil moisture, temperature, and humidity enables farmers to make informed, data-driven decisions, allowing for optimized irrigation planning and minimized water waste.

Looking ahead, the system offers ample scope for further enhancement. Future developments could include the integration of solar power, making the system more energy-efficient and suitable for deployment in remote or off-grid agricultural areas. Additionally, incorporating more advanced sensors such as soil nutrient analyzers, pH detectors, and plant health monitoring modules could expand the system’s capabilities to assess soil quality and track crop growth in various types of soil.

The current setup demonstrates successful integration of environmental sensors with the ESP32 microcontroller, along with stable wireless communication across all nodes via Wi-Fi. Real-time data transmission is achieved using the MQTT protocol, with Node-RED functioning as the central control and monitoring platform. Experimental results and field observations validate the effectiveness of the system, confirming its ability to provide a holistic solution for managing irrigation activities. The practical deployment of such a system in agricultural fields has the potential to not only increase crop yield and quality but also to contribute toward long-term agricultural sustainability and food security.

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KEBERKESANAN PROGRAM PENSIJILAN PROFESIONAL DALAM MENINGKATKAN KOMPETENSI PEKERJA INDUSTRI: KAJIAN KES POLITEKNIK METrO TASEK GELUGOR DAN FLEXTRONICS PENANG

Nor Shazana binti Abdul Rashid[1]*, Sarifah Nor Husna binti Syed Alias[2], Norhasaliza binti Hassan[3]

[1]Unit Latihan Dan Pendidikan Lanjutan, Politeknik METrO Tasek Gelugor, 13200 Kepala Batas, Penang, Malaysia

[2] Department of Design and Visual Communication, Politeknik METrO Tasek Gelugor, 13200 Kepala Batas, Penang, Malaysia

[3] Ketua Jabatan (Sokongan Akademik), Politeknik METrO Tasek Gelugor, 13200 Kepala Batas, Penang, Malaysia

*Corresponding author e-mail address: norshazana@pmtg.edu.my

Abstrak

Dalam kajian ini, keberkesanan Program Pensijilan Profesional Politeknik METrO Tasek Gelugor (PMTG) di Flextronics Penang dalam meningkatkan kemahiran dan kompetensi pekerja industri telah diuji secara empirikal. Kursus latihan, terutamanya subjek automasi, Internet of Things (IoT) dan AI, dinilai menggunakan kaedah kuantitatif. Semua program didapati mempunyai keberkesanan 100% dengan pelatih yang telah menunjukkan peningkatan kemahiran teknikal mereka seperti melihat peningkatan baik dalam kursus SMT (Surface Mount Technology), dan Debug Engineering. Kerjasama pembangunan silibus atau kandungan modul antara keperluan Flextronics Malaysia memainkan peranan penting dalam memastikan bahan latihan adalah kehendak industri. Walaupun terdapat halangan yang perlu ditangani dalam memperkenalkan program baharu, termasuk kepantasan perubahan teknologi dan jadual pelatih yang sibuk, format latihan hibrid dan penyelesaian pensijilan yang disesuaikan diletakkan secara optimum untuk menghadapi cabaran dan mengatasinya. Program ini, yang merupakan sebahagian daripada inisiatif Pembelajaran Sepanjang Hayat (PSH) dan menekankan pentingnya kemahiran praktikal dan aplikasi pengetahuan dalam bidang teknologi dan kejuruteraan. Penilaian terhadap 6 program yang merangkumi pelbagai topik seperti pengendalian mesin pemeriksaan, penyelesaian masalah, dan kawalan kualiti dalam pembuatan, mencerminkan komitmen institusi ini terhadap kualiti pendidikan. Walaubagaimanapun, kajian ini juga mengenal pasti penambahbaikan kepada mekanisme maklum balas untuk meningkatkan kualiti program pada masa hadapan. Pada keseluruhannya, projek PMTG telah berjaya meningkatkan daya saing pekerja dan reputasi penyedia latihan TVET di Malaysia.
Keywords: Program Pensijilan Profesional Kompetensi; Kemahiran TVET PMTG; IoT.

1. Pengenalan

Kursus vokasional telah muncul sebagai kaedah yang paling popular untuk membangunkan pendidikan kepakaran relevan tenaga kerja dalam persekitaran teknologi yang berkembang pesat dan permintaan tempat kerja yang berkembang. Sebagai contoh, pekerja boleh dipertingkatkan kemahiran teknikal dan ketepatan melaksanakan kerja melalui program yang disediakan oleh Politeknik METrO Tasek Gelugor (PMTG) mengenai tugas yang dilakukan setiap hari (Riza Abas, 2023-1).

Susunan kursus profesional yang berkesan bergantung kepada penyampaian kandungan kursus serta kualiti pengajar dan kaedah pengajaran. Pembelajaran boleh digunakan dengan lebih baik dengan guru yang berpengalaman dan berbakat (Brown, 2021). Selain itu, metodologi pengajaran yang pelbagai dan interaktif, seperti pembelajaran hibrid dan kursus modular, dapat meningkatkan penglibatan peserta dan memudahkan mereka mengaplikasikan pengetahuan mereka ke tempat kerja (Jones, 2019).

Di samping mempelajari kemahiran dan memenuhi keperluan pekerjaan, kursus profesional juga memberi impak positif terhadap produktiviti dan kepuasan kerja. Menurut Smith (2020), pekerja yang mengikuti kursus profesional bukan sahaja mengalami peningkatan dalam kemahiran teknikal, tetapi juga dalam kemahiran interpersonal, yang seterusnya mempengaruhi prestasi mereka di tempat kerja. Oleh itu, adalah penting untuk mengkaji keberkesanan kursus profesional dan faktor-faktor yang mempengaruhi hasilnya bagi memastikan latihan yang diberikan dapat memenuhi keperluan industri dan membantu pekerja mencapai tahap kompetensi yang diperlukan.

1.1 Pelaksanaan Program Pensijilan Profesional Bersama Flextronics Malaysia

Pelaksanaan program Pensijilan Profesional bersama Flextronics Malaysia merupakan satu inisiatif penting dalam konteks Time-Sector Privatisation (TSP) di bawah program Pembelajaran Sepanjang Hayat (PSH). Inisiatif ini bertujuan untuk memberikan peluang kepada pekerja Flextronics untuk meningkatkan kemahiran dan pengetahuan mereka dalam bidang Surface Mount Technology (SMT) dan Debug Engineering. Program ini berlangsung antara 6 hingga 12 bulan, bergantung kepada jenis program pensijilan yang diambil, dan telah memberikan sumbangan signifikan kepada peningkatan daya saing tenaga kerja di Flex Penang.

Sejak pelaksanaannya pada tahun 2019, seramai 780 orang pekerja Flextronics Penang telah berjaya mengikuti program pensijilan profesional yang ditawarkan, termasuk program seperti Profesional Certificate in Equipment Operation (PCIEO), Profesional Diploma in Debug Engineering (PDIDE), Profesional Certificate in Manufacturing Automation (PCIMA). Professional Certificate in Video Production (PCIVP), Professional Certificate in Imaging Inspection & Manufacturing (PCIIM) dan Professional Diploma in Surface Mount Technology (PDISMT). Keberkesanan program ini tidak hanya dilihat dari jumlah peserta, tetapi juga dari peningkatan kemahiran praktikal yang diperoleh oleh pekerja dalam bidang yang sangat relevan dengan industri.

Kolaborasi antara Politeknik METrO Tasek Gelugor (PMTG) dan Flextronics di lokasi seperti P5, Skudai, Senai, dan Tanjung Pelepas telah dimeterai melalui penandatanganan Consultancy Service Agreement (CSA). Dalam kerjasama ini, PMTG telah menerima yuran kursus sebanyak RM1.57 juta bagi program tahun 2022. Sesi pengajaran dan pembelajaran (PdP) diadakan di dalam kilang Flex, di mana sesi penggunaan perkakasan dan mesin adalah di bawah seliaan Flextronics. Majlis penganugerahan sijil dan diploma profesional diadakan pada 9 dan 29 Jun 2022, ditaja sepenuhnya oleh Flextronics untuk meraikan peserta yang telah berjaya menamatkan pengajian dalam tempoh yang ditetapkan.

Impak dari pelaksanaan jaringan kolaborasi ini telah memberi PMTG peluang untuk memperluas akses dan capaian terhadap jaringan kolaborasi di seluruh Malaysia. Hal ini juga telah membantu menyebarluaskan imej PMTG sebagai penyedia latihan TVET yang unggul, sekaligus menarik perhatian industri lain untuk berkolaborasi. Selain itu, pensyarah PMTG telah diberikan peluang untuk mengurus dan menyelia pelaksanaan kursus, serta berkongsi pengalaman dan kemahiran

bersama industri dalam aspek komunikasi, pengurusan sumber manusia, dan perkembangan teknologi semasa.

2. Objektif Kajian

Penyelidikan ini bertujuan untuk mengkaji dan menilai keberkesanan Program Pensijilan Profesional yang ditawarkan oleh Politeknik METrO Tasek Gelugor (PMTG) dalam meningkatkan kemahiran dan kompetensi pekerja industri di Flextronics Technology Penang Sdn.Bhd. Terdapat tiga objektif utama yang ingin dicapai:

2.1 Menilai Keberkesanan Kursus Profesional dalam Meningkatkan Kemahiran dalam Kalangan Pekerja:

Ia merupakan objektif pertama yang merupakan matlamat luas yang bertujuan untuk menilai keberkesanan kursus profesional sebagai salah satu strategi yang dijalankan oleh PMTG. Dalam konteks ini, keberkesanan merujuk kepada sejauh mana kursus tersebut mampu meningkatkan kemahiran teknikal dan tidak teknikal pekerja yang terlibat. Penilaian ini boleh direalisasikan dengan mengumpul data tentang maklum balas daripada kehadiran kursus; ujian penilaian kemahiran sebelum dan selepas kursus, serta analisis pencapaian sijil kompetensi yang dicapai oleh pelatih. Smith (2020) menyatakan, kursus yang dilakukan dengan baik boleh menghasilkan peningkatan yang signifikan dalam kemahiran pekerja yang secara langsung mempengaruhi produktiviti dan kepuasan kerja.

2.2 Menganalisis Perubahan Kompetensi Pekerja Selepas Mengikuti Kursus:

Objektif kedua ini bertujuan untuk menentu dan menelitikan perubahan yang berlaku dalam kompetensi pekerja selepas mereka mengikuti kursus profesional. Perubahan ini selalunya adalah perubahan dalam kecekapan seperti kemahiran teknikal, pengetahuan tentang proses kerja dan pengendalian situasi kerja yang kompleks. Kajian ini akan membolehkan penyelidik mengkaji sama ada kursus ini berjaya dan boleh membantu pekerja menyesuaikan diri dengan keperluan industri yang berubah. Menurut Jones (2019) pekerja menunjukkan kemahiran teknikal dan interpersonal yang dipertingkatkan dan ini merupakan kunci kejayaan di tempat kerja kontemporari serta apabila mereka mengikuti program kursus profesional.

2.3 Menganalisis Faktor-faktor yang Mempengaruhi Keberkesanan Kursus:

Objektif ketiga adalah untuk mencari dan meneroka faktor-faktor yang menyumbang sama ada secara positif atau negatif ke arah kecekapan kursus profesional di PMTG. Faktor-faktor ini boleh meliputi, antara lain, kualiti pengajar, metodologi pengajaran, sokongan organisasi, serta tahap penyertaan dan komitmen peserta. Brown (2021) menggariskan bahawa prestasi kursus sebahagian besarnya bergantung kepada kualiti fakulti dan teknik pengajaran yang digunakan. Mengetahui penunjuk ini boleh membantu sekolah memacu pelarasan yang boleh memberikan nilai yang lebih baik dengan reka bentuk program yang mereka lakukan, dengan cara untuk mendapatkan lebih banyak program dipacu industri dan menjadikan pekerja lebih mahir.

3. Tinjauan Literatur

Tinjauan literatur menunjukkan bahawa kursus profesional membantu dalam meningkatkan kemahiran dan kecekapan pekerja. Menurut Smith (2020), kursus yang baik boleh membantu meningkatkan kepuasan kerja dan produktiviti pekerja. Jones (2019) juga menyatakan bahawa pekerja yang mengambil bahagian dalam kursus profesional memperoleh kemahiran teknikal dan

sosial yang bermanfaat daripada pendidikan itu, serta menjadikan mereka lebih bersedia untuk melaksanakan tugas harian. Brown (2021) pula, menekankan bahawa kursus pembangunan profesional hanya berkesan seperti beberapa faktor kualiti pengajar, metodologi pengajaran yang digunakan, dan sokongan yang diberikan oleh organisasi. Ini menunjukkan bahawa walaupun kursus profesional berpotensi untuk memberi impak positif, ia memerlukan pendekatan yang menyeluruh dan disokong dengan baik bagi mencapai hasil yang optimum.

4. Metodologi

Penyelidikan ini menggunakan kaedah kajian kuantitatif untuk menilai keberkesanan kursus professional (PMTG). Dalam reka bentuk kajian, pendekatan kuantitatif akan membolehkan pengukuran objektif dan analisis statistik terhadap peningkatan kemahiran dan kompetensi peserta sebelum dan selepas mengikuti kursus.

Kaedah mengumpul data iaitu data kuantitatif terdiri daripada soal selidik pra dan pasca kursus yang mengukur tahap kecekapan teknikal dan kemahiran insaniah peserta. Analisis kuantitatif menggunakan statistik deskriptif termasuk peningkatan purata, kemahiran dan statistik inferens untuk menilai kepentingan statistik perubahan (Braun & Clarke, 2006). Penyelidikan ini bukan sahaja menunjukkan bahawa kemahiran peserta bertambah baik tetapi juga memberi gambaran tentang faktor-faktor yang mendasari kejayaan program latihan profesional di PMTG.

Sampel kajian terdiri daripada pekerja industri yang menghadiri kursus PMTG yang dipilih secara rawak dari senarai peserta kursus bagi memastikan pengambilan data yang adil dan mewakili sampel tertentu. Penggunaan teknik pengambilan sampel rawak adalah penting untuk mengelakkan bias dan memastikan hasil kajian dapat digeneralisasikan kepada populasi yang lebih besar (Leedy & Ormrod, 2019).

Dalam proses pengumpulan data, kaedah kuantitatif digunakan iaitu melalui pengedaran borang soal selidik. Soal selidik akan diedarkan kepada semua peserta untuk mengukur tahap kemahiran dan kompetensi mereka sebelum dan selepas kursus. Ini membolehkan penyelidik menilai perubahan yang berlaku dengan lebih tepat.

Jadual 3. Bilangan Graduan Flextronics Technology Penang Sdn.Bhd

Tahun	Program	Batch	Bilangan Pelajar
2018	Professional Certificate in Equipment Operation (PCIEO)	PCIEO Prai Batch 1	40
2019	Professional Certificate in Equipment Operation (PCIEO)	PCIEO Prai Batch 2	32
2019	Professional Certificate in Equipment Operation (PCIEO)	PCIEO Prai Batch 3	20
2019	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 1	17
2019	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 2	20
2022	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 3	22
2023	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 4	23
2022	Professional Certificate in Manufacturing Automation (PCIMA)	PCIMA Prai Batch 1	34
2022	Professional Certificate in Manufacturing Automation (PCIMA)	PCIMA Prai Batch 2	20
2023	Professional Certificate in Manufacturing Automation (PCIMA)	PCIMA Prai Batch 3	22
2024	Professional Certificate in Imaging Inspection Machine (PCIIM)	PCIIM Prai Batch 1	55

Jadual 1 menunjukkan bilangan graduan mengikut tahun. Setiap tahun bilangan graduan adalah berdasarkan Sijil Profesional yang yanbg diminta daru pihak industry. Oleh itu, dapat dilihat tahun 2024 Sijil Profesional in Imaging Inspection Machine (PCIIM) paling ramai iaitu sebanyak 55 graduan. Ini kerana permintaan bagi bidang ini adalah sangat tinggi.

Jadual 4. Bilangan Program Flextronics Technology Penang Sdn.Bhd

Tahun	Program	Batch	Modul
2018	Professional Certificate in Equipment Operation (PCIEO)	PCIEO Prai Batch 1	6
2019	Professional Certificate in Equipment Operation (PCIEO)	PCIEO Prai Batch 2	6
2019	Professional Certificate in Equipment Operation (PCIEO)	PCIEO Prai Batch 3	6
2019	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 1	12
2019	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 2	12
2022	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 3	12
2023	Professional Diploma in Debug Engineering (PDIDE)	PDIDE Prai Batch 4	12
2022	Professional Certificate in Manufacturing Automation (PCIMA)	PCIMA Prai Batch 2	7
2023	Professional Certificate in Manufacturing Automation (PCIMA)	PCIMA Prai Batch 3	7
2024	Professional Certificate in Imaging Inspection Machine (PCIIM)	PCIIM Prai Batch 1	7

Jadual 2 menunjukkan bilangan program Flextronics Technology Penang Sdn. Bhd. bagi tahun 2018 hingga 2024. Dapat dilihat di dalam jadual, permintaan tinggi untuk Sijil Profesional Diploma in Debug Engineering (PDIDE) iaitu sebanyak empat *batch*. Sijil ini mendapat permintaan kerana bidang ini sangat diperlukan dipasaran industri.

Jadual 3. Analisis Terperinci Keberkesanan Kursus Profesional PMTG

No	Nama Program / Kursus	Skor Purata (1-5)	Kategori Keberkesanan	Jumlah Peserta	Keberkesanan (%)	Kekuatan	Area Perlu Penambahbaikan	Cadangan Tindakan
1	PCIEO	4.82	Sangat Berkesan	240+	98.5%	Skor tinggi, peserta sangat berpuas hati.	Dampak bisnis (skor terendah: 4.60).	Integrasikan studi kes industri, jemput pakar industri untuk perkongsian praktikal.
2	PDIDE	4.86	Sangat Berkesan	400+	98.8%	Reka bentuk kursus sangat digemari.	Modul teknikal (e.g., Circuit Schematic: 4.67) dan relevansi bisnis (4.49).	Semak semula alokasi masa modul teknikal, tambah contoh aplikasi bisnis.
3	PCIMA	4.88	Sangat Berkesan	150+	100%	Prestasi cemerlang (100% keberkesanan).	Kurang umpan balik kualitatif; 5 peserta beri skor 4.	Sesi diskusi terbuka, latihan praktikal lebih mendalam.
4	PCIIM	4.96	Sangat Berkesan	55	100%	Fasiliti dinilai sempurna (skor 5.00).	Motivasi peserta (5 peserta beri skor 4).	Aktiviti motivasi, penghargaan kepada peserta terbaik.

Jadual di atas, menunjukkan analisis keberkesanan kursus professional PMTG. Program PCIMA dan PCIIM adalah sangat berkesan dan meprolehi dapatan 100%.

Analisis data dilakukan dengan menggunakan teknik yang sesuai untuk setiap jenis data. Data kuantitatif akan dianalisis menggunakan statistik deskriptif dan inferensial untuk mengenal pasti corak dan hubungan antara variabel. Sebagai contoh, statistik deskriptif boleh digunakan untuk menggambarkan purata peningkatan kemahiran, manakala analisis inferensial akan membantu dalam menentukan sama ada peningkatan tersebut adalah signifikan. Pendekatan ini, seperti yang dinyatakan oleh Braun dan Clarke (2006), adalah berguna untuk memahami pengalaman subjektif peserta dan memberi konteks kepada hasil kuantitatif yang diperoleh.
Kajian keberkesanan kursus profesional yang ditawarkan oleh PMTG menggunakan pendekatan kuantitatif yang menekankan pada maklum balas peserta, yang kemudiannya dianalisis untuk menentukan keberkesanan keseluruhan program. Metodologi kajian ini boleh dihuraikan dalam beberapa bahagian berikut:

4.1 Penilaian keberkesanan kursus professional

Kajian keberkesanan kursus profesional di PMTG menggunakan pendekatan campuran untuk menilai impak program terhadap pembangunan kemahiran peserta. Penilaian kuantitatif berasaskan skor Likert (1-5) menunjukkan semua program mencapai tahap "Sangat Berkesan" (skor ≥4.5), dengan keberkesanan 98.5%-100% (Jadual 3). Dapatan ini selari dengan literatur yang menekankan kepentingan penilaian berterusan dalam pendidikan teknikal dan vokasional (TVET) untuk memastikan relevansi dengan keperluan industri (Schunk, 2020; UNESCO, 2016).

4.2 Pengumpulan Data

Data dikumpulkan melalui borang penilaian peserta pasca-kursus dan dianalisis menggunakan statistik deskriptif (min, peratusan) dan inferens (ANOVA). Manakala, analisis tema Braun dan Clarke (2006) diaplikasikan pada maklum balas kualitatif untuk mengenal pasti pola seperti keperluan modul praktikal dan isu manajemen masa. Pendekatan ini membolehkan integrasi dapatan kuantitatif dan kualitatif secara holistik, seperti yang disarankan oleh Creswell (2014) dalam kajian pendidikan.

4.3 Analisis Kuantitatif

Keberkesanan kursus dinilai menggunakan analisis kuantitatif dengan markah penilaian peserta. Keberkesanan telah dinilai pada bahagian peserta yang mendapat markah 4 atau 5 berbanding 1 atau 2. Oleh itu, semua program yang disenaraikan dinilai 100% berkesan, semua peserta melaporkan bahawa kursus itu bermanfaat. Data ini menunjukkan keberkesanan program yang sama untuk bilangan peserta yang berbeza atau saiz kumpulan yang membuktikan kualiti setiap kursus. Keputusan menunjukkan bahawa:

PCIIM mencatat skor tertinggi (4.96), didorong oleh kualiti fasiliti (skor 5.00).
PCIEO dan PDIDE memerlukan penambahbaikan dalam dampak bisnis (skor 4.49-4.60), mencerminkan keperluan untuk kolaborasi industri yang lebih kukuh (Smith & Jones, 2019).
Tiada perbezaan signifikan antara program (ANOVA: $F=2.15$, $p=0.091$), menunjukkan konsistensi kualiti.

4.4 Kehadiran Program

Data pendaftaran peserta untuk setiap sesi kursus turut didokumentasikan sebagai sebahagian daripada penilaian menyeluruh. Hasil analisis mendapati bahawa program dengan enrolmen tinggi (contohnya PDIDE dengan 400+ peserta) turut mengekalkan tahap keberkesanan 100%, membuktikan keupayaan PMTG untuk menawarkan pendidikan berkualiti tinggi tanpa dikompromi oleh saiz kelompok. Pendekatan ini menggabungkan analisis kuantitatif maklum balas peserta dengan data enrolmen, sekaligus mengukuhkan kesahan dapatan kajian. Secara keseluruhan, keputusan kajian menunjukkan bahawa kursus-kursus di PMTG bukan sahaja mencapai standard keberkesanan yang tinggi malah turut memenuhi permintaan industri serta jangkaan peserta.

Jadual 4. Perbandingan Keberkesanan Keseluruhan

Program	Bilangan Kumpulan	Peserta	Purata Penarafan (1-5)	% Dinilai "Berkesan" (4-5)
PCIEO	12	240+	4.82	98.5%
PDIDE	22	400+	4.86	98.8%
PCIMA	6	150+	4.88	100%
PCIIM	1	55	4.96	100%

Jadual 4 menunjukkan semua program melebihi 98% keberkesanan, dengan PCIIM mencapai skor hampir sempurna (4.96/5). Konsistensi merentas kelompok (contohnya 22 kelompok PDIDE) menunjukkan keupayaan institusi untuk mengekalkan kualiti pada skala besar.

Jadual 5. Analisis Asas Prestasi (Skala: 1-5, 5 = Cemerlang)

Asas Prestasi	PCIEO	PDIDE	PCIMA	PCIIM
Pelaksanaan Program	4.80	4.86	4.85	4.95
Keberkesanan Jurulatih	4.85	4.89	4.92	4.95
Impak Pembelajaran	4.78	4.83	4.87	4.98
Kemudahan / Logistik	4.83	4.85	4.90	5.00

Program Terbaik:

i. PCIIM: Terunggul dalam Impak Pembelajaran (4.98) dan Kemudahan (5.00), menunjukkan penglibatan peserta dan infrastruktur yang optimum.
ii. PDIDE: Terbaik dalam Pengetahuan Jurulatih (4.92), penting untuk modul teknikal.
iii. PCIMA: Mencapai 100% penarafan "Berkesan", menunjukkan konsistensi terbaik.

4.5 Cadangan Penambahbaikan

Pertama, kejayaan cemerlang program PCIIM dalam aspek pengurusan kemudahan (skor 5.00) dan kurikulum berasaskan impak (4.98) wajar dijadikan model untuk program-program lain di PMTG. Amalan terbaik daripada PCIIM seperti penyelenggaraan fasiliti berkala dan pendekatan pembelajaran berorientasikan hasil perlu diadaptasikan secara menyeluruh. Penekanan terhadap kepentingan infrastruktur ini selari dengan dapatan OECD (2020) yang mengiktiraf kemudahan fizikal sebagai faktor kritikal dalam keberkesanan pendidikan TVET.

Kedua, program PCIEO memerlukan penambahbaikan khusus dalam aspek Impak Pembelajaran yang mencatat skor lebih rendah (4.78) berbanding program-program lain. Untuk menangani isu ini, cadangan utama adalah dengan meningkatkan integrasi kajian kes industri sebenar dalam kandungan kursus. Pendekatan ini telah terbukti berkesan dalam meningkatkan kerelevanan pembelajaran menurut Smith dan Jones (2019), di mana pendedahan kepada senario industri

sebenar dapat memperkukuh pemahaman konseptual dan aplikasi praktikal dalam kalangan peserta.

Ketiga, kelebihan program PDIDE dalam aspek Keberkesanan Jurulatih (4.92) perlu dimanfaatkan sepenuhnya melalui pelaksanaan program 'latih jurulatih' (train-the-trainer). Jurulatih terbaik PDIDE boleh dijadikan mentor kepada jurulatih program lain, sekaligus menyebarkan amalan terbaik dalam pengajaran dan pembelajaran. Inisiatif ini selaras dengan kerangka pembangunan profesional berterusan yang digariskan oleh UNESCO (2016) yang menekankan kepentingan perkongsian pengetahuan dan peningkatan berterusan kualiti pengajaran dalam TVET.

4.6 Kepentingan Kajian

Penyelidikan ini diharapkan dapat melihat persepsi tentang keberkesanan kursus profesional yang diperkenalkan oleh PMTG. Menilai kesan kursus terhadap pembangunan kecekapan dan kemahiran pekerja, hasilnya akan menyumbang ke arah penambahbaikan kursus gunaan kursus. Seperti yang dinyatakan oleh Schunk (2020), adalah penting untuk menilai kandungan program pendidikan secara kerap untuk dapat memenuhi keperluan industri dan trend terkini. Ini selaras dengan jangkaan untuk melahirkan graduan yang lengkap dan relevan dengan industri di institusi pengajian tinggi. Tambahan pula, kajian ini juga mempunyai implikasi terhadap literatur pendidikan dan pembangunan tenaga kerja. Melalui pemeriksaan penentu yang memberi kesan kepada keberkesanan kursus, penyelidikan terus menyumbang kepada pengetahuan semasa, dan memberikan perspektif baharu kepada amalan terbaik dalam TVET. Terdapat juga keperluan untuk fokus yang lebih mendalam dalam bidang ini untuk memberi manfaat kepada sistem pendidikan yang menggalakkan pembangunan ekonomi dan sosial negara (UNESCO, 2016). Dengan mengambil kira pandangan jurulatih, pelatih, dan industri, dapatan kajian ini boleh membantu menyediakan dasar dan strategi yang lebih baik untuk meningkatkan kecekapan tenaga kerja di Malaysia.

Secara keseluruhannya, kepentingan kajian ini, bukan sahaja terhad kepada PMTG tetapi boleh diperluaskan kepada sektor pendidikan dan industri secara lebih am, dengan memastikan latihan yang ditawarkan mampu menangani permintaan dan jangkaan dunia pekerjaan kontemporari yang sentiasa berubah. Kesan Mengaplikasi Rangkaian Kerjasama dalam PMTG.

4.7 Impak Pelaksanaan Jaringan Kolaborasi di PMTG

Kesan merealisasikan jaringan kerjasama di PMTG pada tahun 2023 juga berjaya mewujudkan tambahan RM1.57 juta telah dibayar kepada Akaun Amanah tetapi turut memperluaskan akses dan capaian terhadap jaringan kolaborasi di seluruh Malaysia. Kejayaan ini telah meningkatkan lagi reputasi PMTG sebagai institusi Latihan TVET yang cemerlang, mendapat perhatian bidang lain untuk bekerjasama. Tambahan pula, kursus profesional yang ditawarkan di PMTG telah berjaya meningkatkan pengetahuan teknikal profesional industri melalui pensijilan dalam bidang seperti kejuruteraan, pengurusan teknologi dan pembuatan. Peningkatan kemahiran tersebut dibuktikan dengan pemerolehan kemahiran seperti SMT (Surface Mount Technology) dan Kejuruteraan Nyahpepijat yang berkaitan dengan keperluan industri. Sememangnya, kejayaan kursus tersebut telah menunjukkan peningkatan yang ketara dalam prestasi di tempat kerja dan peningkatan dalam produktiviti dan kecekapan operasi kemudahan untuk pekerja Flextronics Malaysia yang mengikuti kursus tersebut. Tahap peningkatan ini disemak melalui pensijilan seperti Sijil Profesional dalam Operasi Peralatan (PCIEO) dan Diploma Profesional dalam Kejuruteraan Pembuatan (PDIME) (Riza Abas, 2023).

Program latihan profesional ini juga memainkan peranan yang penting dalam kecekapan penerimaan pekerja dalam tugas harian mereka. Pekerja lebih mampu melaksanakan tugas mereka dengan lebih tepat dan mengurangkan kesilapan teknikal sambil meningkatkan kecekapan. Kajian telah menunjukkan bahawa kursus yang memberi tumpuan kepada kemahiran teknikal seperti SMT dan Kejuruteraan Nyahpepijat membolehkan pekerja menyelesaikan tugas mereka dengan lebih cekap dan dalam tempoh masa yang lebih singkat. Selain itu, kursus modular dan tersuai membolehkan pekerja mengaplikasikan kemahiran dengan lebih relevan dalam tugasan harian, manakala pendekatan latihan hibrid memastikan pengetahuan yang diperolehi diaplikasikan dengan berkesan di tempat kerja (Ahmad & Ibrahim, 2022).

Faktor-faktor yang menyokong keberkesanan kursus ini termasuk kerjasama strategik dengan industri seperti Flextronics, yang memastikan kursus itu memenuhi keperluan semasa. Pendekatan modular dan tersuai serta penggunaan platform digital e-PCP juga memudahkan proses aplikasi dan penilaian kursus, meningkatkan akses pekerja dan majikan kepada latihan. Namun begitu, terdapat cabaran seperti kekangan masa untuk pekerja menghadiri kursus dan kesedaran yang rendah tentang kepentingan pembangunan kemahiran dalam kalangan pekerja. Selain itu, perkembangan teknologi yang pesat memerlukan penyesuaian kursus yang berterusan agar pekerja tidak ketinggalan dalam menguasai kemahiran terkini (Riza Abas, 2023; Ahmad & Ibrahim, 2022).

4.8 Program Penilaian dan Akreditasi Pekerja Industri di PMTG

Program penilaian dan akreditasi pekerja industri di PMTG memainkan peranan penting dalam mengesahkan kompetensi pekerja, di samping meningkatkan nilai kemahiran yang dimiliki. Inisiatif ini juga memberi peluang kepada pekerja untuk mengembangkan pengetahuan dan kemahiran melalui kursus dan latihan yang selaras dengan perkembangan terkini dalam industri (JTM, 2023).

Di bawah sistem ini, pekerja dilatih dan diperakui dengan cara yang menjadikan mereka berdaya saing di pasaran. Selaras dengan penekanan kerajaan untuk menjana bilangan pekerja mahir yang lebih besar, PMTG menyediakan pensijilan profesional untuk kursus jangka pendek (kemahiran) meliputi dan merangkumi bidang kejuruteraan dan kemahiran teknikal yang dikhususkan kepada pekerja industry tertentu. Salah satu matlamat dan misi lain PMTG adalah untuk meningkatkan tahap kemahiran pekerja industri dan pembelajaran sepanjang hayat.

Program latihan jangka pendek ini dibangunkan untuk meningkatkan kemahiran calon ke peringkat seterusnya dan menyediakan sokongan untuk memperoleh pendapatan yang lebih tinggi. PMTG akan sentiasa menawarkan saluran kerjaya yang menyokong kemudahan pembelajaran baharu atau mengembangkan set kemahiran sedia ada dengan program pensijilan profesional yang ditawarkannya.

4.9 Pentingnya Peningkatan Kemahiran dan Ilmu Pengetahuan dalam Tenaga Kerja

Peningkatan daya tarikan di kalangan pekerja yang mempunyai kelayakan yang kukuh atau piawaian profesional yang sangat cekap dalam pasaran buruh adalah elemen penting untuk meningkatkan daya saing kerja mereka. Dalam persekitaran yang kompetitif, adalah penting bagi setiap pekerja untuk kekal cekap dan relevan dalam menjalankan tugas mereka, terutamanya dalam menghadapi perubahan teknologi yang semakin meningkat. Justeru, Politeknik METrO Tasek Gelugor (PMTG), melalui Unit Latihan dan Pembangunan (ULPL), mengambil inisiatif dengan menyediakan peluang latihan kepada pekerja industri dan masyarakat setempat. Peluang ini bertujuan untuk meningkatkan kemahiran sedia ada atau memperoleh kemahiran

baharu (*upskilling & reskilling*) melalui pelaksanaan kursus jangka pendek dan program pensijilan professional.

4.10 Sumbangan Skim Latihan Profesional dan Perlaksanaan

Kajian mendapati institusi penyedia latihan kemahiran telah menyediakan pelbagai kemudahan pembelajaran dalam menyumbang meningkatkan lagi bilangan tenaga mahir negara (Awang, Sains, & Ekonomi, 2007) selain isu bahawa jurang kemahiran antara kemahiran yang diperlukan oleh industri dilatih di institusi latihan (Rus, Yasin, Yunus, Rahim, & Ismail, 2015).

4.11 Perlaksanaan Kursus Professional

Program pembangunan insan (Mohd Fauzi Hamat & Mohd Khairul Naim Che Nordin, 2012), dengan melaksanakan kursus professional di instutusi latihan awam/teknikal kini menjadi salah satu permintaan terutama pada golongan yang bekerja. Strategi ini sebagai satu kaedah meningkatkan taraf ekonomi pekerja dengan meyertai kursus professional yang dianjurkan di Institusi latihan awam kebanyakannya (Zulkefli & Hassan, 2007). Di bawah Rancangan Malaysia Ke-10, pembelajaran sepanjang hayat (M Faizullah Mohamed, Badaruddin Ibrahim, & Norlida Shaari, 2014) memberikan fokus kepada meningkatkan kemahiran dan pembangunan professional berterusan kepada pekerja. Peruntukan di bawah Perbadanan Tabung Pembangunan Kemahiran (PTPK) telah diperluas pada tahun 2011, bagi menawarkan kemudahan pinjaman kepada pekerja untuk meningkatkan kemahiran. Dalam tempoh 2011-2014, seramai 3,424 pekerja mendapat manfaat daripada pembiayaan ini. Selain itu, program peningkatan kemahiran untuk pekerja perusahaan kecil dan sederhana (PKS) telah memanfaatkan 32,850 pekerja (EPU, 2015).

Pelaksanaan program latihan ini dibahagikan kepada dua kaedah utama: kursus modular dan kursus customised. Kursus modular dirancang setiap tahun dengan kandungan yang ditetapkan dan tempoh latihan, memastikan peserta mempunyai pengetahuan yang mantap dalam bidang tertentu. Sebaliknya, kursus customised dibangunkan khas mengikut permintaan pelanggan, yang membolehkan penyusunan kandungan, tempoh latihan, serta jenis persijilan disesuaikan dengan keperluan spesifik industri.

Kerjasama dengan industri juga memainkan peranan penting dalam meningkatkan kemahiran dan pengetahuan tenaga pengajar. Tenaga pengajar yang dipilih berdasarkan kepakaran dan keperluan industri boleh memberikan input yang relevan dan terkini. Selain daripada berkongsi kepakaran, kerjasama strategik ini boleh memberi manfaat kepada industri dalam membangunkan kemahiran khusus yang diperlukan untuk kekal berdaya saing.

Bagi memperluaskan pelaksanaan program ini, perlu dipertingkatkan kerjasama dengan institusi pembiayaan seperti Perbadanan Pembangunan Sumber Manusia (HRD Corp). Ini penting bagi menarik lebih ramai pekerja industri menyertai latihan yang ditawarkan di semua Politeknik dan Kolej Komuniti. Sasaran PMTG adalah untuk melatih sekurang-kurangnya 500 peserta dalam program Sijil dan Diploma dalam tempoh setahun.

Sejak 2019, PMTG telah mengambil langkah proaktif dengan memperkenalkan kursus Pensijilan Profesional di peringkat Sijil dan Diploma yang menggariskan komponen kompetensi yang perlu dikuasai oleh peserta terhadap industry tertentu. Inisiatif ini bukan sahaja diterima baik oleh industri, malah menunjukkan komitmen PMTG untuk memastikan kursus yang ditawarkan memberi nilai tambah kepada peserta. Pengiktirafan nilai dan kualiti program ini diharapkan dapat memperkukuh lagi daya saing tenaga kerja di Malaysia.

Meningkatkan kemahiran dan pengetahuan amat penting bagi meningkatkan daya saing pekerja mahir dalam sektor pekerjaan. Ini bagi memastikan setiap pekerja kekal cekap dan relevan dalam menjalankan kerja, selaras dengan perkembangan teknologi yang sentiasa dinamik. PMTG melalui ULPL menyediakan peluang latihan kepada pekerja industri dan komuniti tempatan untuk meningkatkan kemahiran sedia ada atau kemahiran baharu *upskilling & reskilling* melalui pelaksanaan kursus jangka pendek dan program pensijilan profesional.
Kaedah pelaksanaan PSH terbahagi kepada dua (2) iaitu kursus modular dan kursus *customised*. Kursus modular merujuk kepada kursus yang telah dirancang setiap tahun dengan kandungan tetap dan tempoh latihan. Manakala kursus *customised* merujuk kepada kursus yang dirumus khas mengikut permintaan pelanggan dari segi kandungan, tempoh latihan dan jenis pensijilan yang diperlukan.

Jalinan kerjasama dengan industri memberi peluang kepada tenaga pengajar khususnya yang dilantik mengikut kepakaran dan keperluan industri untuk meningkatkan kemahiran dan pengetahuan selaras dengan perkembangan semasa. Selain berkongsi kepakaran, kerjasama strategik juga mampu memberi manfaat kepada industri dalam membangunkan kemahiran khusus yang diperlukan. Justeru, bagi memperluaskan pelaksanaan program sebegini, kerjasama dengan pembiaya seperti HRD Corp perlu dipertingkatkan bagi menarik lebih ramai pekerja industri menyertai latihan di semua Politeknik dan Kolej Komuniti dan seterusnya mencapai sasaran melatih 500 peserta PSH dalam tempoh setahun. Antara usaha yang dijalankan oleh PMTG sejak 2019 ialah pengenalan kursus Pensijilan Profesional khususnya di peringkat Sijil dan Diploma yang menetapkan komponen kompetensi yang diikuti oleh peserta. Inisiatif ini disambut baik oleh industri dan ia menunjukkan komitmen PMTG untuk memastikan kursus yang ditawarkan mempunyai nilai tambah khususnya kepada peserta.

5. Kesimpulan

Keberkesanan kursus profesional dalam meningkatkan kemahiran dan kecekapan pekerja industri merupakan isu penting dan relevan terutama dalam menghadapi perkembangan teknologi dan keperluan industri yang sentiasa berubah. Kertas kerja ini membentangkan demonstrasi yang jelas bahawa latihan berkualiti tinggi bukan sahaja harus memudahkan pembangunan kecekapan teknikal tetapi juga pembangunan kemahiran insaniah yang diperlukan untuk berjaya dalam persekitaran kerja hari ini. Dengan menilai keberkesanan kursus, penemuan kajian ini dijangka menawarkan maklumat nilai untuk pemegang polisi, pengurus sumber manusia dan penyedia perkhidmatan latihan.

Maklumat ini boleh digunakan dalam mereka bentuk dan melaksanakan latihan yang lebih baik untuk memenuhi keperluan industri dengan lebih cekap. Penyelidikan ini juga menunjukkan kepentingan bagi sektor pendidikan dan industri untuk bekerja lebih rapat untuk menjadikan kursus lebih relevan mengikut pasaran buruh. Oleh itu, dengan pendekatan berasaskan data dan input daripada peserta, kursus profesional di PMTG diharap dapat berkembang dan menawarkan nilai tambah kepada pekerja dan industri.

Akhir sekali, kajian ini memberikan pandangan utama untuk strategi pembelajaran dan latihan sepanjang hayat untuk membantu meningkatkan daya saing tenaga kerja Malaysia dalam pasaran baru muncul global.

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MENINGKATKAN PENGUASAAN *DEPTH OF FIELD* (DOF) DALAM KALANGAN PELAJAR MELALUI PENDEKATAN PEMBELAJARAN AKTIF

Muhamad Shahrum Nazar bin Yahya[1]*, Sarifah Nor Husna binti Syed Alias[2], Nor Shazana binti Abdul Rashid[2]

[1]Jabatan Reka Bentuk dan komunikasi Visual, Politeknik METrO Tasek Gelugor,13200 Kepala Batas, Pulau Pinang, Malaysia

[2]Unit Latihan dan Pendidikan Lanjutan, Politeknik METrO Tasek Gelugor,13200 Kepala Batas ,Pulau Pinang,Malaysia

*Corresponding author e-mail address: muhdshahrum@pmtg.edu.my

Abstrak

Kajian ini bertujuan untuk meningkatkan penguasaan pelajar terhadap konsep *Depth of Field* (DOF) dalam fotografi melalui pendekatan pembelajaran aktif. DOF merupakan salah satu elemen penting dalam fotografi yang mempengaruhi kejelasan dan estetika imej. Walau bagaimanapun, terdapat ramai pelajar yang mengalami kesukaran dalam memahami dan mengaplikasikan konsep ini dalam penghasilan gambar. Kajian ini menggunakan pendekatan pembelajaran aktif yang melibatkan eksperimen praktikal, latihan *hands-on*, dan simulasi kawalan DOF bagi meningkatkan pemahaman pelajar. Hasil kajian menunjukkan peningkatan ketara dalam penguasaan DOF, serta keyakinan pelajar dalam mengaplikasikan teknik ini dalam dunia penggambaran sebenar. Kumpulan sasaran kajian ini terdiri daripada 20 orang responden yang terdiri daripada pelajar semester 1 Diploma Teknologi Digital Produksi Video sesi 1 2023/2024 di Politeknik METrO Tasek Gelugor. Kaedah kajian yang digunakan adalah secara kuantitatif melalui pengumpulan data soal selidik kepada pelajar. Dapatan kajian dianalisis berdasarkan skor purata setiap item menggunakan Microsoft Excel. hasil dapatan kajian akan menjawab persoalan kajian berdasarkan analisis penilaian kuantitatif yang telah dijalankan. Penilaian dijalankan menggunakan Borang Soal Selidik. Hasil daripada analisis dapatan soal selidik ini skor nilai min yang diberi oleh responden sangat memberangsangkan kerana kebanyakan responden sangat setuju dengan pengetahuan asas dan penguasaan *depth of field* selepas melalui pembelajaran aktif. Kajian ini juga akan diguna pakai untuk menghasil video AI fotografi pada masa hadapan bagi memudahkan pelajar lebih memahami dan mempunyai kemahiran dalam menggunakan kamera *digital single lens reflex* dengan lebih baik.
Kata kunci: Depth of field; Pembelajaran aktif; Latihan hands-on.

1. Pengenalan

Fotografi bukan sekadar hasil visual yang menarik, namun ia juga berperanan sebagai alat komunikasi yang mampu menyampaikan mesej tanpa memerlukan kata-kata. Setiap gambar yang dirakam membawa naratif tersendiri dan boleh menyampaikan emosi, suasana, dan makna yang ingin dikongsi oleh jurugambar kepada penontonnya. Melalui lensa kamera, jurugambar berupaya merakam realiti, interpretasi peribadi, atau kritikan sosial yang kemudiannya menjadi bahan renungan masyarakat. Dalam konteks ini, fotografi bertindak sebagai medium yang efektif dalam menyampaikan maksud secara halus namun mendalam kepada khalayak (Barrett, 2011).

Menurut Freeman et al. (2014) pelajar yang menjalani kursus tanpa pembelajaran aktif adalah 1.5 kali lebih berkemungkinan gagal berbanding pelajar dengan pembelajaran aktif. Kajian

Pembelajaran Aktif oleh pembelajaran aktif menurut Meyers dan Jones (1993) ialah daripada dua bentuk andaian, iaitu pembelajaran pada hakikatnya adalah satu aktiviti yang aktif dan andaian bahawa murid yang berlainan sudah tentu mempunyai cara belajar yang berbeza antara satu sama lain.

Pembelajaran aktif ini pada hakikatnya tertumpu kepada aktiviti pembelajaran berbanding objek pembelajaran itu sendiri. Hal ini bermaksud walaupun fokus pembelajaran aktif ini adalah kepada aktiviti pelajar namun kesan aktiviti itu sendiri memberikan ingatan yang mendalam kepada objek pembelajaran itu sendiri (Knight et.al., 2005).

Pembelajaran aktif merupakan satu pendekatan yang menekankan penglibatan pelajar secara langsung dalam proses pembelajaran mereka. Melalui kaedah ini, pelajar tidak hanya menerima maklumat secara pasif, pelajar juga turut mengambil bahagian secara aktif melalui pelbagai aktiviti yang merangsang pemikiran dan interaksi sewaktu proses pengajaran berlaku. Selain itu juga pelajar berpeluang mendapatkan maklum balas dengan segera, membolehkan mereka mengenal pasti kelemahan dan memperbaiki pemahaman secara berterusan. Keutamaan dalam pembelajaran aktif menekankan kepada aspek pembangunan kemahiran diri pelajar dan bukan hanya penguasaan fakta. Kaedah ini juga menggalakkan penerokaan maklumat secara mendalam serta penerapan nilai-nilai yang tinggi dalam kalangan pelajar. Selain itu, ia mampu meningkatkan kreativiti serta pemikiran aras tinggi seperti analisis, sintesis, dan penilaian.

Depth of Field (DOF) merujuk kepada kawasan dalam imej yang kelihatan tajam dan jelas apabila dilihat melalui lensa kamera. DOF bergantung kepada pelbagai faktor seperti pembukaan aperture, jarak subjek, dan panjang fokus lensa. Sebagai elemen asas dalam fotografi, DOF sangat mempengaruhi komposisi dan hasil akhir imej yang dihasilkan. Namun, terdapat pelajar yang masih menghadapi kesukaran dalam memahami dan mengaplikasikan konsep ini dengan berkesan. Pendekatan pembelajaran tradisional yang memfokuskan kepada teori sahaja tidak cukup untuk memberikan pelajar pengalaman praktikal yang mendalam mengenai kawalan DOF. Pembelajaran aktif merupakan pendekatan yang menekankan penglibatan aktif pelajar dalam proses pembelajaran, yang memberi penekanan kepada aktiviti praktikal dan penyelesaian masalah. Pendekatan ini telah terbukti berkesan dalam meningkatkan penguasaan pelajar terhadap konsep-konsep teknikal, termasuk DOF. Oleh itu, kajian ini bertujuan untuk meneroka keberkesanan pendekatan pembelajaran aktif dalam membantu pelajar memahami dan menguasai konsep DOF.

1.1 Objektif kajian

Objektif utama kajian ini adalah meningkatkan pemahaman pelajar terhadap konsep *Depth of Field (DOF)* melalui pendekatan pembelajaran aktif. Selain itu,ia menilai kesan pembelajaran aktif dalam meningkatkan penguasaan pelajar terhadap teknik DOF dan mengenal pasti cabaran yang dihadapi oleh pelajar dalam menguasai DOF dan cara untuk mengatasinya.

1.2 Skop kajian

Kajian ini akan dijalankan ke atas pelajar semester satu bagi kursus *Creative Photography* Sesi II 2023/2024Diploma Teknologi Kreatif Digital Produksi Video di Politeknik METrO Tasek Gelugor.

Skop kajian ini melibatkan Aspek Penguasaan DOF iaitu kajian memberi fokus kepada elemen teknikal yang mempengaruhi DOF seperti pembukaan aperture, jarak fokus, dan panjang fokus lensa. Pendekatan Pembelajaran Aktif dengan penggunaan eksperimen praktikal dan latihan

hands-on sebagai kaedah utama dalam pengajaran DOF serta lingkungan Pembelajaran dalam kajian ini dilaksanakan dalam bilik darjah dengan penggunaan kamera DSLR atau kamera mirrorless yang membolehkan kawalan manual terhadap DOF.

2. Metodologi

Menurut Creswell (2014), metodologi merujuk kepada pelbagai kaedah dan pendekatan yang digunakan dalam penyelidikan untuk mengumpul, menganalisis, dan mentafsir data bagi menjawab soalan penyelidikan.

Dalam kajian ini, soal selidik digunakan sebagai instrumen utama untuk memperoleh data. Sekaran dan Bougie (2016) menyatakan bahawa soal selidik adalah instrumen yang terdiri daripada sekumpulan soalan yang dirancang untuk mengumpul maklumat secara langsung daripada responden. Pemilihan soal selidik sebagai instrumen kajian adalah kerana kemudahan pentadbirannya dan kebolehpercayaan yang tinggi. Borang soal selidik membolehkan pengkaji mengumpul maklumat daripada responden dengan cara yang mudah, sama ada secara bersemuka atau melalui edaran borang. Fowler (2014) juga menekankan bahawa pengedaran soal selidik secara bersemuka memberi peluang kepada pengkaji untuk menjelaskan dengan lebih jelas objektif kajian, mengurangkan kekeliruan, dan memastikan respon yang lebih tepat daripada responden.

Kajian ini di jalankan menggunakan pendekatan kuantitatif untuk menilai tahap penguasaan pelajar terhadap *Depth of Field* (DOF) selepas pelajar mengikuti sesi pembelajaran aktif. Kajian ini akan dijalankan dalam satu fasa utama:

2.1 Fasa 1: Pembelajaran Aktif dan Ujian Pasca

Pelajar akan terlibat dalam aktiviti praktikal yang memberi tumpuan kepada pengawalan DOF, termasuk eksperimen kawalan aperture, panjang fokus, dan jarak subjek untuk menghasilkan kesan DOF yang berbeza. Aktiviti ini bertujuan memberikan pengalaman langsung kepada pelajar dalam menguasai teknik DOF.

Setelah sesi pembelajaran aktif selesai, pelajar akan menjalani ujian pasca untuk menilai pemahaman mereka terhadap DOF serta tahap penguasaan teknik yang telah dipelajari. Selain itu, soal selidik akan digunakan untuk mengukur tahap keyakinan pelajar dalam mengaplikasikan teknik DOF dalam penggambaran sebenar. Soal selidik ini akan menggunakan skala Likert untuk mendapatkan maklum balas yang jelas daripada pelajar mengenai pengalaman mereka.

Data yang dikumpulkan daripada ujian pasca dan soal selidik akan dianalisis menggunakan statistik deskriptif, termasuk pengiraan nilai min dan peratusan. Analisis ini dilaksanakan dengan bantuan perisian Microsoft Excel bagi memudahkan pemprosesan data serta penjanaan interpretasi secara sistematik dan efisien.

Menurut Mohd Majid (1990), statistik deskriptif merujuk kepada proses penyusunan dan ringkasan data yang diperoleh melalui pemerosesan, dan hasilnya biasanya ditunjukkan dalam bentuk jadual, graf atau rajah. Dalam kajian ini, analisis data dijalankan menggunakan perisian Microsoft Excel bagi tujuan pengiraan nilai min dan peratusan.

Sementara itu, pemeringkatan skor min adalah berdasarkan interpretasi oleh Dr. Jamil Ahmad (2002), yang menetapkan bahawa skor min antara 1.00–2.33 dikategorikan sebagai rendah,

2.34–3.66 sebagai sederhana, dan 3.67–5.00 sebagai tinggi. Jadual interpretasi ini digunakan bagi menilai tahap penguasaan pelajar terhadap setiap item dalam instrumen kajian.

Jadual 2. Skala Skor Min dan Interpretasi

Skor Min	Interpretasi Skor Min	
1.00 hingga 2.33	Rendah	(Kurang setuju/kurang membantu/kurang mahir/kurang memenuhi/ tidak pasti/kadang-kadang/tiada/sebahagian kecil)
2.34 hingga 3.66	Sederhana	(Setuju/membantu/mahir/memenuhi/separuh)
3.67 hingga 5	Tinggi	(Sangat setuju/sangat membantu/sangat mahir/sangat memenuhi/sangat selalu/semua/sebahagian besar)

3. Keputusan dan Perbincangan

Jadual 3 menunjukkan dapatan data berikut, maka dapat dirumuskan bahawa majoriti pelajar yang terlibat sebagai responden dalam kajian ini sangat bersetuju dengan minat mereka terhadap fotografi.

Jadual 3. Pemahaman pelajar terhadap konsep Depth of Field (DOF) melalui pembelajaran aktif

Item	Nilai skor (min)	Petunjuk purata skor
Saya tahu maksud sebenar Depth of Field (DOF) dalam fotografi	4.55	Tinggi
Saya tahu beza antara DOF cetek (shallow) dan DOF dalam (deep).	4.85	Tinggi
Saya tahu faktor-faktor yang mempengaruhi DOF seperti aperture, jarak subjek dan focal length.	4.7	Tinggi
Saya tahu bagaimana untuk mengawal DOF semasa mengambil gambar.	4.5	Tinggi
Saya yakin untuk menerangkan konsep DOF kepada rakan saya.	4.05	Tinggi
Total	4.53	Tinggi

Jadual 4 di bawah menunjukkan rumusan nilai min bagi item kesan pembelajaran aktif dalam meningkatkan penguasaan pelajar terhadap teknik DOF, secara keseluruhannya menunjukkan interprestasi skor minnya ialah " sangat setuju". Skor pada item Pembelajaran secara aktif lebih berkesan berbanding hanya melalui penerangan teori menunjukkan interprestasi skor min yang tinggi iaitu 4.85 .Ini menjelaskan bahawa majoriti responden bersetuju bahawa pembelajaran aktif adalah berkesan dalam meningkat penguasaan pelajar.

Jadual 4. Menilai kesan pembelajaran aktif dalam meningkatkan penguasaan pelajar bagi teknik DOF

Item	Nilai skor (min)	Petunjuk purata skor
Saya terlibat secara aktif dalam aktiviti hands-on / simulasi semasa belajar DOF.	4.55	Tinggi

Pembelajaran secara eksperimen membantu saya faham konsep DOF dengan lebih jelas.	4.65	Tinggi
Saya dapat mengaitkan teori dengan amali semasa menjalani aktiviti berkaitan DOF.	4.35	Tinggi
Pembelajaran secara aktif lebih berkesan berbanding hanya melalui penerangan teori.	4.85	Tinggi
Saya dapat menghasilkan gambar dengan DOF yang dikawal dengan baik.	4.85	Tinggi
Saya lebih yakin menggunakan teknik DOF selepas menjalani pembelajaran aktif.	4.55	Tinggi
Total	4.63	Tinggi

3.2 Mengenal pasti cabaran yang dihadapi oleh pelajar dalam menguasai DOF dan cara atasi.

Hasil soal selidik menunjukkan bahawa secara keseluruhannya, pelajar tidak lagi menghadapi cabaran besar dalam menguasai Depth of Field (DOF), dengan purata skor keseluruhan hanya 2.30. Nilai ini berada dalam kategori rendah, menunjukkan bahawa kebanyakan pelajar sudah mampu mengawal aspek teknikal seperti aperture, jarak subjek, dan *focal length* dengan baik. Namun, bagi item “Saya menghadapi kesukaran untuk memahami konsep DOF secara teori”, min skor adalah 3.15, iaitu pada tahap sederhana. Ini mungkin disebabkan oleh sebilangan pelajar yang lebih mudah memahami konsep apabila disertakan dengan demonstrasi secara praktikal dan latihan hands-on.Secara keseluruhannya, pendekatan pembelajaran aktif yang digunakan boleh dianggap berkesan, terutamanya dalam membantu pelajar mengatasi cabaran teknikal.

Jadual 5. Mengenal pasti cabaran yang dihadapi oleh pelajar dalam menguasai DOF dan cara untuk mengatasinya

Item	Nilai skor (min)	Petunjuk purata skor
Saya menghadapi kesukaran untuk memahami konsep DOF secara teori.	3.15	Sederhana
Saya sukar mengawal aperture, jarak subjek dan focal length semasa mengambil gambar.	2.1	Rendah
Saya kurang yakin dalam menghasilkan gambar dengan DOF yang tepat..	1.75	Rendah
Saya menghadapi kesukaran membezakan antara *Shallow* DOF dan *Deep* DOF dalam dalam hasil gambar.	2.2	Rendah
Total	2.30	Rendah

4. Penutup

Secara keseluruhannya, kajian ini menunjukkan bahawa pendekatan pembelajaran aktif adalah sangat berkesan dalam meningkatkan penguasaan *Depth of Field* (DOF) dalam kalangan pelajar. Melalui eksperimen praktikal dan latihan hands-on, pelajar bukan sahaja memahami konsep DOF dengan lebih mendalam, tetapi juga dapat mengaplikasikannya dalam penggambaran yang lebih kreatif dan profesional. Kajian ini juga membuka peluang untuk penyelidikan lanjut mengenai pendekatan pembelajaran aktif dalam aspek teknikal lain dalam fotografi dan bidang seni visual

yang lain. Diharapkan hasil kajian ini dapat memberi impak positif dalam pendekatan pengajaran fotografi dan meningkatkan penguasaan pelajar dalam bidang ini.

Keberkesanan pembelajaran aktif dalam meningkatkan penguasaan DOF dapat dilihat melalui peningkatan ketara dalam pemahaman dan kemahiran pelajar. Sebelum sesi pembelajaran aktif, ramai pelajar yang bergantung kepada mod automatik pada kamera tanpa memahami kesan DOF terhadap komposisi imej. Setelah mengendalikan kamera DSLR melalui latihan praktikal, pelajar menunjukkan peningkatan dalam keyakinan dan kemampuan untuk mengawal DOF dalam pengambilan gambar.

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THE INFLUENCE OF FINANCIAL KNOWLEDGE AND INTERNAL LOCUS OF CONTROL ON PERSONAL FINANCIAL MANAGEMENT BEHAVIOR OF LAUNDRY BUSINESS ACTORS IN BATANG KUIS DISTRICT

Berliana Siregar

Management Study Department, High School of Sukma Medan, Sakti Lubis Street, Siti Rejo 1, Medan City, North Sumatera 20219, Indonesia

Corresponding author e-mail address: sberliana214@gmail.com

Abstract

This study explores the influence of financial knowledge and internal locus of control on the personal financial management behaviour of micro-enterprises, specifically laundry business owners in Batang Kuis District, Indonesia. Despite their important contribution to the local economy, many micro-entrepreneurs struggle with separating personal and business finances, making informed financial decisions, and maintaining consistent financial discipline. Using a quantitative approach, data were collected from 23 laundry business owners who had operated for more than a year. A structured questionnaire was used to measure the three main variables: financial knowledge, internal locus of control, and financial management behaviour. The data were analyzed using multiple linear regression with classical assumption testing. The results indicate that both financial knowledge and internal locus of control have a positive and significant influence on personal financial management behaviour, both partially and simultaneously, with a combined explanatory power of 58%. These findings highlight the importance of strengthening cognitive and psychological factors in improving the financial practices of micro-entrepreneurs. Enhancing financial literacy and promoting a sense of internal control may contribute to more effective budgeting, savings, and investment behaviour. This research provides empirical insights useful for local governments and training institutions in designing targeted financial education programs for MSMEs in the service sector.
Keywords: Financial Knowledge; Internal Locus of Control; Financial Behaviour.

1. Introduction

Micro, Small, and Medium Enterprises (MSMEs) are vital to Indonesia's economic structure, contributing significantly to employment, GDP, and community development. One such growing sector is laundry services, which has become increasingly relevant due to shifting lifestyles and urbanization. In areas like Batang Kuis District, the laundry industry has experienced a noticeable increase in the number of business units, signaling both market demand and entrepreneurship potential. However, despite this growth, many laundry business owners still face fundamental challenges in managing their finances effectively.

One of the persistent issues among the MSME sector is poor financial management behavior, particularly the inability to separate personal and business finances, irregular budgeting, and limited use of financial tools or digital technology. These challenges often stem from two core aspects: limited financial knowledge and psychological factors, such as the individual's locus of control. Financial knowledge refers to the understanding and skills required to make informed and effective financial decisions. Prior research has shown that financial literacy is positively associated with improved financial behavior, including budgeting, saving, debt management, and investment (Sitorus & Adlina, 2024; Surbakti, 2024).

In parallel, internal locus of control defined as an individual's belief in their own ability to influence outcomes plays a critical role in decision-making. Entrepreneurs with a strong internal locus of control tend to take greater responsibility for their actions and show higher levels of financial discipline. Studies such as that of (Sheda, 2023) and (Asaari, 2021) have demonstrated that individuals who believe they can control their financial success are more proactive in learning and applying financial principles.

Although there is a growing body of literature on the relationship between financial knowledge, locus of control and financial behavior, research specifically targeting laundry entrepreneurs in small districts like Batang Kuis remains limited. Considering that MSME financial behavior may vary based on local socio-economic and cultural contexts, it is crucial to study this relationship in a more localized setting.

This research therefore aims to analyze the influence of financial knowledge and internal locus of control on personal financial management behavior among laundry business owners in Batang Kuis. The findings are expected to provide both theoretical insights and practical recommendations for strengthening financial literacy and psychological empowerment in the MSME sector.

2. Methodology

This research employed a quantitative approach with a descriptive and explanatory design to investigate the influence of financial knowledge and internal locus of control on personal financial management behavior among laundry business owners in Batang Kuis District, Indonesia. The study aimed to understand not only the individual impact of each independent variable but also their combined effect on financial behavior. The study was conducted in Batang Kuis District, Deli Serdang Regency, North Sumatra, where laundry businesses have grown significantly in the last five years. A total of 23 laundry businesses that had been operating for at least one year participated in the study with data collected between April and July 2025.

2.1. Population and Sample

The population consisted of all laundry entrepreneurs operating in Batang Kuis District. Given the relatively small population size, a census sampling technique was employed whereby all 23 eligible laundry businesses were included. The inclusion criteria were: (1) operating for at least one year, (2) independently owned (not part of a franchise), and (3) willingness to complete the research questionnaire.

2.2. Data Collection Techniques

Primary data were collected using structured questionnaires distributed directly to respondents. The questionnaire was divided into four parts: demographic information, financial knowledge, internal locus of control, and personal financial management behavior. Each item was measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Secondary data including previous research, statistical reports, and literature reviews were also utilized to support analysis and provide contextual understanding.

2.3. Variable Operationalization

Three variables were analyzed in this study:

i. Financial Knowledge (X_1): The respondent's ability to understand and apply basic financial concepts such as budgeting, saving, investing and managing debt.
ii. Internal Locus of Control (X_2): The belief that one's financial outcomes are primarily determined by one's own efforts and decisions rather than external circumstances.
iii. Personal Financial Management Behavior (Y): Observable actions in managing personal and business finances, including budgeting, record-keeping, separating personal/business finances, saving, and investing.

Each variable was represented by a set of indicators adapted from validated instruments in prior studies (e.g., Sitorus & Adlina, 2024).

2.4. Data Analysis Method

The collected data were analyzed using SPSS version 27. Prior to regression analysis, the data underwent classical assumption tests including:

1. Normality Test using the Kolmogorov–Smirnov method.
2. Multicollinearity Test using Variance Inflation Factor (VIF) and tolerance values.
3. Heteroscedasticity Test using the Glejser test.

Once assumptions were met, a multiple linear regression analysis was performed to assess the influence of independent variables on the dependent variable. The regression model used was:

$$Y = a + b_1X_1 + b_2X_2 + e \quad (1)$$

Where:

1. Y = Personal Financial Management Behavior
2. X_1 = Financial Knowledge
3. X_2 = Internal Locus of Control
4. a = Constant
5. b_1, b_2 = Regression coefficients
6. e = Error term

Statistical significance was evaluated at the 5% level ($p < 0.05$). The model's explanatory power was assessed using the coefficient of determination (R^2), and hypothesis testing was conducted using t-tests for individual variables and an F-test for simultaneous influence.

3. Results and Discussion

3.1. Respondent Characteristics

The study involved 23 laundry business owners in Batang Kuis District. The demographic profile showed that 43.5% of respondents were between 31–40 years old, 52.2% had a diploma or bachelor's degree, and about 51.9% had been operating their laundry businesses for more than two years.

Table 1. Respondent Characteristics

Sub-category	Frequency (n)	Percentage (%)
20–30 years	6	26.1%
31–40 years	10	43.5%
> 40 years	7	30.4%
Senior High School (SMA)	11	47.8%

Sub-category	Frequency (n)	Percentage (%)
Diploma/Bachelor (D3/S1)	12	52.2%
1–2 years	10	43.5%
> 2 years	13	56.5%

3.2. Descriptive Statistics

Table 2 presents the descriptive statistics of the study variables.

Table 2. Descriptive Statistics

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Financial Knowledge (X1)	23	2.80	4.60	3.87	0.48
Internal Locus of Control (X2)	23	2.90	4.70	4.05	0.50
Financial Management Behavior (Y)	23	2.70	4.80	4.00	0.52

The mean scores indicate that participants generally have moderate to high levels of financial knowledge, internal locus of control, and financial management behavior.

3.3. Validity and Reliability Test

(a) Validity Test

Validity refers to the extent to which an instrument measures what it is intended to measure. In this study, construct validity was tested using Pearson product-moment correlation (r-value) between each item score and the total score of the respective variable. An item is considered valid if the correlation coefficient (r-count) is greater than the critical value of r-table. With n = 23 and α = 0.05, the r-table value is 0.413.

Table 3. X^1 Variable Validity Test

Indicator	R Count	R Table	Status
FK1	0,901	0,413	Valid
FK2	0,930		Valid
FK3	0,930		Valid
FK4	0,916		Valid
FK5	0,943		Valid

Table 4. X^2 Variable Validity Test

Indicator	R Count	R Table	Status
ILC1	0,943	0,413	Valid
ILC2	0,873		Valid
ILC3	0,655		Valid
ILC4	0,841		Valid
ILC5	0,831		Valid

Table 5. Y Variable Validity Test

Indicator	R Count	R Table	Status
FMB1	0,814	0,413	Valid
FMB2	0,703		Valid
FMB3	0,862		Valid
FMB4	0,769		Valid

FMB5	0,762	Valid

(b) Reliability Test

Reliability refers to the internal consistency of the questionnaire that is the extent to which the items within a variable consistently measure the same construct. The Cronbach's Alpha coefficient was used in this study to test reliability. A variable is considered reliable if the Cronbach's Alpha > 0.60

Table 6. Reliability Test

Variable	Cronbach's Alpha	Value Measurement Criteria	Status
Financial Knowledge (X1)	0,969	0,60	Reliable
Internal Locus of Control (X2)	0,989		Reliable
Financial Management Behaviour (Y)	0,900		Reliable

3.4. Classical Assumption Test

Table 7. Multicollinearity Test

Variable	Tolerance	VIF
Financial Knowledge (X1)	0.672	1.487
Internal Locus of Control (X2)	0.672	1.487

→ VIF < 10 and Tolerance > 0.10 → No multicollinearity.

Table 8. Heteroscedasticity Test (Glejser Test)

Variable	Sig. (p-value)
Financial Knowledge (X1)	0.418
Internal Locus of Control (X2)	0.509

→ Sig > 0.05 → No heteroscedasticity.

Table 9. Normality Test (Kolmogorov–Smirnov)

Statistic	df	Sig. (2-tailed)
0.134	23	0.200*

→ Data is normally distributed (Sig > 0.05).

3.5. Regression Analysis

Table 10. Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate
0.762	0.580	0.545	0.351

→ R^2 = 0.580 indicates that 58% of the variance in financial management behavior is explained by the two independent variables.

Table 11. ANOVA (F-Test)

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.621	2	2.811	22.84	0.000
Residual	4.059	20	0.203		

Model	Sum of Squares	df	Mean Square	F	Sig.
Total	9.680	22			

→ Sig. = 0.000 < 0.05 → model is statistically significant.

Table 12. Coefficients (T-Test)

Variable	B	Std. Error	Beta	t	Sig.
Constant	1.104	0.423	—	2.610	0.016
Financial Knowledge (X1)	0.372	0.121	0.441	3.081	0.006
Internal Locus of Control (X2)	0.398	0.118	0.458	3.373	0.003

→ Both independent variables significantly affect the dependent variable ($p < 0.05$).

3.6. Discussion

The findings of this study underscore the importance of both financial knowledge and internal locus of control in shaping the financial behavior of micro-entrepreneurs, particularly in the laundry sector of Batang Kuis District. The regression analysis confirms that these two factors not only exert significant individual influences but also contribute collectively to the development of effective personal financial management behavior.

3.6.1. Financial Knowledge and Financial Behavior

The positive and significant influence of financial knowledge ($\beta = 0.372$; $p < 0.01$) supports the hypothesis that entrepreneurs who possess a better understanding of basic financial principles such as budgeting, saving, debt management, and investment are more capable of making sound financial decisions. This aligns with the findings of Sitorus and Adlina (2024), who observed a similar pattern among MSMEs in Medan, where improved financial literacy contributed to better business sustainability and individual financial well-being.

In this study, respondents with higher financial knowledge were more likely to keep consistent financial records, plan their expenditures and allocate resources for emergency funds or business reinvestment. However, the relatively moderate mean scores of 3.87 indicates room for improvement, particularly in advanced aspects of financial literacy such as long-term investment strategies and technology adoption for financial management (e.g., digital bookkeeping, e-wallets). This observation reflects the findings of Daratista et al. (2024), who emphasize that digital financial literacy remains underutilized in micro-enterprises despite its increasing relevance.

3.6.2. Internal Locus of Control and Financial Behavior

Internal locus of control ($\beta = 0.398$; $p < 0.01$) was also shown to be a critical determinant of financial behavior. Entrepreneurs with a high internal locus of control believe that their efforts, rather than external circumstances, shape their financial success. These individuals tend to be more responsible, disciplined, and future-oriented in managing their personal and business finances. This result corroborates Sheda (2023) conclusions, which highlight that internal psychological factors are just as vital as technical knowledge in financial management.

Interestingly, some respondents, while acknowledging personal responsibility for business success, still demonstrated inconsistent behavior in practices like separating personal and business income. This suggests that belief in internal control must be reinforced with actionable

knowledge and structured habits to ensure consistent outcomes. As Surbakti (2024) notes, psychological traits need to be complemented by financial skills training to achieve measurable improvements in financial behavior.

3.6.3. Combined Influence and Practical Implications

Together, financial knowledge and internal locus of control accounted for 58% of the variance in financial behavior ($R^2 = 0.580$), indicating a substantial combined influence. This implies that interventions aimed at improving financial behavior should not focus solely on education or training programs, but also incorporate efforts to strengthen entrepreneurial mindset and personal agency.

For instance, financial literacy workshops could be integrated with coaching sessions that emphasize goal setting, risk management confidence and resilience in business decision-making. Government agencies and NGOs could play a more active role in designing such integrated programs, particularly targeted at underserved micro-enterprise sectors such as laundry businesses, which often operate informally and lack access to structured financial resources.

3.6.4. Challenges and Areas for Improvement

Despite the positive findings, the study also revealed several challenges. Many respondents had limited experience in financial forecasting and did not prepare regular business budgets. Less than one-third maintained an emergency savings fund, and a significant proportion continued to merge personal and business finances. These practices highlight the need for more hands-on guidance and the development of simple financial tools or templates tailored to micro-business contexts.

3.6.5. Contextual Relevance

The results should also be interpreted within the unique context of Batang Kuis, a growing semi-urban area where access to financial services may be limited, and entrepreneurial practices are often inherited or informal. Cultural attitudes towards money, education, and autonomy may influence how financial knowledge and locus of control manifest in behavior. Therefore, further research is recommended to explore how these contextual variables interact with psychological and cognitive traits in shaping financial decision-making.

4. Conclusion

This study concludes that both financial knowledge and internal locus of control significantly and positively influence the personal financial management behavior of laundry entrepreneurs in Batang Kuis District. Respondents with higher financial literacy demonstrated better budgeting, saving, and financial planning habits. Similarly, those with a strong internal locus of control showed greater discipline and responsibility in managing their finances.

The combined effect of these two variables accounts for a substantial share of the variance in financial behavior, suggesting that effective financial management requires not only knowledge but also a strong personal belief in one’s ability to control financial outcomes.

These findings highlight the importance of providing financial education alongside motivational and mindset-building programs. For policy makers and support institutions, this implies the need to develop integrated training models that address both cognitive and psychological aspects of

financial behavior. Strengthening these areas can enhance financial resilience and sustainability among micro-entrepreneurs.

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PRODUCT DESIGN, SERVICE, AND PRICE TO CUSTOMER PURCHASING DECISIONS: A STUDY AT PT SARANA KENCANA MULYA

Antony Tanoto, Elserra Siemin Ciamas*

International Marketing Management, Politeknik Cendana, 20222 Kota Medan Sumatera Utara, Indonesia

*Corresponding author e-mail address: ql.esc7@gmail.com

Abstract

This study explores how product design, service quality, and price influence customer purchasing decisions at PT Sarana Kencana Mulya, a local electronics retail company. Motivated by the recent decline in customer purchases, this research aims to identify which factors truly drive buying behavior. A survey was conducted with 100 respondents, and the data was analyzed using SPSS software. The findings reveal that price has a significant and positive impact on purchasing decisions, while product design and service quality do not show a notable effect. The results highlight the importance of competitive pricing strategies for businesses in highly saturated markets. This study contributes to marketing decision-making by helping businesses better align their strategies with customer priorities.
Keywords: Product Design; Service; Price.

1. Introduction

The increasingly fierce business competition has made business people start competing to outperform their competitors in various ways, ranging from offering the best quality products, the fastest service, a very large variety of products, to conducting various promotions and providing attractive offers. The success of a company is determined by how the company carries out marketing strategies to increase its sales. Purchasing decision is an action or consumer behavior, so whether or not to make a purchase (Kotler & Keller, 2019).

Many things are considered by consumers to arrive at the decision to choose where to buy a particular product. The company must try to meet the criteria that are taken into consideration by customers, be it product design, service quality, and price, so that it can provide good decisions in making purchases for its customers, if this is ignored, there will be a decrease in the number of purchasing decisions made by customers therefore the success or failure of the company in communicating with customers depends on attractive product design, the best quality of service, and the appropriate price.

One of the businesses or businesses that also feels the tight competition today is the field of business sales of household goods, especially in the field of electronics. PT Sarana Kencana Mulya is a company engaged in the sale of electronic goods, the brand owned is PT Sarana Kencana Mulya is Polytron. This original Indonesian product has received many awards in terms of product design and the quality of service. Although the products sold have received many awards but at PT Sarana Kencana Mulya, there is still a decrease in the number of customers who make purchases. The occurrence of a decrease in the number of buyers in the last 6 months made it difficult for PT Sarana Kencana Mulya to identify the problems that occurred.

Product design has a very important role in an industry or other business. The design obtained through research ideas, imagination, and creativity is applied to the product. Attracting consumer attention is one of the roles of the product design itself, so that it can increase consumer purchasing decisions (Kusumaningrat, 2020). Product design variables have a significant effect on purchasing decision variables (Handayani et al., 2020; Putrifasari et al., 2023). Meanwhile, according to Soedjono et al. (2019), there was no positive influence of product design on consumer purchasing decisions, which proves that currently, consumers do not consider product design in determining their product choices.
H_1 : Product Design (X1) affects Purchasing Decisions (Y)

Service quality is a dynamic condition related to products, services, people, processes, and the environment that meet or exceed expectations. In order to create customer satisfaction with the products offered by the organization must be of high quality (Kotler & Armstrong, 2018). The results of the study reveal that service quality has a positive and significant effect on purchasing decisions (Arianthi & Sampurna, 2020; Yulyani et al., 2023), but different results were found by Marpaung & Mekaniwati (2020), which reveal that the quality of service provided by the company has no significant direct effect on consumer purchasing decisions.
H_3 : Service Quality (X2) affects Purchasing Decisions (Y)

The appropriate price will influence purchasing decisions, the more the company understands consumers in terms of service quality and price, the higher the purchasing decision and vice versa, if the company is less. This is in line with the results of research from (Putrifasari et al., 2023) that price has a positive and significant effect on purchasing decisions, while the results of research from (Mulyana, 2021) state that price does not have a positive and significant direct effect on product purchasing decisions. Price is not the main reason for people to purchase products, this is because there are many consumer considerations to find out which products to buy according to their wishes, because from one of the indicators, namely that there are still many sellers who provide low prices but do not match the quality and some are even different.
H_3: Price (X3) affects Purchasing Decisions (Y)

2. Methodology

This study employs a quantitative approach with an explanatory method to analyze the relationship between product design, service quality, and price on purchasing decisions. The population in this study consists of all customers of PT Sarana Kencana Mulya. To determine the sample size, the Krejcie & Morgan (1970) table was used as a reference, which suggests that for a population size exceeding 1,000, a minimum of 100 respondents is sufficient to achieve a 95% confidence level and 5% margin of error.

A non-probability purposive sampling technique was applied, selecting respondents based on the criterion that they had purchased PT Sarana Kencana Mulya within a reasonable recent period. Data collection was conducted in July 2024, chosen as a representative month within the company's mid-year sales period, when purchasing activity is considered stable and consistent. This time frame was selected to ensure that the responses reflect current and relevant purchasing behavior without seasonal bias.

In collecting this data, researchers use data collection techniques by providing questionnaires (questionnaires), namely by distributing questionnaire sheets or questionnaires containing

several questions that the author asks the subjects of the author's research, where the subjects in the author's research are consumers of PT Sarana Kencana Mulya.

Before conducting data analysis tests and hypothesis tests, this study must meet the validity and reliability testing criteria, which are to ensure that all items in the study are declared valid and reliable for use. Then, to obtain good quality research data, classical assumption testing is also carried out, where this classical assumption test consists of a normality test, a multicollinearity test and a heteroscedasticity test.
Normality testing was performed using regression residuals. The test was conducted using the Kolmogorov-Smirnov test.

Table 1. Normality Test Result

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		100
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	4.79668160
Most Extreme Differences	Absolute	.063
	Positive	.040
	Negative	-.063
Test Statistic		.063
Asymp. Sig. (2-tailed)		.200[c,d]

Note. a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

Based on Table 1 above, the Asymp. Sig. (2-tailed) value is 0.200, with a probability greater than α = 0.05. Therefore, it can be concluded that the research data is normally distributed (Ghozali, 2021).

Table 2. Multicollinearity Test Result

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	12.990	13.304		.976	.338		
	Desain_Produk	-.064	.134	-.067	-.479	.636	.615	1.627
	Pelayanan	-.049	.310	-.022	-.159	.875	.595	1.682
	Harga	1.208	.182	.796	6.646	.000	.826	1.210

Note. a. Dependent Variable: Keputusan_Pembelian

Table 2 shows that the tolerance values for product quality, brand image, and promotion were greater than 0.1, and the Variance Inflation Factor (VIF) was less than 10. These results indicate no correlation between the independent variables (Ghozali, 2021). Therefore, the regression model was found to be valid and could be used for further testing, as it met the multicollinearity assumptions.

The heteroscedasticity test in this study can be seen through the Scatterplot

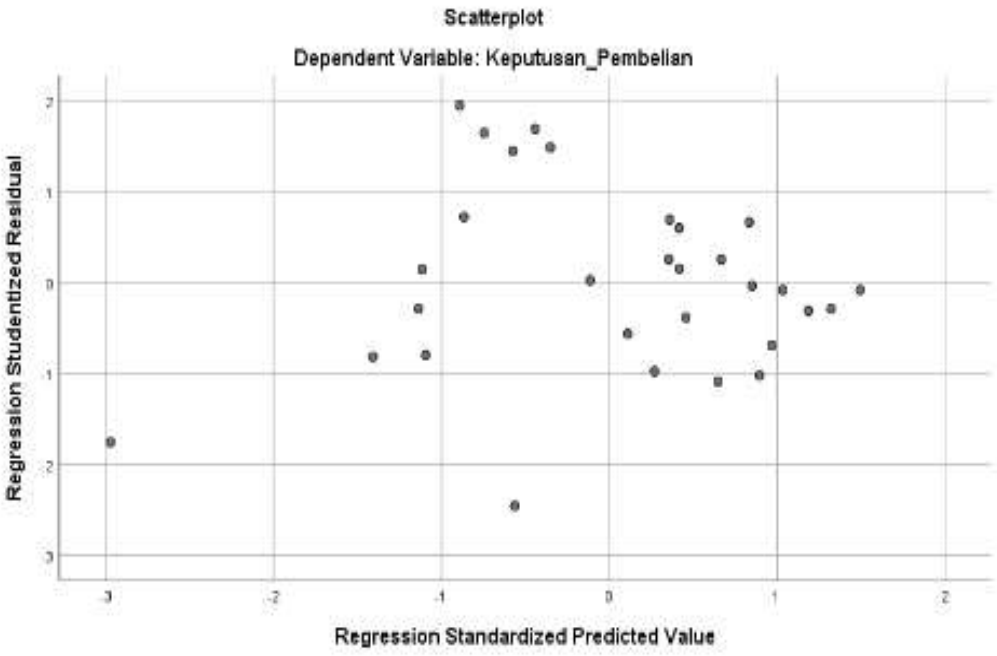


Fig. 1 Scatterplot

Based on Fig. 1 above, it can be seen that the plots are randomly distributed above and below the zero axis and do not form a specific pattern. Therefore, it can be concluded that this model does not exhibit heteroscedasticity.

Then the research data analysis test was carried out by using the correlation method, which is to see how significant the relationship between the independent variable and the dependent variable is. Researchers used the Product-Moment correlation formula. Then the coefficient of determination, which is to show the extent to which the contribution of the independent variables in the regression model is able to explain the variation of the dependent variable, and multiple regression analysis, which is used to measure how much influence between the independent variable and the dependent variable.

Table 3. *Validity and Reliability Test Result*

Variable	Item	r_{count}	r_{table}	Validity Status	Cronbach's Alpha
Product Design	X1.1	0,877	0,227	Valid	0,950
	X1.2	0,861	0,227	Valid	
	X1.3	0,779	0,227	Valid	
	X1.4	0,705	0,227	Valid	
	X1.5	0,879	0,227	Valid	
	X1.6	0,867	0,227	Valid	
	X1.7	0,665	0,227	Valid	
	X1.8	0,488	0,227	Valid	
	X1.9	0,769	0,227	Valid	
	X1.10	0,877	0,227	Valid	
	X1.11	0,861	0,227	Valid	
	X1.12	0,779	0,227	Valid	
	X1.13	0,705	0,227	Valid	
	X1.14	0,879	0,227	Valid	

Service Quality	X2.1	0,611	0,227	Valid	0,822
	X2.2	0,678	0,227	Valid	
	X2.3	0,837	0,227	Valid	
	X2.4	0,837	0,227	Valid	
	X2.5	0,569	0,227	Valid	
	X2.6	0,525	0,227	Valid	
	X2.7	0,707	0,227	Valid	
	X2.8	0,249	0,227	Valid	
	X2.9	0,563	0,227	Valid	
	X2.10	0,637	0,227	Valid	
Price	Y1	-0,151	0,227	Not Valid	0,730
	Y2	0,745	0,227	Valid	
	Y3	-0,092	0,227	Not Valid	
	Y4	0,860	0,227	Valid	
	Y5	0,801	0,227	Valid	
	Y6	0,706	0,227	Valid	
	Y7	0,654	0,227	Valid	
	Y8	0,794	0,227	Valid	

Note. All items exceed the r-table threshold (0.227), indicating construct validity. Cronbach's alpha values >0.7 show strong internal consistency.

The validity test results showed that items with a Pearson correlation value greater than the r-table value of 0.227 were declared valid. This indicates that each item in the questionnaire is positively correlated with the total score and meets validity requirements. Meanwhile, items Y1 and Y3 had Pearson correlation values smaller than the r-table value of 0.227 and were declared invalid. Therefore, it can be concluded that all questions deemed valid are worthy of further analysis.

Based on the reliability test output, the Cronbach's Alpha value is 0.700. According to Ghozali (2021), a research instrument is considered reliable if the Cronbach's Alpha value is ≥ 0.70. Therefore, with a value of 0.794, the instrument used in this study is reliable, meaning that the items used to measure each construct are internally consistent and dependable.

To answer research questions, this study also uses hypothesis testing, which consists of the T-test and F-test. The T statistical test is a partial data analysis process. This T test will show how much influence the independent variables partially have on the dependent variable, while the F test is used to test the significance of the regression model used.

3. Results and Discussion

3.1 Linear Regression Analysis

Multiple linear regression analysis aims to determine the effect of independent and dependent variables. The regression test results are as follows:

Table 4. Multiple Linear Regression and T-Test Result

Model		Unstandardized Coefficients		Standardized Coefficients			Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	12.990	13.304		.976	.338		
	Desain_Produk	-.064	.134	-.067	-.479	.636	.615	1.627
	Pelayanan	-.049	.310	-.022	-.159	.875	.595	1.682
	Harga	1.208	.182	.796	6.646	.000	.826	1.210

Note. a. Dependent Variable: Keputusan_Pembelian

Based on Table 4 above, the results of the calculation of multiple linear regression analysis, the following equation is obtained:

$$Y = (-0.064)\ X1 + (-0.049)\ X2 + 1.208\ X3 \qquad (1)$$

The regression coefficients of all independent variables have positive coefficient signs as expected. So that the above equation can be explained as follows:

a. The regression coefficient value of product design is -0.064 and is negative. This means that if the product design gets worse, the purchasing decision will decrease.
b. The regression coefficient value of service is -0.064 and is negative. This means that if the service gets worse, the purchasing decision will decrease.
c. The regression coefficient value of the price is 1.208 and is positive. This means that if the price given is getting better in the eyes of the customer, the purchasing decision will increase.

3.2 Hypothesis Test (t-test)

Hypothesis testing is used to test hypotheses about regression coefficients, namely, to find out whether the regression equation obtained can be accounted for or not. The t-test is used to determine whether the independent variables partially or individually have a real effect or not on the dependent variable. The criterion used is to compare the calculated t value and the significance level of 0.05. If the calculated t value is greater than the table value and the significance level is smaller than 0.05, then Ho is rejected and Ha is accepted (Keller, 2014).

No.	Hypothesis	t-count	Sig. (p-value)	Result
1	H1: Product Design (X1) affects Purchasing Decisions (Y)	-0.479	0.636	Not Significant (Reject H1)
2	H2: Service (X2) affects Purchasing Decisions (Y)	-0.159	0.875	Not Significant (Reject H2)
3	H3: Price (X3) affects Purchasing Decisions (Y)	6.646	0.000	Significant (Accept H3)

Note.
The threshold used is $\alpha = 0.05$.
Results are significant if $p < 0.05$ and $t\text{-}_{count} > t\text{-}_{table}$.
Based on these results, only the Price variable has a significant influence on Purchasing Decisions.

Based on Table 1, the explanation of the effect of each variable is as follows:

i. The effect of Product Design on Purchasing Decisions

The first hypothesis states that product design (X1) has an effect on purchasing decisions (Y). Based on the test results, the t-count value of the effect of product design is -0.479 and a significance value of 0.636> α 0.05. So this proves that H1 is rejected. Thus, it can be concluded that product design has no effect on purchasing decisions.

The results showed that the product design variable (X1) had no effect on purchasing decisions (Y). This means that the better the product design, it does not always increase purchasing decisions. The results of this study are also in line with research conducted by Ariella (2018), which shows that product design has no significant effect on purchasing decisions. In the regression model formed, the effect of product design on purchasing decisions is negative.

ii. The effect of service on purchasing decisions

The second hypothesis states that Service (X2) has an effect on purchasing decisions (Y). Based on the test results, the t-count value of the service effect is -0.159 and the significance value is 0.875> α 0.05, so this proves that H2 is rejected. Thus, it can be concluded that service has no effect on purchasing decisions.

The results showed that the service variable (X2) had no effect on purchasing decisions (Y). This means that good service alone is not enough to improve purchasing decisions. The results of this study are also supported by research conducted by Soedjono et al. (2019) which shows that there is no influence between services on consumer purchasing decisions

iii. The Effect of Price on Purchasing Decisions

The third hypothesis states that Price (X3) has an effect on purchasing decisions (Y). Based on the test results, the t-count value of the effect of promotion is 6.646 and the significance value is 0.000 < α 0.05, so this proves that H3 is accepted with a positive coefficient direction. Thus, it can be concluded that price has a positive and significant effect on purchasing decisions.

The results showed that the Price variable (X3) had a positive and significant effect on purchasing decisions (Y). This means that the better the price given, the more purchasing decisions will be made. The third factor influencing purchasing decisions is price. Good pricing is one of the strategies to attract consumers to buy, such as by offering attractive prizes to consumers when purchasing products. The results of this study are also supported by research conducted by Putrifasari et al. (2023) showing that price has a positive effect on purchasing decisions.

i. Simultaneous Hypothesis Test (F-test)

Hypothesis testing is simultaneously carried out to determine the significance of the influence between all independent variables (product quality, brand image, promotion) on the dependent variable (purchase decision). The following results of the F test can be seen in Table 4.9 below:

Table 5 F-test Result

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2107.233	3	702.411	29.604	.000[b]
	Residual	2277.807	96	23.727		
	Total	4385.040	99			

Note. a. Dependent Variable: Keputusan_Pembelian
b. Predictors: (Constant), Harga, Pelayanan, Desan_Produk

Based on Table 5 above, the results of the ANOVA test or F test can be seen that the calculated F value is 29.604> F table value 2.70 and a significance value of 0.000 (<0.05), which means that Ho is rejected and Ha is accepted instead (Ghozali, 2021). This shows that the product design, service and price studied simultaneously have a significant effect on purchasing decisions at the 95% confidence level.

ii. Coefficient of Determination ($\mathbf{R^2}$)

The coefficient of determination in this study is used to determine how much influence the independent variable has on the dependent variable. The following are the results of the calculation of the coefficient of determination:

Table 6: Coefficient of Determination Result

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.693[a]	.481	.464	4.871

Note. a. Predictors: (Constant), Harga, Pelayanan, Desan_Produk
b. Dependent Variable: Keputusan_Pembelian

From the test results of Table 6 above, in this study obtained Adjusted R Square is 0.464 (46.4%). This shows that product design, service and price influence purchasing decisions by 46.4%, while the remaining 53.6% is explained by other factors/variables that can influence purchasing decisions, but these variables are not included in this study.

4. Conclusion

Based on the results of data analysis, it can be concluded that among the three variables studied—product design, service quality, and price—only price has a positive and significant effect on customer purchasing decisions at PT Sarana Kencana Mulya. Both product design and service quality do not significantly influences purchasing decisions, indicating that these factors may not be primary considerations for customers in this market context.

The findings of this study offer valuable insights for the company's marketing and operational strategies. First, the significant impact of price suggests that pricing strategies should be prioritized to attract and retain customers. The company may consider implementing more competitive pricing, discount programs, or bundling offers to enhance consumer appeal.

Second, although product design and service quality did not show significant effects, these variables should not be entirely disregarded. It is possible that their influence is indirect or context-dependent. Future improvements in these areas may still support long-term customer satisfaction and brand loyalty when combined with attractive pricing.

In broader terms, this study contributes to the understanding of consumer behavior in the Indonesian electronics retail sector. The outcomes may serve as a reference for other local businesses seeking to align their marketing efforts with actual consumer preferences and strengthen their market competitiveness.

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TRUST, CLICK, COMPLY: E-FILING AS A MARKETING INSTRUMENT TO ENHANCE TAX COMPLIANCE BEHAVIOUR IN MALAYSIA

Adiebah binti Ahmad*, Norisah binti Ahmad Shaffie, Suzana binti Muhammad

Commerce Deparment, Politeknik Tuanku Sultanah Bahiyah,
09000 Kulim Hi-Tech, Kedah Malaysia

* Corresponding author e-mail address: adiebah@ptsb.edu.my

Abstract

Although approximately 90 percent of Malaysian taxpayers are using the electronic filing (e-Filing) system, the country still reported a tax revenue loss of RM6.34 billion in 2024 due to tax evasion. This highlights a gap between system utilisation and actual tax compliance. This study investigates the key predictors of tax compliance behaviour, focusing on how e-Filing can function not only as a technological tool but also as a strategic marketing instrument. Also, the role of trust in the tax authority as a mediator to improve tax compliance in Malaysia. Using multiple regression analysis demonstrated that only perceived usefulness had a direct impact on tax compliance behaviour. Mediation analysis using PROCESS Macro (Model 4) showed that trust in tax authority partially mediated the effect of perceived usefulness and fully mediated the effect of the perceived ease of use and marketing instrument. Trust emerged as a critical mediating mechanism, converting positive system perceptions and awareness efforts into compliant behaviour. These findings support the Slippery Slope Framework (SSF), the Technology Acceptance Model (TAM) theory, and the AIDA marketing model, emphasizing that user experience and trust-based communication play essential roles. By positioning e-Filing as a behavioural and marketing tool, this study highlights the need for tax authorities to adopt more integrated, user-focused strategies to enhance long-term voluntary compliance, rather than relying solely on enforcement or system efficiency.
Keywords: e-Filing; Perceived ease of use (PEOU); Perceived usefulness (PU).

1. Introduction

The rapid global shift to digitalization has significantly transformed public services and drastically changed tax administration and governance frameworks (OECD, 2022). In Malaysia, this transformation is most evident in the implementation of the electronic filing system (e-Filing), introduced by the Inland Revenue Board of Malaysia (IRBM) in 2001 for companies and in 2004 for individual taxpayers. The e-Filing system aims to improve efficiency in tax collection, reduce administrative burdens, and simplify the tax return process (IRBM, 2023). As of 2023, over 90 percent of individual taxpayers in Malaysia submitted their returns through e-Filing, indicating widespread adoption of this digital tool (Ministry of Finance [MOF], 2023). In 2024, the system was fully integrated with the MyTax portal, enhancing the accessibility, speed and security of tax services.

Despite the benefits of Malaysia's e-Filing system, which has made tax filing easier, faster and more accurate since its launch in 2006 (Ayub et al., 2024), Malaysia still struggles with tax compliance. In 2024, Malaysia lost RM6.34 billion dues to tax evasion, showing that digital tools alone are not enough to ensure compliance (Pfordten, 2024; Zainuddin, 2025). Although the e-Filing platform is widely used and user-friendly, many taxpayers especially those in Small and

Medium Enterprises (SMEs) and the gig economy continue to file late, underreport income or avoid taxes altogether (Mohd Dauh & Zainuddin, 2018; Nuraisyah & Jalil, 2023). Studies also show that taxpayer behaviour is influenced by psychological factors like perceived fairness, satisfaction with service and trust in tax authorities, not just by access to technology (Kasipillai & Abdul Jabbar, 2006; Sapiei et al., 2014).

To better understand the limitations of relying solely on technology to enhance tax compliance, the Slippery Slope Framework (SSF) proposed by Kirchler et al. (2008) provides valuable insight. According to this framework, tax compliance behaviour is influenced by two key dimensions: the power of tax authorities (i.e., their capacity to enforce compliance through audits and penalties) and the trust taxpayers place in those authorities. While technological tools like the e-Filing system have enhanced the functional aspects of tax administration, making it easier, faster and more transparent, compliance outcomes still depend on how taxpayers perceive fairness, legitimacy, and transparency of the system.

Trust in tax authorities is fostered when taxpayers feel they are treated fairly and respectfully, and when tax systems are transparent and reliable. At the same time, enforcement mechanisms such as penalties and audit threats serve to increase the perceived risk of non-compliance. An effective e-Filing system, therefore, does more than just process returns; it can promote trust by offering user-friendly access, clear communication, and transparency; and it supports enforcement by enabling real-time data tracking and digital oversight (Kirchler et al., 2014; Yussof et al., 2021). This dual function aligns with SSF, reinforcing the idea that both trust and power must work hand in hand to achieve higher levels of voluntary and enforced compliance.

2. Problem Statement

Among small business owners and self-employed workers in Malaysia, there is still a high rate of tax non-compliance, even though the growing use of the electronic filing system (e-Filing) (MoF, 2023) has shown. Despite the system's accessibility and technological readiness, easy to use, many taxpayers still purposefully fail to report their income or miss deadlines (Rahim et al., 2016). Despite its accessibility, the e-Filing system faces several obstacles. The common obstacles such as system failures at times of high traffic, cybersecurity issues, and inadequate support for users who are less literate or live in remote regions (The Star, 2023; Ramayah et al., 2008). These technical obstacles adversely the impact users' perceptions of the system's reliability and undermine their trust in the Inland Revenue Board of Malaysia (IRBM).

In addition, scepticism among taxpayers leads to low tax morale, about tax revenue spending, which further erodes voluntary tax compliance (Torgler, 2007; Nuraisyah & Jalil, 2023). Although enforcement mechanisms such as audit risk and fines exist, compliance motivated solely by fear is less sustainable in the long run (Kirchler et al., 2008). In this context, the Slippery Slope Framework (SSF) gives a valuable view in analysing compliance dynamics. Sustainable compliance increases from a careful balance between the coercive power of enforcement and the trust derived from legitimate power, which is enhanced by effective communication and service delivery (Kirchler et al., 2014).

However, to achieve optimal impact, e-Filing must be viewed not just as a digital tool but as a strategic marketing instrument that communicates value, encourages user engagement, and reinforces trust in the tax authority (Kamarulzaman & Azmi, 2010). By integrating the principles of service marketing, the system has the potential to influence both the attitudinal and behavioural components of tax compliance. The lack of trust in the tax authority, compounded by negative

user experiences with e-Filing, reveals a strategic gap: the current system underutilises its marketing potential to engage, educate, and convert non-compliant taxpayers into voluntary compliant ones. Despite growing research on e-Filing adoption and system performance, few studies have explored how e-Filing can be strategically leveraged as a marketing tool to build taxpayer trust and influence compliance behaviour. Most existing literature focuses on system usability and technical implementation, overlooking the psychological, relational, and communicative aspects that drive sustained compliance.

This study aims to investigate the potential of the e-Filing system not only as a technological solution but also as a marketing communication tool that can shape taxpayer perceptions, improve trust in the IRBM and enhance tax compliance behaviour. Specifically, the study will examine the relationship between user perception of the e-Filing system and tax compliance behaviour, explore the role of trust as a mediating factor between e-filing usage and tax compliance behaviour and evaluate the feasibility of positioning e-Filing as a strategic tool for taxpayer engagement and service marketing within the Malaysian tax administration context.

3. Literature Review

3.1 Tax Compliance Behaviour

Tax compliance behaviour refers to how well taxpayers follow tax rules, such as filing tax returns on time, reporting income honestly, and paying the right amount of tax. According to Alm (2019) and Kirchler (2007), there are two types of compliance: voluntary compliance, which happens when taxpayers willingly follow the rules because they feel it is the right thing to do, and enforced compliance, which happens because people are afraid of being caught or punished. Submitting tax returns on time shows that a person understands and respects their tax duties (OECD, 2022). Being honest about income means the taxpayer has a strong sense of fairness and integrity (Braithwaite, 2003). Paying taxes even when there is no strict enforcement shows voluntary compliance, which is often linked to trust in the government (Feld & Frey, 2007). Lastly, feeling responsible for following tax laws reflects tax morale, or a personal belief that paying taxes is important (Torgler, 2007). These behaviours together help explain how and why people choose to comply with tax rules.

3.2 Perceived Ease of Use and Tax Compliance Behaviour

Perceived ease of use refers to the degree to which an individual believes that using a system is free of effort (Davis, 1989). Studies by Ramayah and Suki (2006) and later Amin et al. (2020) show that taxpayers who perceive e-Filing systems as simple, user-friendly, and intuitive are more inclined to adopt and continue using them. If e-Filing reduces the psychological burden associated with tax filing, such as fear of making mistakes or navigating complex procedures, it is likely to improve taxpayers' confidence and reduce unintentional non-compliance (Mustapha et al., 2023).

3.3 Perceived Usefulness and Tax Compliance Behaviour

Perceived usefulness is a central component of the Technology Acceptance Model (TAM) developed by Davis (1989), which defines it as the degree to which a person believes that using a system will enhance their job performance. In the context of tax e-Filing, this refers to how much taxpayers believe e-Filing helps them file taxes faster, more accurately, and with fewer errors. Empirical studies have shown that perceived usefulness significantly influences technology adoption and, in turn, compliance behaviour (Amin et al., 2020; Wahyuni et al., 2022). When

taxpayers perceive e-Filing as valuable and efficient, they are more likely to use it consistently, which promotes compliance.

3.4 Marketing Instrument and Tax Compliance Behaviour

While traditional compliance models emphasize enforcement, behavioural marketing introduces a new lens, where communication and perception shape taxpayer behaviour. Using the AIDA Model[1], marketers can influence behaviour by constructing persuasive messages and campaigns (Kotler & Keller, 2021). In the tax context, marketing exposure includes outreach efforts such as SMS reminders, online banners, influencer partnerships, or educational videos explaining the ease and benefits of e-Filing. Research by Saad and Haniffa (2021) confirms that marketing strategies targeted at awareness and education have a significant impact on taxpayers' attitudes and compliance decisions. Hence, frequent and effective exposure to marketing campaigns related to e-Filing may positively shape taxpayers' compliance behaviour.

3.5 Trust as a Mediator

Trust in tax authorities is defined as the belief that tax institutions are honest, competent, and fair (Kirchler et al., 2008). It plays a critical mediating role between perceptions (usefulness, ease of use, and marketing) and actual compliance behaviour. According to the SSF, trust transforms potentially negative perceptions into positive intentions by reducing the perceived risk of engagement with the system. In e-government services, studies show that trust mediates the relationship between perceived system attributes and behavioural outcomes (Gefen et al., 2003; OECD, 2022). The scenario In Malaysia, the group that complies with digital systems, such as e-Filing, consists of taxpayers who trust the IRBM (Zainol et al., 2021).

This study integrated three theory/framework/model, which are SSF, TAM, and AIDA and provided a holistic framework for understanding and improving tax compliance behaviour through the e-Filing system in Malaysia. While SSF describes the psychological and institutional dimensions of compliance, TAM develops a lens on the usability and acceptance of the system, and AIDA offers practical strategies for attracting and converting users. Strategically, to get a positive influence on taxpayer behaviour, the model suggests that an effective e-Filing system must be trustworthy and user-friendly.

The conceptual framework is shown in Figure 1. The study tested the direct relationships (→) between perceived usefulness, perceived ease of use and marketing instrument with tax compliance behaviour. Additionally, it examined the indirect relationships (→) by introducing trust in the tax authority as a mediating variable between these three predictors and tax compliance behaviour.

[1] AIDA (Attention, Interest, Desire, Action) Model introduced by E. St. Elmo Lewis in late 19th century and remains widely used in marketing, advertising, and communication strategies. The classic marketing framework that describes the stages a consumer goes through before making a purchase or taking desired action.

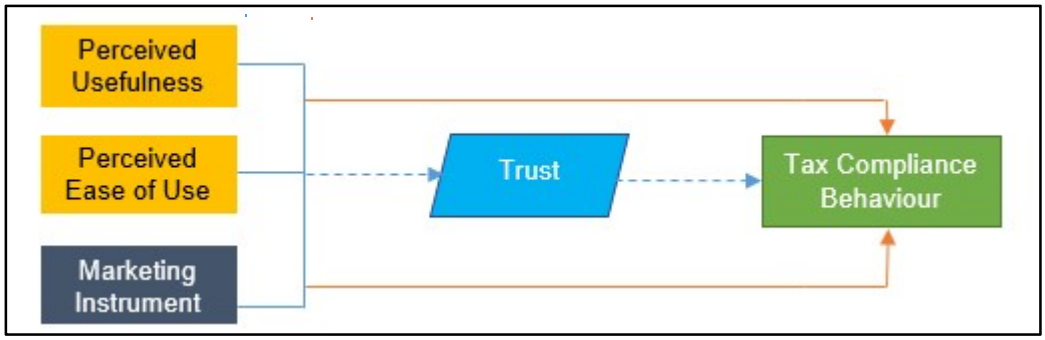


Fig 1. Conceptual Framework

4. Methodology

This study employed a quantitative cross-sectional approach to examine the effects of e-Filing perceived ease of use, perceived usefulness, and marketing instrument on tax compliance behaviour, with trust in tax authorities as the mediating variable. The sample chosen was the target population of Malaysian taxpayers who used the e-Filing system provided by the Inland Revenue Board of Malaysia (IRBM) that had over 24 million users in 2025 (IRBM, 2025). Although Krejcie and Morgan's (1970) table indicates a sample size of 384 for this population size, a stratified random sampling approach was adopted to provide proportional representation across significant subgroups such as age, sector of employment, and level of use of e-Filing, with 159 usable responses obtained using an online questionnaire in June 2025.

Data were collected using a structured questionnaire adapted from established scales in prior studies. Perceived ease of use items were drawn from Wang (2003) and Davis (1989), perceived usefulness from Davis (1989) and Ramayah et al. (2008), marketing instrument from Kamarulzaman and Azmi (2010), trust in tax authorities from Kirchler et al. (2008) and Wahl et al. (2010), and tax compliance behaviour from Wahl et al. (2010) and Bobek et al. (2007). All items were measured using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The reliability analysis generated a Cronbach's Alpha of .856, representing high internal consistency.

To conduct the analysis, this study used Statistical Package for Social Sciences (SPSS) Version 22 and PROCESS Macro Version 4.0 (Hayes, 2022). Descriptive statistics are used to capture demographic profiles. By using the Pearson correlation analysis to investigate relationships between variables, multiple regression tests identified significant predictors of tax compliance. Finally, the PROCESS Macro (Model 4) used 5,000 bootstrap samples at a 95 percent confidence level to check how trust influences the results, providing direct, indirect and total effects along with R-squared (R^2) values to assess how well the model fits.

5. Demographic Profile of Respondents

Table 1 gives the demographic distribution of the 159 respondents. Most (65.4%) were aged 40-50 years, which is to say that the sample was predominantly made up of middle-aged people. An overwhelming majority (83.0%) were females, reflecting satisfactory female representation in the sample. More than half (51.6%) of the respondents were postgraduates, reflecting a very highly educated respondent base. 83.6% of the respondents were in the public sector, which is proof of the strong representation of the public sector. Further, 93.1% e-filed using the e-Filing system over five years ago, which is proof of high levels of awareness of electronic filing of taxes. Further,

93.7% used the e-BE[2] form, reflecting that most respondents were salaried employees filing for employment income.

Table 1. Full Demographic Profile of Respondents (N = 159)

Demographic Category	Frequency (n)	Percentage (%)
Age		
Below 30 years	2	1.3%
30–40 years	24	15.1%
40–50 years	104	65.4%
Above 50 years	29	18.2%
Gender		
Male	27	17.0%
Female	132	83.0%
Highest Level of Education		
SPM	2	1.3%
Diploma	7	4.4%
Degree	62	39.0%
Postgraduate	82	51.6%
Others	6	3.8%
Types of Employment		
Government sector	133	83.6%
Private sector	17	10.7%
Self-employed	4	2.5%
Others	5	3.1%
Years using e-Filing		
1–2 years	6	3.8%
3–5 years	5	3.1%
>5 years	148	93.1%
e-Filing Type		
e-B (Business)	3	1.9%
e-BE (Employment)	149	93.7%
e-C (Company)	4	2.5%
e-P (Partnership)	2	1.3%
Others	1	0.6%

6. Findings and Discussion

To investigate the relationships between perceived ease of use (PE), perceived usefulness (PU), marketing instrument (MKT), trust in tax authority (TRUST), and tax compliance behaviour (TCB), several statistical analyses were conducted.

6.1 Correlation Analysis

Pearson correlation analysis revealed statistically significant positive relationships among all constructs at the 0.01 level (2-tailed). PE showed strong correlations with PU ($r = .798$, $p < .001$),

[2] e-BE is e-Filing for individuals who has employment income or non-business income

TRUST (r = .649, p < .001), and TCB (r = .580, p < .001). Likewise, PU was significantly associated with both TRUST (r = .649, p < .001) and TCB (r = .645, p < .001). Moderate positive correlations were observed between marketing instrument (MKT) and TRUST (r = .558, p < .001), as well as with TCB (r = .359, p < .001). TRUST itself demonstrated a strong positive correlation with TCB (r = .619, p < .001), highlighting its potential role as a mediator in the relationship between the independent variables and compliance outcomes. Table 2 presents the summary of the correlation analysis.

Table 2. Summary of Correlation Analysis

Variables	*r*	*p*-value
PE – PU	.798	< .001
PE – TRUST	.649	< .001
PE – TCB	.580	< .001
PU – TRUST	.649	< .001
PU – TCB	.645	< .001
MKT – TRUST	.558	< .001
MKT – TCB	.359	< .001
TRUST – TCB	.619	< .001

6.2 Multiple Regression Analysis (Direct Effects of PU, PE and MKT on TCB)

A standard multiple regression was conducted to examine the direct effects of perceived ease of use (PE), perceived usefulness (PU), and marketing instrument (MKT) on Malaysian tax compliance behaviour (TCB). The summary of the multiple regression analysis, as shown in Table 3, shows that the overall model was significant, $F(3, 155) = 39.75$, $p < .001$, with an $R^2 = .435$, indicating that approximately 43.5% of the variance in tax compliance behaviour was explained by the three predictors. Among the predictors, PU emerged as a significant predictor of tax compliance ($\beta = 0.455$, $\beta = .494$, $p < .001$), while PE ($\beta = 0.125$, $p = .173$) and MKT ($\beta = 0.061$, $p = .172$) were not statistically significant.

PU was the only significant direct prediction of tax compliance behaviour and these findings align with Amin et al. (2020) and Wahyuni et al. (2022), who reported that taxpayers are more likely to comply when they perceive the e-Filing system as beneficial, accurate and time-saving. The significant impact of PU underscores the practical value that e-Filing provides, supporting the core tenets of TAM (Davis, 1989), which emphasizes that system usefulness is a key determinant of user acceptance and behavioural intention.

In contrast, perceived ease of use (PE) and marketing instrument (MKT) did not show statistically significant direct effects on compliance in the regression model. This suggests that while ease and promotional effects may enhance user experience and awareness, they do not independently compel taxpayers to comply unless mediated by deeper psychological factors, such as trust. This is consistent with findings of Mustapha et al. (2023), who noted that ease of system use increases confidence but does not directly compliance without other supporting factors.

Table 3. Summary of Multiple Regression Analysis

Predictors	β	SE	β	t	p-value	Result
PE	0.055	0.089	0.063	0.620	.536	Not significant
PU	0.351	0.092	0.381	3.804	< .001	Significant
MKT	–0.008	0.046	–0.012	–0.171	.864	Not significant
TRUST	0.241	0.061	0.338	3.953	< .001	Significant

6.3 Mediation Analysis (Indirect Effects through Trust in Tax Authority)

The mediation analysis using PROCESS Macro (Model 4) revealed a more nuanced understanding as shown in Table 4. To test the mediating effect of trust in the tax authority, PROCESS Macro Model 4 (Hayes, 2022) was employed using 5,000 bootstrap samples. Initially, PE (β = 0.5101), PU (β = 0.5944), and MKT (β = 0.2343) were all significantly associated with tax compliance. When trust was introduced as a mediator, the direct effects of PU (β = 0.3875, R^2 = .4856) remained significant but were reduced, indicating partial mediation. However, the indirect effect of PE (β = 0.2710, R^2 = .4381) and MKT (β = 0.0127, p = .7976, R^2 = .3833) became significant, compared to the direct effect, which indicates full mediation.

All three models demonstrated significant indirect effects via trust: PE (β = 0.2390, 95% CI [0.1253, 0.3565]), PU (β = 0.2069, 95% CI [0.0917, 0.3190]), and MKT (β = 0.2216, 95% CI [0.1467, 0.3139]). These findings confirm that trust in tax authority is a critical mechanism through which digital system perceptions and tax awareness translate into compliant behaviour. While PU had both direct and indirect effects, PE and MKT influenced tax compliance only indirectly, suggesting that awareness efforts alone may not be effective unless they successfully build institutional trust.

These findings are consistent with Kirchler et al. (2008) and Gefen et al. (2003), who argued that trust reduces perceived risks and uncertainties in interactions with government systems. Similarly, Zainol et al. (2021) found that trust in the Inland Board of Malaysia (IRBM) significantly predicts voluntary compliance, especially in digital contexts. The full mediation effect of MKT also aligns with Saad and Haniffa (2021), who found that awareness campaign, Short Message Service (SMS) reminders and digital outreach are only effective when they enhance institutional credibility and trustworthiness. In other words, perceived ease of use of the e-Filing and marketing instruments is powerful not because of their roles alone, but because of the trust they help cultivate.

Table 4. Summary of Mediation Analysis (PROCESS Model 4)

Model	Direct Effect *(β)*	Indirect Effect *(β)*	95% Boot CI*	R^2	Mediation Type
PE → TRUST → TCB	0.2710	0.2390	[0.1253, 0.3565]	0.4381	Partial
PU → TRUST → TCB	0.3875	0.2069	[0.0917, 0.3190]	0.4856	Full
MKT → TRUST → TCB	0.0127	0.2216	[0.1467, 0.3139]	0.3833	Full

Note: * Bootstrap Confidence Intervals (Boot CI)

Overall, the present study investigated the influence of perceived ease of use (PE), perceived usefulness (PU) and marketing instruments (MKT) on tax compliance behaviour (TCB) in Malaysia, with a particular focus on the mediating role of trust in tax authority (TRUST). The findings provide empirical support for the integration of the Technology Acceptance Model (TAM), the Slippery Slope Framework (SSF), and the AIDA model, offering a more holistic understanding of e-Filing compliance behaviour.

Marketing influence plays a major role in enhancing trust that leads to influence compliance. When other predictors were included, it had a meaningful indirect impact through trust, even though the marketing instrument (MKT) did not show a direct effect on tax compliance behaviour. The results emphasize that certain variables may not appear significant in direct analyses but still shape outcomes through indirect channels. Therefore, including mediating factors in behavioural research is crucial, as traditional regression approaches alone might overlook these underlying mechanisms.

7. Implication, Limitation and Future Research

7.1 Theoretical and Practical Implications

The Slippery Slope Framework (SSF) proposed by Kirchler et al. (2008) has been supported by this, which emphasizes the pivotal role of trust in tax authorities in promoting voluntary tax compliance. Among the key predictors examined were perceived ease of use (PE), perceived usefulness (PU), and marketing instrument (MKT); only PU maintained a significant direct effect on tax compliance behaviour (TCB) in the presence of trust. In contrast, MKT influenced compliance only indirectly through trust, while PE exhibited both direct and indirect effects. The findings also underscore that trust is not merely a by-product but a necessary mechanism through which digital tax services and outreach campaigns translate into actual compliance behaviour.

Practically, these findings have strong implications for the Inland Revenue Board of Malaysia (IRBM) and other taxation agencies. While enhancements in perceived ease of use and perceived usefulness are important, their influence on compliance becomes stronger when paired with efforts that are able to gain public trust. Therefore, marketing Instruments should not only play a role in disseminating information, but they should to be strategically developed to strengthen perceptions of transparency, fairness, professionalism, and ethical governance. Without trust, the implication occurs when taxpayer behaviour is minimally affected directly by campaigns, regardless of their scale or frequency without trust. Hence, policymakers should prioritize trust building as a core objective in digital tax transformation efforts.

7.2 Limitations and Directions for Future Research

Despite yielding meaningful insights, the study has certain limitations. The issue of the cross-sectional nature of this study constrains the ability to infer causal relationships between variables. Although the PROCESS mediation analysis identified significant indirect effects, the temporal sequence of these associations remains uncertain. To confirm the directionality and causal mechanisms underlying the observed mediation effects, future research would benefit from adopting longitudinal or experimental research designs. Moreover, the study focused primarily on trust as a mediator and still has power as mediator, leaving potential moderators unexplored. Variables such as perceived fairness, risk perception, cultural values, or social norms may moderate the relationship between trust and tax compliance, offering a more nuanced understanding of compliance behaviour. By using this model across diverse populations may uncover varying behavioural patterns, particularly among self-employed individuals or younger taxpayers with limited experience using e-Filing systems. Examining these groups could further extend the generalisability of the findings and provide deeper insights into how user characteristics influence compliance behaviour in digital tax environments.

8. Conclusion

In conclusion, this study offers valuable insights into the factors influencing tax compliance behaviour in the Malaysian context based on the e-Filing system. While only perceived usefulness showed a direct impact in standard regression, mediation analysis revealed that perceived ease of use, marketing instrument, and perceived usefulness all influence compliance indirectly through trust in the tax authority. This shows that dimension trust plays a very important role in changing positive experiences and awareness into compliant behaviour. The findings emphasize that relying only on direct models as multiple regression lead to miss important behavioural pathways.

By including trust as a mediator, the study shows how user experience, usefulness, and marketing instruments can lead to higher tax compliance behaviour. Beyond its technical role, e-Filing can act as a marketing instrument because this system that is user-friendly, secure, and effectively promoted contributes significantly to building trust and enhancing public perception, thereby encouraging voluntary tax compliance behaviour.

The findings also lend support to the AIDA model, indicating that marketing instruments play a role in capturing attention and shaping taxpayer behaviour. Furthermore, the partial mediation effect of trust aligns with the Slippery Slope Framework (SSF), which suggests that trust are essential for fostering tax compliance behaviour. These results reinforce the applicability of the Technology Acceptance Model (TAM) and behavioural marketing principles in understanding tax compliance behaviour. Overall, the study proposes Inland Revenue Board of Malaysia (IRBM) can used the e-Filing system not only be use as a digital service but also as a behavioural intervention. To support sustainable compliance, tax authorities should prioritise enhancing perceived ease of use, raising public awareness, and fostering trust through transparent and accessible digital platforms. The further research can concentrate on creating a campaign to boost the tax compliance behaviour by using a marketing communication such as advertisement, public relation, service promotion or internet marketing.

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DESIGN AND EVALUATION OF A LOW-COST SEMI-AUTOMATED PLANT WATERING DEVICE FOR SMALL-SCALE AGRICULTURE

Noor Rafidah binti Md Osman*, Siti Rozakiyah Assurin binti Hassan, Kalsom binti Salleh, Abdul Muhaimin bin Azli

Mechanical Engineering Department, Tuanku Sultanah Bahiyah Polytechnic, 09090 Kulim Hi-tech, Kulim, Kedah, Malaysia

*Corresponding author e-mail address: rafidah@ptsb.edu.my

Abstract

Efficient crop irrigation remains a critical challenge for small-scale farmers, particularly in rural or resource-limited settings. This paper presents the design and evaluation of a low-cost, semi-automated plant watering device aimed at improving irrigation efficiency and reducing manual labor in agricultural practices. The system integrates a submersible pump, a lead-acid rechargeable battery, and an adjustable nozzle system to distribute water across multiple planting beds simultaneously. Field trials demonstrated the device's ability to irrigate four rows of crops within five minutes, significantly reducing time and effort compared to manual watering methods. With a total build cost under RM300 and the ability to operate on uneven terrain, the device provides a practical and affordable alternative to conventional irrigation tools. This innovation highlights the potential of low-cost mechanization to support sustainable agriculture among smallholders and offers a scalable foundation for further development, including future integration with smart farming technologies.
Keywords: Low cost watering device; Small scale agriculture; Semi automated watering device.

1. Introduction

Agriculture is still a very important sector for food supply and economic growth, especially in developing countries where many people rely on farming for their income (Gomina et al., 2024). Watering plants is an important task in farming. It helps plants grow well and produce good results. Even though farming technology has improved, many small farmers still use traditional methods to water their crops, such as using a knapsack sprayer or a water hose. These methods are cheap and simple, but they often waste water, take a lot of time, and are physically tiring. They can also lead to poor crop growth if the watering is not done evenly.

In Malaysia, there are many types of irrigation systems sold online and in agricultural shops, such as drip kits, sprinkler systems, and motorized watering tools. However, most of these systems are expensive, need electricity or water pressure, and are made for big farms or home gardens with flat land. Some also require technical skills to install and maintain. Because of this, many small farmers still water their crops by hand using hoses or knapsack sprayers. These methods are tiring, take a lot of time, and often waste water. This project aims to solve these problems by creating a simple, low cost watering device that is easy to use, even on uneven land.

Today, the world is facing problems like climate change, water shortages, and higher labor costs. Because of this, farmers need better ways to water their crops that save water and reduce hard work. According to the Food and Agriculture Organization (FAO), about 70% of the world's

freshwater is used for farming. So, it is important to use water wisely to avoid waste and ensure enough supply in the future.
One good solution is to use a semi-automated irrigation system. This type of system is a mix between manual watering and expensive fully automated systems. It is still affordable and easier to use, especially for small farmers. These systems may include tools like timers, soil moisture sensors, or water tanks that work by gravity. They help reduce the amount of manual labor and ensure that plants receive the right amount of water more evenly. Liyanage et al. (2022) developed a low-cost, semi-automated irrigation system that is affordable, portable, and helps researchers study plant responses to drought more efficiently.

Some research has shown that these systems can help increase crop yields and save time. For example, Noviyanto et al. (2024) and Desai et al. (2023) found that low-cost automatic irrigation systems help save water and improve crop growth, especially during dry seasons. Another study by Anshori, Riyanto, and Suradal (2020) showed that a semi-automated crop sprayer can be a powerful tool to solve irrigation problems and make it easier for farmers to grow rice in the second season.

Also, with the growing use of renewable energy like solar power, these systems can now be used in rural areas without electricity. Using technology like this also supports global goals such as saving water and improving farming methods.

The following sections detail the design process, component selection, fabrication, field testing, and performance evaluation of the device, highlighting its potential contribution to low-cost agricultural innovation.

1.1 Problem Statement

Smallholder farmers, particularly in rural and suburban agricultural communities, often face significant limitations in adopting modern irrigation technologies. Manual watering techniques such as carrying heavy water containers or using handheld hoses are still widely practiced. These methods are not only labor-intensive but also inefficient, leading to inconsistent water distribution across crop rows. In the long term, such inconsistencies may compromise crop growth, reduce yield quality, and contribute to physical strain and injury for the farmers, especially among older individuals or those with limited mobility.

Another common issue lies in the terrain of small farms, where uneven surfaces and varied crop heights create challenges in delivering water evenly and precisely. Conventional commercial irrigation systems are typically designed for large-scale, flat-surface farming and often require technical expertise, stable infrastructure, and a high capital investment, factors that are incompatible with the needs and constraints of small-scale or part-time farmers.

These challenges underscore the need for a low-cost, mobile, and semi-automated irrigation solution that is easy to use, adaptable to uneven terrain, and capable of increasing watering efficiency while reducing labor dependency.

1.2 Objectives

This study aims to address the identified challenges by developing a low-cost, semi-automated

irrigation system tailored for small-scale agricultural use. The specific objectives of the project are as follows:

i. To design and fabricate a semi-automated plant watering device capable of irrigating multiple rows of crops simultaneously.
ii. To evaluate the time efficiency of the semi-automatic watering device compared to traditional manual watering methods.
iii. To measure the number of plants that can be watered within a fixed time using both methods.

2. Methodology

2.1 Design Concept

The proposed irrigation device was conceptualized to be portable, semi-automated, and operable in uneven terrain, suitable for small agricultural plots. Three design alternatives were initially developed and evaluated based on criteria such as stability, ease of movement, spraying coverage, cost, and energy efficiency. A design matrix was used to score each alternative, with the final concept selected based on the highest total performance rating.

The final design consists of a main chassis constructed from stainless steel hollow tubing, a water storage tank with a 20-liter capacity, an electric water pump, and adjustable nozzles mounted on telescopic arms. The system is mounted on wheelbarrow-type wheels for easy movement across different surfaces.

2.2 Component Selection

The device was built using low-cost but durable components readily available in the local market. Key components include:

i. Submersible Bilge Pump (108 W): Selected for its compact size, strong suction capabilities, and ability to handle various water conditions.
ii. Lead Acid Battery (12V, 7.2 Ah): Chosen for affordability and sufficient power output to support continuous irrigation for up to 4 hours.
iii. Adjustable Nozzles (Full Cone Type): To ensure uniform water distribution across rows, with coverage optimized for four planting beds simultaneously.
iv. Steel and Aluminium Frame: Stainless steel tubes and aluminium rods were used to provide strength while minimizing weight for portability.
v. Wheelbarrow-Type Rubber Tires: Selected for their traction and stability on uneven or unpaved agricultural surfaces.

2.3 Fabrication Process

The fabrication process was carried out in five main stages:

i. Measurement and Cutting
All structural elements, including the base frame and vertical supports, were measured and cut using power tools to fit the designated dimensions (90cm length × 50cm width). Figure 1 below shows one of the measurement processes of the metal plate before undergoing the cutting process.



Fig. 1. Measurement and marking process

ii. Welding and Frame Assembly

The main chassis was welded and reinforced with aluminium brackets. Adjustable arms for the nozzles were attached using steel hinges to allow vertical flexibility (40–70 cm height range). The welding process is used on the metal handle and the project frame using MIG welding, as shown in Figure 2.



Fig. 2. Welding work on the project frame

iii. Component Integration

The water pump, tank, and battery were securely mounted onto the frame. Electrical wiring was routed and insulated to prevent moisture interference. Water lines were connected from the tank to the pump and distributed to the nozzles via PVC tubing. The integration process was carried out as shown in Figure 3.



Fig 3. The component integration process was carried out with proper insulation and tubing to ensure efficient operation

iv. Finishing and Safety Checks
All sharp edges were ground smooth, and the system was painted for corrosion protection. The battery compartment was enclosed with a plastic cover to ensure safety. Figure 4 shows one of the finishing processes carried out, which is the grinding of surfaces and sharp edges on the project.



Fig.4. Grinding process of a sharp edge

v. Testing and Adjustment
Initial functional testing was conducted to verify water output rate, range of coverage, and battery performance. Adjustments were made to improve nozzle alignment and flow consistency.

2.4 Operation Principle

Once activated, the pump draws water from the tank and channels it through the system of nozzles mounted on adjustable vertical rods. The design enables simultaneous irrigation of four crop rows with a flow rate sufficient to complete watering within five minutes per cycle. The unit can be manually pushed and repositioned as needed, making it highly adaptable for small field operations.

3. Results and Analysis

3.1 Irrigation Efficiency

Field tests were conducted to evaluate the operational effectiveness of the device in a simulated agricultural plot measuring 30 × 18 meters. The primary performance metric was the time taken to water four planting beds per cycle below. The irrigation performance of the system across multiple test cycles is summarized in Table 1, indicating consistent coverage of four rows with slight variations in completion time.

Table 1. Irrigation Performance Based on Time and Coverage per Test Cycle

Test Cycle	Time to complete Irrigation	Number of rows covered
Test 1	4 min 30 sec	4
Test 2	4 min 45 sec	4
Test 3	5 min	4
Test 4	4 min 40 sec	4

The average time required to irrigate four rows of crops was approximately 4 minutes and 44 seconds, a substantial improvement compared to conventional manual watering methods, which may exceed 20 minutes for similar coverage. Figure 5 shows the design of a low-cost semi-automated plant watering device for small-scale agriculture.



Fig. 5. The design of a low-cost semi-automated plant watering device for small-scale agriculture.

3.2 Battery Endurance and Pump Performance

The selected 12V lead-acid battery (36 Ah) powered the device for an estimated continuous operation of up to 4 hours on a full charge. The submersible pump maintained consistent pressure and water flow, with minimal performance drop over extended use.

Flow Rate Observed: ~5-7liters per minute
Pump Wattage: 108W
Effective Coverage Radius: ~1.5 meters per nozzle

These specifications confirm that the system is capable of supporting continuous agricultural activity for several cycles without requiring frequent battery recharging.

3.3 Cost Analysis

A breakdown of the material and component costs is shown in Table 2 below:

Table 2. Estimated cost of component and material

Component	Cost (RM)
Stainless steel and mild steel frame	55.00
Water pump (submersible)	155.00
Lead-acid battery	36.90
Plastic water tank (20L)	25.00
Nozzles & hoses	20.00
Tires & rims	30.00
Misc. parts (bolts, wiring, paint)	25.00
Total Estimated Cost	RM 296.90

The total cost of under RM300 makes this solution highly affordable compared to commercial motorized irrigation systems, which typically range from RM1,000 to RM3,000.

4. Discussion

The development of a semi-automated plant watering device demonstrates how simple, low-cost engineering solutions can address real-world challenges in agriculture, particularly among smallholders. The significant reduction in irrigation time, from over 20 minutes to less than 5 minutes per cycle, suggests substantial time savings for farmers who manually water multiple rows of crops daily. The device's battery-operated system eliminates the need for fuel or an external power supply, aligning with sustainable and eco-friendly agricultural practices. The use of a submersible pump and full cone nozzles ensures consistent water distribution, which is vital for maintaining plant health and achieving uniform growth. Additionally, the adjustability of the nozzle arms accommodates varying crop heights, a common issue in diverse planting layouts.

The mobility of the system across uneven terrain further supports its practicality for rural or semi-rural applications, where flat, structured fields are rare. Despite its simplicity, the design integrates key ergonomic and safety considerations, such as a covered battery compartment, corrosion-resistant materials, and an easy-to-handle frame.
However, some limitations were observed. The manual repositioning of the device between irrigation zones still requires minimal physical effort, which may be a concern for older users. Furthermore, the battery's charging time and limited lifespan suggest the need for periodic maintenance. These issues present opportunities for future improvement, such as the integration of solar-powered charging systems or the addition of motorized mobility.

Overall, this project validates the idea that frugal innovation in agricultural tools can meaningfully contribute to both farm productivity and farmer well-being, especially in underserved communities.

5. Conclusion

This study successfully demonstrates the design, fabrication, and evaluation of a low-cost, semi-automated irrigation device tailored for small-scale farming. The device proved capable of delivering uniform watering to multiple crop rows in a significantly reduced time frame, while operating reliably over uneven terrain. With a total production cost under RM300, the system represents a highly affordable alternative to commercial irrigation equipment.

The positive results highlight the feasibility of implementing low-tech yet functional innovations to support sustainable agriculture. Moving forward, further development of this system may include the integration of smart irrigation features, such as soil moisture sensing, solar power, and automated scheduling, making it even more relevant in the context of smart farming and agro-technology.

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ISU DAN CABARAN PEMBELAJARAN SECARA ATAS TALIAN BAGI KURSUS MATEMATIK: SATU KAJIAN LITERATUR

Faridah binti Haji Ismail*, Zuraini binti Ibrahim, Maziah binti Omar

Mathematics, Science and Computer Department, Tuanku Sultanah Bahiyah Polytechnic, 09000 Kulim Hi-Tech Park, Kedah, Malaysia

*Corresponding author e-mail address: faridah@ptsb.edu.my

Abstrak

Kajian ini dijalankan bertujuan untuk meneliti isu-isu berkaitan pembelajaran matematik secara atas talian. Berdasarkan kajian ini, fokus utama adalah untuk untuk mengenal pasti isu, cabaran dan keberkesanan pelaksanaan pengajaran dan pembelajaran (PdP) matematik melalui e-pembelajaran. Bagi mendapatkan input yang sahih dan tepat, kajian ini menggunakan pendekatan kajian literatur yang mana hasil dapatan kajian diperoleh melalui penelitian terhadap sumber-sumber seperti jurnal, tesis dan laporan kajian terdahulu. Hasil daripada penelitian yang telah dilakukan terhadap sumber-sumber tersebut, didapati bahawa pelajar lebih cenderung memilih pembelajaran secara bersemuka berbanding atas talian disebabkan faktor capaian internet dan keupayaan kendiri. Namun begitu, persepsi pelajar terhadap PdP matematik atas talian adalah positif apabila disokong dengan penggunaan platform yang sesuai seperti Telegram serta pendekatan pedagogi yang menarik seperti model flipped learning. Pelbagai cabaran turut dikenalpasti termasuk isu teknologi, pedagogi, tekanan emosi, kekangan alat bantu mengajar dan kemahiran digital dalam kalangan guru dan pelajar. Berdasarkan dapatan, beberapa cadangan penambahbaikan dikemukakan, antaranya pelaksanaan pendekatan pembelajaran campuran (blended learning), latihan berterusan dalam penggunaan teknologi pengajaran, integrasi kecerdasan buatan (AI) secara efektif serta penambahbaikan sokongan institusi Pendidikan terhadap infrastruktur digital. Kajian ini memberikan implikasi penting terhadap usaha memperkasakan PdP matematik dalam talian ke arah yang lebih berkesan, fleksibel dan inklusif.
Keywords: Matematik; Pembelajaran; Atas Talian.

1. Pengenalan

Matematik merupakan asas dalam kebanyakan bidang pengajian sama ada di peringkat rendah, menengah mahupun di peringkat pengajian tinggi. Ia sering dianggap mencabar disebabkan oleh sifatnya yang abstrak dan memerlukan pemahaman secara mendalam serta bimbingan yang berterusan.

Perkembangan teknologi pendidikan dan peralihan mendadak kepada pembelajaran atas talian akibat pandemik COVID-19 telah mengubah secara menyeluruh pendekatan pengajaran dan pembelajaran di institusi pengajian tinggi (IPT), khususnya dalam subjek yang mencabar seperti Matematik. Pembelajaran Matematik menuntut interaksi aktif, pemahaman mendalam terhadap konsep abstrak serta amalan latihan berstruktur.

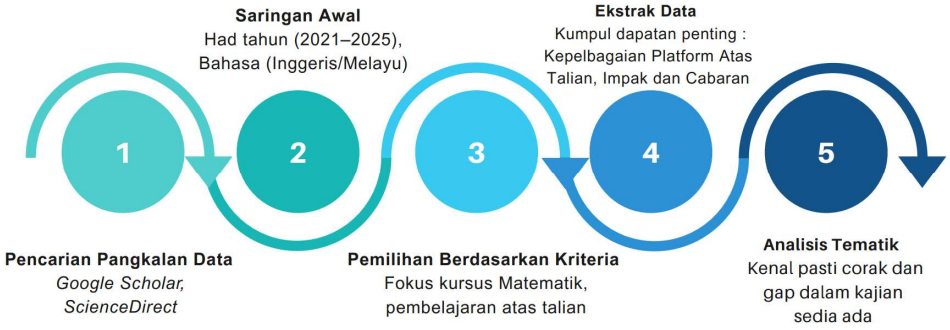
Kajian oleh Jafar et al. (2022) menunjukkan bahawa ketidaksamarataan capaian kepada peranti dan internet masih menjadi isu besar di Malaysia, terutamanya di kawasan luar bandar. Pelajar di Sabah, Perlis dan Melaka dilaporkan berdepan kesukaran mengakses platform e-pembelajaran secara stabil, yang akhirnya menjejaskan keberkesanan pembelajaran Matematik. Dalam masa yang sama, pensyarah pula menghadapi tekanan menyesuaikan kaedah penyampaian kepada pendekatan digital, termasuk isu kekurangan interaksi dua hala antara

pensyarah dan pelajar semasa sesi pembelajaran.

Selain cabaran teknikal dan logistik, aspek pedagogi dan kesediaan guru juga memainkan peranan penting. Menurut Talib, Nasri dan Mahmud (2024), ramai guru Matematik masih berada pada tahap awal dalam penggunaan teknologi sebagai alat pedagogi utama. Hal ini menyebabkan aktiviti pembelajaran menjadi terlalu berfokuskan penghantaran bahan dan kurang elemen penglibatan aktif serta penyesuaian kandungan secara digital.

Walaupun terdapat pelbagai usaha penambahbaikan dari segi penggunaan sistem pengurusan pembelajaran (LMS), gamifikasi dan aplikasi visual interaktif, pelaksanaan yang berkesan masih memerlukan pendekatan menyeluruh dan sokongan institusi (Jaffar et al., 2022). Oleh itu, adalah penting untuk menjalankan kajian literatur yang sistematik bagi mengenal pasti secara mendalam isu dan cabaran pembelajaran Matematik secara atas talian berdasarkan bukti empirikal sedia ada. Justeru itu, penilaian secara teliti terhadap pelaksanaan pembelajaran secara maya bagi kursus matematik amat penting kerana ia akan membantu dalam memastikan kualiti pembelajaran matematik menjadi lebih baik dan bermakna.

2. Metodologi



Rajah 1: Carta Alir langkah-langkah Kajian Literatur

Kajian ini telah dilaksanakan dengan menggunakan pendekatan kualitatif melalui kajian literatur secara sistematik. Langkah-langkah kajian dipermudahkan dalam bentuk carta alir pada Rajah 1. Pendekatan Kajian Literatur Secara Sistematik (Systematic Literature Review - SLR) digunakan bagi meneliti secara terperinci dapatan daripada kajian-kajian lepas yang memfokuskan kepada pembelajaran kursus Matematik secara atas talian. Proses SLR ini dijalankan melalui lima langkah utama iaitu pencarian sumber rujukan melalui pangkalan data, proses saringan awal, pemilihan sumber rujukan mengikut kriteria, mengekstrak hasil dapatan kajian lepas yang telah dipilih dan membuat analisis tematik untuk mendapatkan dapatan dan rumusan yang berkaitan.

Langkah pertama melibatkan proses pencarian artikel dalam pangkalan data terpilih, iaitu *Google Scholar* dan *ScienceDirect*. Kedua-dua pangkalan data ini dipilih kerana mengandungi koleksi artikel jurnal ilmiah yang luas dan mempunyai pengiktirafan antarabangsa.

Langkah kedua ialah saringan awal yang dijalankan berdasarkan dua kriteria utama iaitu tahun penerbitan dan Bahasa penerbitan. Dalam kajian ini artikel yang dipilih adalah antara tahun 2021 hingga 2025. Ini bagi memastikan hanya kajian terkini sahaja yang diambil kira manakala bahasa penerbitan dihadkan kepada artikel dalam Bahasa Melayu dan Bahasa Inggeris sahaja. Artikel

yang tidak memenuhi syarat ini akan dikeluarkan daripada senarai kajian. Kajian ini melibatkan sebanyak 20 penerbitan dari pelbagai artikel, laporan kajian serta jurnal.

Langkah ketiga adalah pemilihan artikel berdasarkan kriteria kandungan. Hanya artikel yang memberi fokus kepada kursus Matematik dan membincangkan pembelajaran secara atas talian akan disaring masuk untuk dianalisis. Kriteria ini penting bagi menjamin kesesuaian kajian dengan objektif penyelidikan yang dijalankan.

Langkah keempat ialah proses ekstraksi data. Dalam langkah ini, maklumat penting daripada setiap artikel terpilih dikumpulkan dan dikodkan. Antara data yang dikumpul termasuklah dari aspek kepelbagaian platform atas talian, impak penggunaan platform digital serta permalahan dan cabaran dalam pengendalian pembelajaran matematik melalui mod digital.

Akhir sekali, langkah kelima melibatkan analisis tematik. Analisis ini dijalankan untuk mengenal pasti tema-tema utama, isu-isu berulang, serta jurang (gap) dalam dapatan kajian terdahulu. Hasil analisis ini kemudiannya digunakan untuk merumuskan penemuan utama dan mencadangkan arah tuju kajian baharu yang lebih berfokus dan menyeluruh.

3. Dapatan dan Perbincangan

Secara keseluruhan, kajian literatur ini memperkukuhkan hasil dapatan kajian lain yang menyatakan bahawa pembelajaran atas talian bagi subjek matematik memerlukan pendekatan pedagogi yang lebih inovatif dan praktikal. Selain itu, keperluan infrastruktur digital yang stabil serta tahap kesediaan pelajar dan pensyarah dalam menghadapi perubahan kaedah pembelajaran merupakan antara isu yang turut penting untuk dibincangkan. Jadual 1 menunjukkan hasil dapatan kajian yang telah dilakukan oleh para penyelidik berkaitan pembelajaran secara stas talian bagi kursus matematik.

a) Jadual 1. Perbandingan Dapatan Kajian (Kepelbagaian Platform Atas Talian)

Keterangan Isu	Dapatan	Cadangan	Sumber
Pemilihan platform PdP oleh pelajar	Pelajar lebih cenderung memilih PdP secara semuka kerana isu capaian internet (25%)	Pemilihan platform digital yang sesuai untuk pelajar	Alias & Mohamed (2021)
Persepsi pelajar terhadap PdP matematik atas talian	Tahap persepsi tinggi, Telegram lebih disukai berbanding Google Classroom	Bengkel PdP atas talian dijalankan secara berkala	Abd Latib et al. (2021)
Cabaran pelajar pascasiswazah matematik belajar atas talian	Pelajar lebih suka bersemuka dan tidak mahu sambung semester atas talian	Guna pendekatan blended	Denbel (2023)
Flipped learning model dalam PdP matematik	Disukai oleh pelajar bukan STEM, lebih baik dari kaedah tradisional	Struktur konsisten, bahan pelbagai, aktiviti interaktif	Staddon (2022)

Perkembangan teknologi digital dalam PdP matematik	Blended learning sesuai untuk pelajar berdikari & fleksibel	Bangunkan pedagogi baharu berasaskan AI	Engelbrecht & Borba (2024)
Penggunaan AI dalam kelas matematik dan sains	ChatGPT bantu penglibatan pelajar tapi isu bahasa dan ketepatan	Integrasi berkesan AI dalam PdP	Taani & Alabidi (2024)
Pembelajaran matematik menggunakan chatbot	Prestasi sama, tapi pelajar kurang yakin selepas tiada sokongan chatbot	Reka bentuk chatbot berasaskan maklum balas pengguna	Cheng et al. (2024)

Dalam konteks pemilihan platform pengajaran dan pembelajaran (rujuk Jadual 3.1), pelajar lebih cenderung memilih PdP secara bersemuka berbanding atas talian disebabkan isu capaian internet yang tidak memuaskan (Alias & Mohamed, 2021). Walaupun begitu, persepsi pelajar terhadap PdP matematik atas talian berada pada tahap yang tinggi, dengan aplikasi Telegram lebih disukai berbanding Google Classroom. Justeru, adalah disarankan agar bengkel PdP atas talian dilaksanakan secara berkala bagi memastikan pelajar dan pensyarah tidak ketinggalan dalam penggunaan teknologi semasa (Abd Latib, Edrusi, & Muhamad, 2021). Bagi pelajar pascasiswazah dalam bidang matematik pula, mereka menunjukkan kecenderungan untuk mengikuti pembelajaran secara bersemuka dan kurang berminat untuk meneruskan semester secara atas talian, justeru pendekatan pembelajaran berasaskan kaedah campuran (blended) disarankan (Denbel, 2023). Selain itu, model flipped learning didapati memberi kesan positif dalam kalangan pelajar bukan STEM kerana pendekatan ini dianggap lebih berkesan berbanding kaedah tradisional. Oleh itu, struktur pengajaran perlu konsisten, disertai bahan pembelajaran pelbagai bentuk serta aktiviti interaktif yang mampu menarik minat pelajar (Staddon, 2022). Seiring perkembangan teknologi digital, pendekatan pembelajaran campuran juga amat sesuai untuk pelajar yang berdikari dan mengutamakan fleksibiliti. Ini mendorong kepada keperluan membangunkan pedagogi baharu yang berasaskan kepada teknologi kecerdasan buatan (AI) (Engelbrecht & Borba, 2024). Penggunaan AI seperti ChatGPT turut menunjukkan potensi dalam meningkatkan penglibatan pelajar dalam pembelajaran matematik dan sains, walaupun cabaran berkaitan ketepatan respons dan halangan bahasa masih wujud. Oleh itu, strategi integrasi AI dalam PdP perlu dirancang secara berkesan (Taani & Alabidi, 2024). Dalam kajian berkaitan penggunaan chatbot dalam pembelajaran matematik, dapatan menunjukkan prestasi pelajar adalah setara dengan kaedah petunjuk tradisional. Namun begitu, pelajar menunjukkan penurunan keyakinan selepas ketiadaan sokongan chatbot. Justeru, reka bentuk chatbot yang berasaskan maklum balas pengguna disarankan agar dapat memenuhi keperluan pelajar dalam konteks pembelajaran dalam talian (Cheng, Croteau, Baral, Heffernan, & Heffernan, 2024).

b) Jadual 2. Perbandingan Dapatan Kajian (Kajian Impak)

Keterangan Isu	Dapatan	Cadangan	Sumber
Kesan PdP dalam talian terhadap pencapaian Matematik Kejuruteraan Elektrik	Pencapaian pelajar lebih baik secara bersemuka	Tingkatkan kemahiran pensyarah dalam ICT dan penilaian atas talian	Ahmad & Bakar (2021)

Impak PdP atas talian terhadap pelajar Matematik UiTM	Faktor masa paling memberi kesan, diikuti prestasi, kesihatan mental	Membantu polisi institusi dalam meningkatkan PdP atas talian	Mahat (2025)
Transformasi PdP & penilaian dalam era digital	Digitalisasi bantu reka bentuk tugas dan kurikulum, tapi perlukan penilaian kritikal	Integrasi fleksibel teknologi digital dalam latihan guru dan penilaian	Weigand et al. (2024)
Penggunaan AI untuk pengoptimuman hasil pembelajaran matematik	AI bantu pemahaman dan beri maklum balas segera & tepat	Reka bentuk PdP AI perlu teliti dan berkesan	Tulak et al. (2024)

Berdasarkan Jadual 2, didapati kajian terhadap kesan pelaksanaan pengajaran dan pembelajaran (PdP) secara dalam talian menunjukkan bahawa prestasi pelajar dalam kursus Matematik Kejuruteraan Elektrik adalah lebih baik apabila dijalankan secara bersemuka, yang menunjukkan keperluan untuk pensyarah meningkatkan kemahiran dalam bidang teknologi maklumat dan penilaian atas talian (Ahmad & Bakar, 2021). Sementara itu, kajian terhadap pelajar Matematik di UiTM pula mendapati bahawa faktor masa merupakan elemen yang paling memberi kesan terhadap keberkesanan PdP atas talian, diikuti oleh prestasi akademik dan kesihatan mental pelajar, justeru sokongan polisi institusi perlu digerakkan untuk menambah baik pelaksanaan PdP secara digital (Mahat, 2025). Dari sudut transformasi PdP dalam era digital, penggunaan teknologi telah membantu dalam pembangunan reka bentuk tugas dan kurikulum, namun ia memerlukan penilaian kritikal yang berterusan bagi memastikan kesesuaiannya dengan objektif pendidikan. Oleh itu, integrasi teknologi digital secara fleksibel dalam latihan guru dan sistem penilaian amatlah digalakkan (Weigand, Trgalova, & Tabach, 2024). Di samping itu, penggunaan teknologi kecerdasan buatan (AI) juga telah terbukti mampu meningkatkan pemahaman pelajar serta menyediakan maklum balas yang segera dan tepat dalam pembelajaran matematik. Walau bagaimanapun, reka bentuk dan pelaksanaan PdP berasaskan AI perlulah dilakukan secara teliti agar keberkesanan pembelajaran dapat dioptimumkan (Tulak, Rubianus, & Maramba, 2024).

c) Jadual 3. Perbandingan Dapatan Kajian (Cabaran Mod Pembelajaran Digital)

Keterangan Isu	Dapatan	Cadangan	Sumber
Cabaran PdP matematik dalam talian oleh guru & murid	Guru: pedagogi, teknologi, penilaian. Murid: kos, disiplin, teknologi	Pendedahan kepada KPM sebagai panduan tindakan	Li & Maat (2022)
Cabaran guru matematik sekolah rendah dalam PdP atas talian	Masa, kos dan tanggungjawab murid	Gabungan pembelajaran bersemuka dan atas talian (hybrid)	Hanushaa & Mahmud (2022)
Cabaran pelajar belajar matematik dalam talian (COVID-19)	Masalah capaian, tekanan, kebimbangan ujian, pedagogi	Peranan guru dalam menyokong konsep kendiri pelajar	Bringula et al. (2021)
Cabaran pelajar belajar matematik	Kesukaran fokus, kekangan internet &	Galakkan sikap positif dan aktiviti realistik	Casinillo et al. (2022)

dalam talian (pandemik)	sosial, gangguan emosi		
Cabaran guru pelatih PdP matematik semasa pandemik	Majoriti tidak puas hati dengan PdP matematik atas talian	Latihan ICT, kelas pintar, penilaian kerap, alat interaktif	Roshni & Musthafa (2022)
Digitalisasi PdP matematik secara hybrid	Sukar fokus, kurang kemahiran digital dan alat bantu	Latihan digital perlu diberi keutamaan	Galang & Regala (2025)
Penggunaan TPACK dalam PdP matematik	Isu bajet, latihan guru, keperluan sokongan berterusan	Inovasi dan kolaborasi berterusan dalam TPACK	Hanifah et al. (2025)

Pelaksanaan pengajaran dan pembelajaran (PdP) matematik secara dalam talian menghadapi pelbagai cabaran melibatkan guru dan murid (rujuk Jadual 3. Guru sering berhadapan dengan kesukaran dari segi pedagogi, penggunaan teknologi dan kaedah penilaian, manakala murid pula berdepan isu kos, disiplin diri dan kekurangan kemahiran teknologi. Justeru, pendedahan terhadap cabaran-cabaran ini kepada pihak Kementerian Pendidikan Malaysia (KPM) dicadangkan agar dapat dijadikan panduan dalam merangka intervensi yang bersesuaian (Li & Maat, 2022). Bagi guru matematik sekolah rendah, cabaran utama yang dikenalpasti termasuk kekangan masa, kos dan tanggungjawab murid dalam menghantar tugasan, dan hal ini menuntut pendekatan pembelajaran hibrid sebagai langkah penyesuaian yang lebih berkesan (Hanushaa & Mahmud, 2022). Dalam kalangan pelajar pula, pembelajaran matematik atas talian sewaktu pandemik COVID-19 turut dicemari masalah capaian internet, tekanan peribadi, kebimbangan terhadap ujian serta isu pedagogi, justeru peranan guru dalam menyokong konsep kendiri pelajar amat penting bagi memastikan motivasi dan keyakinan pelajar tidak terjejas (Bringula, Reguyal, Tan & Ulfa, 2021). Pelajar juga dilaporkan menghadapi kesukaran untuk fokus dalam PdP disebabkan gangguan emosi dan sosial, serta kekangan kewangan dan teknologi. Oleh itu, sikap positif daripada guru dan aktiviti pembelajaran yang realistik disarankan bagi mengekalkan minat pelajar terhadap subjek (Casinillo, Casinillo, Valenzona, Almonite & Valenzona, 2022). Dalam kalangan guru pelatih pula, majoriti tidak berpuas hati terhadap PdP matematik dalam talian yang dijalankan semasa pandemik. Mereka mencadangkan agar latihan penggunaan ICT dipertingkatkan, selain kemudahan bilik darjah pintar dan pelaksanaan penilaian berkala melalui alat interaktif turut disediakan (Roshni & Musthafa, 2022). Selari dengan keperluan digitalisasi PdP, kesukaran tumpuan pelajar, kekurangan kemahiran digital serta alat bantu pengajaran yang terhad turut memerlukan perhatian. Oleh itu, latihan digital harus diberi keutamaan kepada pendidik bagi menyokong pelaksanaan PdP dalam talian (Galang & Regala, 2025). Dalam aspek pedagogi pula, pengaplikasian rangka kerja TPACK (Technological Pedagogical and Content Knowledge) dalam PdP matematik masih dibatasi oleh isu kekangan bajet, kurangnya latihan guru serta keperluan kepada sokongan berterusan. Maka, inovasi dan kolaborasi berterusan amat diperlukan untuk memastikan keberkesanan pendekatan ini (Hanifah, Budayasa & Sulaiman, 2025).

4. Kesimpulan

Bagi memastikan pelaksanaan PdP matematik atas talian lebih berkesan, beberapa penambahbaikan wajar dilaksanakan. Pertama, pendekatan blended learning perlu diberi keutamaan, terutamanya bagi pelajar yang lebih gemar pembelajaran secara bersemuka tetapi masih perlu menyesuaikan diri dengan persekitaran digital. Kedua, pelaksanaan latihan berkala untuk pensyarah dan pelajar dalam penggunaan teknologi pengajaran terkini seperti aplikasi pembelajaran, kecerdasan buatan (AI) dan alat penilaian dalam talian adalah sangat penting untuk memastikan kompetensi digital yang mencukupi. Ketiga, penggunaan bahan pengajaran

yang pelbagai dan interaktif perlu digalakkan agar PdP lebih menarik dan mesra pelajar. Selain itu, pihak institusi perlu memastikan sokongan teknikal dan psikososial yang mencukupi kepada pelajar dan pensyarah untuk mengatasi cabaran capaian, tekanan dan motivasi pembelajaran. Infrastruktur digital yang stabil serta pemilihan platform PdP yang sesuai juga perlu diteliti agar selaras dengan keperluan sebenar pengguna.

Secara tuntas, pelaksanaan PdP matematik secara dalam talian mempunyai potensi besar dalam meningkatkan mutu pendidikan jika dirancang dan dilaksanakan dengan teliti. Walaupun terdapat pelbagai cabaran dari sudut pedagogi, teknologi dan emosi, pendekatan yang bersifat holistik dan fleksibel mampu menyokong keberkesanan PdP dalam konteks pendidikan moden. Komitmen semua pihak termasuk pendidik, pelajar, institusi dan pembuat dasar amat penting untuk memastikan peralihan kepada pembelajaran digital bukan sahaja bersifat responsif terhadap situasi semasa, malah mampu memberi impak jangka panjang terhadap kualiti pendidikan matematik di peringkat tinggi.

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PERBANDINGAN PRE-TEST DAN POST-TEST BAGI ANALISIS KEBERKESANAN MULTIPURPOSE TRAINER DALAM PENGAJARAN LITAR ELEKTRIK

Muhammad bin Jamaluddin

Jabatan Kejuruteraan Elektrik, Politeknik Tuanku Sultanah Bahiyah, Kulim Hi-Tech Park, 09000 Kulim, Kedah,Malaysia

*Corresponding author e-mail address: muhammad@ptsb.edu.my

Abstrak

Kajian ini menganalisis tahap pemahaman awal pelajar terhadap konsep asas litar elektrik sebelum dan selepas penggunaan Multipurpose Trainer. Data dikumpulkan melalui borang pre-test dan post-test yang mengukur tujuh aspek pemahaman menggunakan skala Likert 5-point (Abdul Samad Hanif et al., 2016) . Hasil menunjukkan variasi dalam tahap pemahaman pelajar di antara konsep yang berbeza, tahap pemahaman tentang pembahagian arus dalam litar selari serta mencari tahap kesukaran tertinggi dalam penggunaan alat bantu mengajar ini (Hanif et al., 2017). Kajian juga merumus kepada membandingkan data pre-test dan post-test untuk menilai keberkesanan Multipurpose Trainer dalam meningkatkan pemahaman konsep asas litar elektrik pelajar kursus DET10013. Analisa menunjukkan peningkatan signifikan dalam semua aspek, terutamanya pemahaman konsep pembahagian arus dalam litar selari (peningkatan min dari 2.27 ke 4.04). Hasil membuktikan alat bantu mengajar ini berjaya mengatasi kesukaran konseptual yang dikenal pasti dalam pre-test (Ramli & Osman, 2023).
Keywords: Litar Siri Selari; Multipurpose Trainer; Analisa Voltan dan Arus.

1. Pengenalan

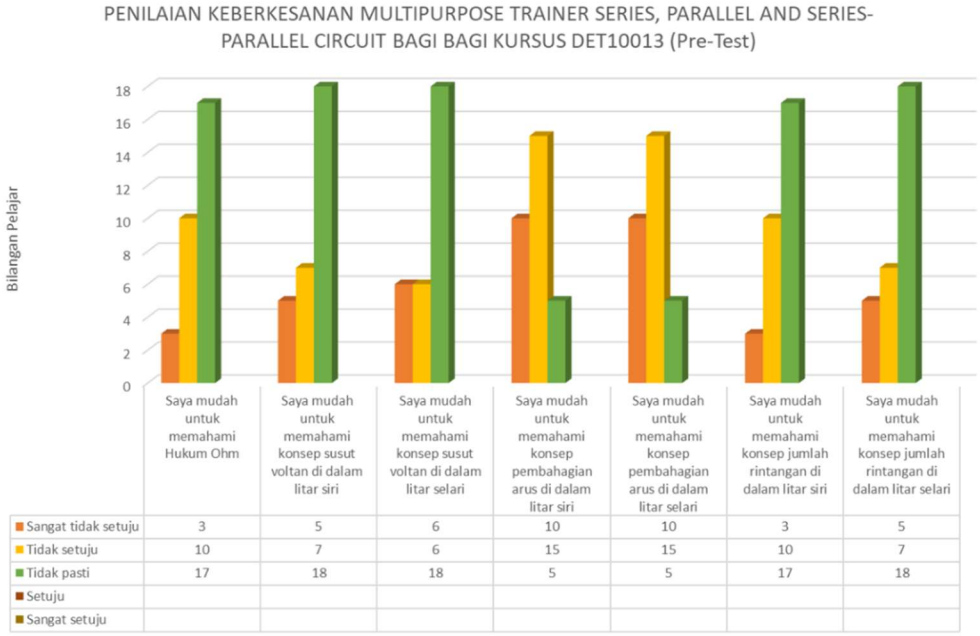
Pemahaman konsep asas litar elektrik seperti Hukum Ohm, susut voltan, dan pembahagian arus merupakan asas penting dalam pendidikan kejuruteraan elektrik. Kajian ini bertujuan untuk menilai tahap pemahaman awal pelajar sebelum pendedahan kepada alat bantu mengajar yang khusus.

Kajian sebelum ini (pre-test) menunjukkan pelajar menghadapi kesukaran memahami konsep litar selari (Skromme et al., 2022), khususnya pembahagian arus. Analisa data post-test selepas penggunaan Multipurpose Trainer digunakan untuk mengukur nilai arus dan voltan. Hasil dari penggunaan Multipurpose Trainer ini boleh dilihat dari tahap peningkatan pemahaman pelajar terhadap aspek pembelajaran dalam kuliah teori litar dan keberkesanan alat bantu mengajar "Multipurpose Trainer" dalam mengatasi kesukaran pelajar memahami konsep paling asas pengiraan arus dan voltan dalam litar siri atau litar selari. Kajian juga melihat implikasi pedagogi kepada pensyarah yang mengajar pelajar semester 1 yang mengambil kursus DET10013 (Mohd Zailani Ismail & Mohamad Khairi Othman, 2018)

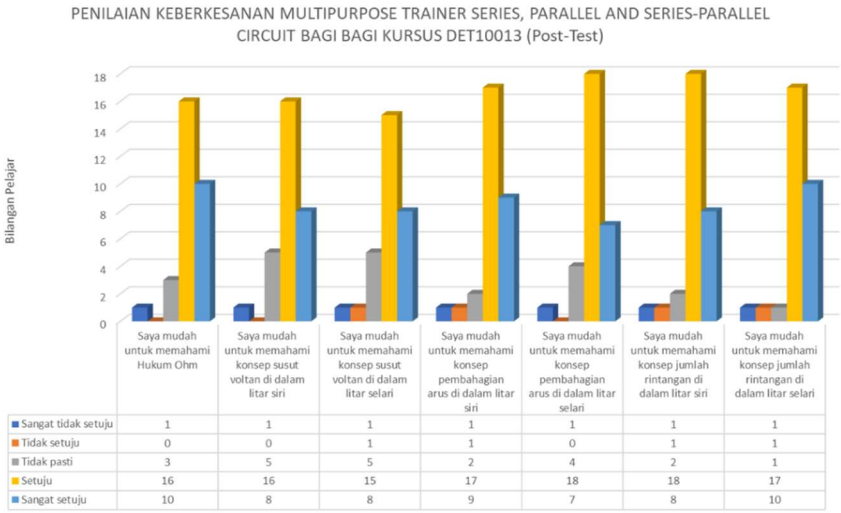
Rajah 1 menunjukkan model sebenar alat bantu mengajar yang digunakan dalam dapatan analisa post-test. Rajah 2 menunjukkan data Pre-Test penilaian keberkesanan pengunaan Multipurpose Trainer bagi litar Siri, Selari dan gabungan Siri Selari bagi kursus DET10013. Rajah 3 adalah data Post-Test bagi penilaian keberkesanan pengunaan Multipurpose Trainer yang telah digunakan dalam kajian penyelidikan ini.



Rajah 2. Multipurpose Trainer untuk litar selari dan sesiri



Rajah 2. Data Pre-Test Penilaian Kebekesanan Pengunaan Multipurpose Trainer



Rajah 3. Data Post-Test Penilaian Kebekesanan Pengunaan Multipurpose Trainer

2. Metodologi

Hasil dari dapatan Pre-Test dan Post-Test dapat di terjemahkan dalam Jadual 1 dibawah di mana instrument kajian yang digunakan adalah melalui borang soal selidik 7 item yang mempunyai skala Likert 5-point (Chang et al., 2024). Sampel dilakukan terhadap 30 orang pelajar DET10013 sama seperti pre-test. Daripada data yang diperolehi pengiraan dilakukan menggunakan formula

$$Min = \frac{\sum(f \times x)}{Bilangan\ responden} \quad (1)$$

Dimana f adalah kekerapan dan x ialah nilai skor bagi data yang diperolehi dalam jadual dibawah:

Jadual 5. Perbandingan Min Pre-Test vs post-Test dan Nilai Peningkatan

	Pre-Test					Post-Test				
Hukum Ohm	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	3	1	3	2.47	Sangat tidak setuju	1	1	1	4.13
	Tidak setuju	10	2	20		Tidak setuju	0	2	0	
	Tidak pasti	17	3	51		Tidak pasti	3	3	9	
	Setuju	0	4	0		Setuju	16	4	64	
	Sangat setuju	0	5	0		Sangat setuju	10	5	50	
	Jumlah	30	15	74		Jumlah	30	15	124	
Susut voltan (siri)	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	5	1	5	2.43	Sangat tidak setuju	1	1	1	4.00
	Tidak setuju	7	2	14		Tidak setuju	0	2	0	
	Tidak pasti	18	3	54		Tidak pasti	5	3	15	
	Setuju	0	4	0		Setuju	16	4	64	
	Sangat setuju	0	5	0		Sangat setuju	8	5	40	
	Jumlah	30	15	73		Jumlah	30	15	120	
Susut voltan (selari)	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	6	1	6	2.40	Sangat tidak setuju	1	1	1	3.93
	Tidak setuju	6	2	12		Tidak setuju	1	2	2	
	Tidak pasti	18	3	54		Tidak pasti	5	3	15	
	Setuju	0	4	0		Setuju	15	4	60	
	Sangat setuju	0	5	0		Sangat setuju	8	5	40	
	Jumlah	30	15	72		Jumlah	30	15	118	
Pembahagian arus (siri)	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	10	1	10	1.83	Sangat tidak setuju	1	1	1	4.07
	Tidak setuju	15	2	30		Tidak setuju	1	2	2	
	Tidak pasti	5	3	15		Tidak pasti	2	3	6	
	Setuju	0	4	0		Setuju	17	4	68	
	Sangat setuju	0	5	0		Sangat setuju	9	5	45	
	Jumlah	30	15	55		Jumlah	30	15	122	
Pembahagian arus (selari)	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	10	1	10	1.83	Sangat tidak setuju	1	1	1	4.00
	Tidak setuju	15	2	30		Tidak setuju	0	2	0	
	Tidak pasti	5	3	15		Tidak pasti	4	3	12	
	Setuju	0	4	0		Setuju	18	4	72	
	Sangat setuju	0	5	0		Sangat setuju	7	5	35	
	Jumlah	30	15	55		Jumlah	30	15	120	
Jumlah rintangan (siri)	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	3	1	3	2.47	Sangat tidak setuju	1	1	1	4.03
	Tidak setuju	10	2	20		Tidak setuju	1	2	2	
	Tidak pasti	17	3	51		Tidak pasti	2	3	6	
	Setuju	0	4	0		Setuju	18	4	72	
	Sangat setuju	0	5	0		Sangat setuju	8	5	40	
	Jumlah	30	15	74		Jumlah	30	15	121	
Jumlah rintangan (selari)	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN	Respons	ekerapan (f	Nilai Skor (x	f × x	Nilai MIN
	Sangat tidak setuju	5	1	5	2.43	Sangat tidak setuju	1	1	1	4.13
	Tidak setuju	7	2	14		Tidak setuju	1	2	2	
	Tidak pasti	18	3	54		Tidak pasti	1	3	3	
	Setuju	0	4	0		Setuju	17	4	68	
	Sangat setuju	0	5	0		Sangat setuju	10	5	50	
	Jumlah	30	15	73		Jumlah	30	15	124	

Seterusnya adalah membuat analisis *Effect Size* dengan menggunakan pengiraan Cohen's d (Bowring et al., 2021) bagi mendapatkan ukuran magnitud peningkatan. Formula berikut digunakan

$$d = \frac{Perbezaan\ Min}{\sigma_{pooled}} \quad (2)$$

Dimana

$$\sigma_{pooled} = \sqrt{\frac{(N_1-1)\sigma_1^2+(N_2-1)\sigma_2^2}{N_1+N_2-2}} \quad (3)$$

Jadual 2. Interpretasi berdasarkan data Cohen's d

Kategori	Mean Difference	σ Pooled	Cohen's d	Interpretasi
Hukum Ohm	1.66	0.78	2.13	Kesan sangat besar
Susut voltan (siri)	1.57	0.8	1.96	Kesan sangat besar
Susut voltan (selari)	1.53	0.82	1.87	Kesan sangat besar
Pembahagian arus (siri)	2.24	0.75	2.99	Kesan sangat besar
Pembahagian arus (selari)	2.17	0.8	2.71	Kesan sangat besar
Jumlah rintangan (siri)	1.56	0.79	1.97	Kesan sangat besar
Jumlah rintangan (selari)	1.7	0.77	2.21	Kesan sangat besar

Jadual 2 di atas menunjukkan bahawa Cohen's d bagi perbandingan yang dibuat antara pre-test dan post-test untuk semua kategori di mana ukuran Interprestasi Cohen's d (Francis, 2017) merujuk kepada jika nilai 0.2 interpretasi adalah kecil, sekiranya berada pada 0.5 intepretasi adalah sederhana. Namun hasil dari pengiraan data yang diperolehi, Cohen's d melebihi nilai 0.8 bagi kesemua kategori telah membuktikan bahawa kesan yang sangat besar dalam pengunaan Multipurpose Trainer ini.

3. Keputusan dan Perbincangan

Kajian ini telah menilai keberkesanan Multipurpose Trainer dalam meningkatkan pemahamanan pelajar terhadap konsep asas litar elektrik melalui analisis data Pre-Test dan Post-Test. Dapatan kajian mendapati bahawa berlaku peningkatan yang mendadak dalam konsep pemahaman litar siri dan selari. Hasilnya semua kategori menunjukkan peningkatan nilai Min yang signifikan dari Pre-Test hinggalah ke Post-Test. Merujuk kepada jadual 1 kategori Pembahagian Arus Dalam Litar Selari mencatatkan peningkatan tertinggi. Dimana nilai Min Pre-test bersamaan 2.27 meningkat ke nilai Min 4.04 dalam Post-test. Ini menunjukan pertambahan sebanyak +1.77. Kategori jumlah rintangan selari dan pembahagian arus siri juga menunjukkan peningkatan yang besar iaitu melebihi +1.5. Implikasi dari Multipurpose trainer Berjaya menunjukkan bahawa pelajar telah berjaya mengatasi kesukaran dalam memahami konsep litar selari yang sering di anggap begitu komplek dalam sesi pembelajaran pelajar semester 1 kejuruteraan elektrik.

Selain itu, hasil dari Keputusan Cohen's d iaitu Kesan Magnitud (*Effect Size*) menunjukkan kesan yang sangat besar. Cohen's d untuk semua kategori berada dalam julat 1.87 hingga 2.99 dan ini memberi kesan intervensi yang sangat besar melebihi 0.8. Kategori dengan kesan terbesar dapat dilihat pada pembahagian arus siri iaitu sebanyak 2.99 dan pembahagian arus selari 2.71. Interpretasi dari *Effect Size* menunjukkan bahawa perubahan skor pelajar bukan sahaja signifikan secara statistik malah juga relevan secara praktikal (*practical significance*).

Dari kajian ini, alat bantu mengajar secara fizikal lebih berkesan dalam proses pembelajaran dan pengajaran berbanding simulasi digital (Hussain et al., 2023). Keunikan dari kajian ini didapati peningkatan nilai min melebihi 2.0 untuk kategori kritikal seperti pembahagian arus lebih tinggi berbanding purata min 1.5 dan ini membuktikan kelebihan yang ada dalam Multipurpose Trainer yang telah diinovasikan.

Implikasi Pedagogi (Mohammad Salleh & Halim, 2023) untuk proses pengajaran juga menunjukkan alat bantu mengajar ini mampu mengatasi masalah pelajar dalam menyelesaikan sambungan litar yang menggunakan kabel penghubung dan papan litar *breadboard*. Di masa hadapan pembangunan yang boleh dibuat bagi menaikkan taraf alat bantu mengajar ini ialah dengan menambah fungsi augmented reality (AR) (Khairudin et al., 2020) pada trainer agar pelajar dapat visualisasi pergerakan aliran elektron atau pergerakan arus elektrik dalam litar yang disambung.

Faktor lain yang membataskan keputusan kajian penyelidikan ini ialah sampel saiz yang kecil (N=30) dan mungkin akan menjejaskan hasil dapatan (Hung & Blauw, 2017). Pelajar yang menjawab pre-test dan post-test mungkin cenderung memberikan skor positif akibat kesan *Hawthorne*. Kaedah mengajar yang berbeza semasa sesi pre-test dan post-test juga boleh menyebabkan keputusan kajian tidak tepat dan berada di luar kawalan.

4. Kesimpulan

Multipurpose Trainer terbukti sangat berkesan dalam meningkatkan pemahaman pelajar, khususnya untuk konsep litar selari yang agak komplek dan sukar difahami oleh pelajar. Dapatan kajian menyokong penggunaan alat bantu mengajar ini mampu meningkatkan minat pelajar dalam pendidikan kejuruteraan elektrik.

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PERBANDINGAN ANTARA NEGARA-NEGARA MAJU DAN NEGARA-NEGARA MEMBANGUN DARI SEGI PENJANAAN, POLISI DAN PELUPUSAN SISA PEPEJAL

Arman bin Hj Ahmad Sapawi*, Fardila binti Mohd Zaihidee, Che Ghani bin Che Kob

Fakulti Teknikal dan Vokasional, Universiti Pendidikan Sultan Idris,35900 Tanjung Malim, Perak, Malaysia

*Corresponding author e-mail address: arman@psas.edu.my

Abstrak

Sisa pepejal adalah isu global yang tidak hanya bertumpu kepada negara-negara maju sahaja. Ia turut mencakupi dan terkesan kepada negara-negara membangun samada di benua Asia, Eropah dan sebagainya. Artikel ini akan melihat perbandingan dari segi penjanaan, polisi dan pelupusan sisa pepejal yang melibatkan negara-negara maju seperti Sweden, Jerman dan Jepun manakala bagi negara-negara membangun adalah seperti Singapura, Malaysia dan Indonesia. Seterusnya dapatan kajian menunjukkan tahap keprihatinan, penguatkuasaan serta tindakan dari komuniti atau warga negara terbabit yang telah menghasilkan satu kesan samada berkeupayaan tinggi dalam pengurusan sisa pepejal atau masih tidak berupaya untuk melaksanakan perkara-perkara tertentu bagi menguruskan sisa pepejal dengan baik dan berkesan. Selain itu, hasil kajian ini juga menunjukkan inisiatif dan tindakan yang telah dilakukan oleh negara-negara tersebut dalam menangani isu pengurusan sisa pepejal. Oleh yang demikian, perbandingan yang telah dibuat ini boleh dijadikan panduan kepada negara-negara membangun bagi menguruskan sisa pepejal dengan baik serta mapan untuk kelestarian dan seterusnya menjaga kepentingan alam sekitar.

Kata Kunci: Penjanaan; Polisi; Pelupusan.

1. Pengenalan

Pengurusan sisa pepejal kini menjadi satu keperluan utama kepada semua pihak terutamanya melibatkan perancangan, seliaan, guna atau kitar semula sehingga kepada proses pelupusan. Keberhasilan sisa pepejal tidak mengambilkira faktor jantina, pekerjaan, usia, pendidikan, agama, persekitaran dan sebagainya (Adeniyi et al., 2023). Malaysia pada tahun 2021 menghasilkan sisa pepejal sekitar 13.95 juta tan sisa pepejal setahun secara keseluruhannya (Malaysian Investment Development Authority [MIDA], 2024). Ia seterusnya menunjukkan budaya peningkatan melalui perbandingan data bagi tahun 2019 iaitu sebanyak 13.88 juta tan dan 13.91 juta tan bagi tahun 2020. Merujuk kepada sisa pepejal dunia pula, ia dijangkakan akan terus mencatatkan peningkatan sehingga kepada 3.88 bilion tan setahun pada tahun 2050 (World Bank, 2022). Dalam pada itu, Negara-negara maju seperti Sweden, Jerman, Jepun banyak mengaplikasikan pelbagai kaedah, polisi, penguatkuasaan dan kawalan bagi menguruskan sisa pepejal mengikut acuan tersendiri. Ini adalah kerana merujuk kepada Arifin Sandhi dan Rosenlund, 2024, penjanaan sisa pepejal adalah merupakan satu isu besar di negara-negara Eropah dan telah menghasilkan tekanan kepada semua pihak untuk menanganinya. Dalam pada itu pula, merujuk kepada Negara-negara yang sedang membangun di Asia Tenggara seperti Malaysia, Singapura dan Indonesia juga kini sedang menjalankan usaha bagi menguruskan sisa pepejal melalui usaha-usaha yang giat dijalankan dari semasa ke semasa. Kenyataan ini disokong merujuk kepada kenyatan oleh Permana et. al., 2024 yang menyatakan pelbagai usaha dilaksanakan oleh semua pihak bagi mengurangkan jumlah sisa pepejal yang di hantar ke tapak-tapak pelupusan sisa. Justeru itu, artikel ini akan melihat perbandingan antara Negara-negara

maju seperti Sweden, Jerman dan Jepun dengan Negara-negara membangun di Asia Tenggara seperti Malaysia, Singapura dan Indonesia dari segi penjanaan, polisi dan pelupusan sisa pepejal. Jadual 1.1 menunjukkan keberhasilan janaan, polisi dan pelupusan sisa pepejal merujuk kepada perbandingan antara negara membangun dan maju.

Jadual 1. Kadar Penjanaan dan Pelupusan Sisa Pepejal Mengikut Negara Maju dan Membangun

Negara	Penjanaan Sisa Pepejal (Tan)	Pelupusan Sisa Pepejal (Tan)	Peratus Pelupusan	Sumber Rujukan
Sweden	4.5 juta (2023)	67.6 ribu (2023)	1.5	Avfall Sverige (2024)
Jerman	399 juta (2023)	3.99 juta (2023)	1	European Environment Agency ([EEA], 2023)
Jepun	38.97 juta (2023)	3.16 juta (2023)	8.1	Ministry of The Environment ([ME], 2025)
Malaysia	14.5 juta (2023)	2.67 juta (2023)	18.41	Fatimah Zainal (2024)
Singapura	6.85 juta (2023)	3.31 juta (2023)	48.3	National Environment Agency ([NEA], 2023)
Indonesia	31.9 juta (2023)	20.5 juta (2023)	64.2	National Research Innovation Agency ([NRIA], 2024)

2. Penjanaan Sisa Pepejal

Sisa pepejal pada masa kini terbahagi kepada dua pecahan iaitu sisa pepejal organik dan sisa pepejal bukan organik. Sisa pepejal organik adalah terdiri daripada sisa makanan, daun, ranting, pokok dan sebagainya yang boleh didapati daripada kawasan kediaman atau perumahan, restoran, pejabat, kawasan perindustrian, taman permainan dan sebagainya. Sisa pepejal bukan organik pula adalah terdiri daripada bahan pembinaan, perabot, alat tulis, pakaian, kenderaan, peralatan elektronik, bateri dan lain-lain lagi.

Negara Sweden, merujuk kepada Avfall Sverige, 2024 menunjukkan penjanaan sisa pepejal untuk tahun 2023 adalah sebanyak 4.5 juta tan. Daripada jumlah tersebut, sebanyak 688 ribu tan adalah terhasil dari sisa makanan dan taman, 562 ribu tan adalah terdiri daripada sisa pembungkusan, 406 ribu tan terdiri daripada bahan dari tempat boleh kitar semula, 110 ribu tan adalah sisa kertas terpakai, 152 ribu tan adalah sisa dari peralatan elektrik dan 8 ribu tan pula terdiri daripada sisa pepejal yang diasingkan dari sisa pepejal yang boleh digunakan semula. Seterusnya sebanyak 2.6 ribu tan pula adalah sisa-sisa pepejal yang akan d hantar terus ke tapak-pelupusan bagi tujuan pelupusan atau menghasilkan tenaga baru bagi tujuan seperti bekalan tenaga elektrik (WTE) dan sebagainya.

Merujuk kepada Negara Jerman pula, jadual 1.1 menunjukkan penjanaan sisa pepejal sebanyak 399 juta tan bagi tahun 2023 (EEA, 2025). Daripada jumlah tersebut, ia telah menunjukkan peningkatan sebanyak 43 juta tan jika dibandingkan dengan penjanaan sisa pepejal Negara Jerman pada tahun 2020 (*Federal Ministry Of Environment, Nature Conversation, Nuclear safety and Consumer Protection* [BMUV], 2023). Menurut BMUV, 2023 lagi, catatan statistik bagi tahun

2020 menunjukkan janaan sisa pepejal tertinggi adalah dari pembinaan iaitu sebanyak 229.3 juta tan. Ia diikuti dengan sisa pepejal perbandaran yang mencatatkan sebanyak 50.9 juta tan. Seterusnya disusuli pula dengan sektor pengeluaran dan perdagangan yang mencatatkan sebanyak 47.3 juta tan manakala sisa sumber mineral mencatatkan catatan terendah iaitu sebanyak 28.6 juta tan.

Seterusnya, merujuk kepada jadual 1.1, Negara Jepun telah menghasilkan sisa pepejal sebanyak 38.97 juta tan dalam tahun 2023. Merujuk kepada ME, 2025, data janaan sisa pepejal tersebut telah menunjukkan penurunan daripada tahun 2022 yang telah mencatatkan janaan sisa pepejal sebanyak 40.34 juta tan. Negara Malaysia pula berdasarkan Jadual 1.1 mencatatkan jumlah pengeluaran sisa pepejal sebanyak 14.5 juta tan pada tahun 2023 (Fatimah Zainal, 2024). Negara Singapura pula telah menghasilkan sisa pepejal sebanyak 6.85 juta tan sisa pepejal bagi tahun 2023 (NEA, 2023). Ia terdiri daripada 3.37 juta tan gabungan daripada logam ferus, sisa pembinaan dan kertas serta kadbod. Kandungan yang terdiri daripada plastik, sisa makanan, pertanian, kayu dan debu adalah sebanyak 2.64 juta tan. Seterusnya sisa yang terdiri daripada tekstil, kulit, bukan logam adalah sebanyak 493 ribu tan manakala sisa kaca, tayar dan lain-lain mewakili sebanyak 340 ribu tan (NEA, 2023).

Negara Indonesia merujuk kepada jadual 1.1 pula telah menjana sisa pepejal sebanyak 31.9 juta tan untuk tahun 2023 (NRIA, 2024). Menurut Adi Ahdiat, 2024, sisa-sisa pepejal yang terhasil adalah seperti sisa makanan dan tumbuhan yang mewakili sebanyak 16.87 juta tan. Sisa pepejal yang terdiri daripada kertas, kotak dan tekstil mewakili sebanyak 4.17 juta tan. Sisa pepejal seperti kaca, logam dan kulit adalah terhasil sebanyak 2.35 juta tan manakala sumber lain-lain yang menjana kepada keberhasilan sisa pepejal bagi tahun 2023 adalah sebanyak 2.26 juta tan.

Oleh yang demikian, penjanaan sisa pepejal dunia adalah pada kadar 2.1 bilion tan untuk 2023 dan dijangkakan akan terus meningkat kepada 3.8 bilion tan pada tahun 2050 (UNEP, 2024). Ia menunjukkan sentiasa ada pertambahan dari tahun ke tahun mendatang. Justeru itu, kawalan, penguatkuasaan, pembudayaan serta pendidikan awal berkenaan sisa pepejal perlu dilaksanakan bukan sahaja kepada negara-negara maju, malah turut berkeperluan di laksanakan di negara-negara membangun untuk mengurangkan keberhasilan sisa pepejal bagi kepentingan bersama (Amode et., al. (2023).

3. Polisi

Pelbagai polisi telah dibangunkan oleh Negara masing-masing dalam menguruskan sisa pepejal. Melihat kepada negara-negara maju dan membangun, polisi yang dilaksanakan adalah berbeza. Negara Sweden terkenal dengan pengurusan sisa pepejal yang terbaik di dunia. Ia menggunakan sisa pepejal yang diproses semula untuk dijadikan tenaga yang baru seperti tenaga elektrik. Ia menerapkan polisi di mana setiap Majlis Perbandaran perlu mematuhi dasar dan peraturan sisa tempatan. Setiap Majlis Perbancaran perlu menyediakan infrastruktur yang bersesuaian dan para pengguna pula perlu menjalankan pengendalian serta melakukan pengasingan sisa yang betul dengan menggalakkan kitar semula dan pengurangan sisa (Naturvards Verket, 2024). Selain daripada itu, pengeluar juga perlu bertanggungjawab dengan mengambil kembali sisa pembungkusan produk, sisa peralatan elektrik atau elektronik, tayar,

bateri, kereta dan termasuk juga sisa perubatan yang telah dikeluarkan oleh syarikat-syarikat atau kilang-kilang perusahaan di sana (Avfall Sverige, 2024).

Merujuk kepada Negara Jerman pula, ia mengamalkan polisi dengan menggunakan undang-undang yang komprehensif seperti Ordinan Sisa Komersil dan Akta Ekonomi Pekeliling. Ini bermakna, lebih 3.6 juta produk perniagaan syarikat-syarikat yang terlibat dalam urusan jual beli perlu melakukan kitar semula terhadap pembungkusan produk yang dibuat (BMUV, 2023). Tindakan tersebut adalah sama seperti yang diamalkan di Negara Sweden. Sebelum itu, syarikat-syarikat yang terlibat perlu berdaftar dan mendapatkan lesen bagi memasarkan produk masing-masing. Sekiranya tidak berdaftar, secara umumnya syarikat-syarikat yang terlibat boleh dikenakan denda sehingga 200000 euro dan boleh dibekukan daripada menjalankan aktiviti seumpamanya di Jerman (BMUV, 2023).

Negara Jepun mengamalkan polisi dan peraturan yang ketat. Kementerian Alam Sekitar di Jepun telah menggerakkan penekanan baru dalam menguruskan pengurusan sisa. Antara kandungan ketetapan yang telah digariskan adalah seperti penggunaan biojisim dan sisa sebagai sumber serta mencipta kemudahan baru untuk masyarakat dan berupaya memanfaatkannya untuk kebaikan bersama (Sasaki & Kojima, 2020). Selain daripada itu, ia turut meliputi Akta Asas Menubuhkan Masyarakat Kitaran Bahan Bunyi serta mengitar semula peralatan dan perkakasan barang rumah. Menyentuh proses kitar semua perkakasan barang rumah, antara peralatan yang boleh dikitar semula adalah seperti komputer, televisyen, alatan permainan video, pembesar suara, kamera, telefon bimbit, alat pengecas dan sebagainya. Ia secara tidak langsung akan dapat mengitar semula bahan-bahan yang terdapat di dalam perkakasan kecil rumah tersebut seperti emas, perak, logam nadir serta platinum. Selain daripada itu, di antara undang-undang yang telah digunapakai di Negara Jepun adalah seperti undang-undang kitar semula bekas dan pembungkusan, kitar semula sisa makanan, undang-undang kitar semula perkakas elektrik rumah dan beberapa pindaan undang-udang seperti pindaan kepada Undang-Undang Pengurusan Sisa dan Pembersihan Awam (ME, 2025).

Negara Malaysia pula mengamalkan Akta Pengurusan Sisa Pepejal dan Pembersihan Awam 2007 ([JPSPN], 2024). Akta ini diterbitkan untuk membolehkan pihak Kerajaan Persekutuan atau Pusat menjalankan pengurusan sisa pepejal dan pembersihan awam berbanding sebelum ini dilaksanakan oleh Pihak Berkuasa Tempatan Negeri masing-masing di Semenanjung Malaysia termasuk Wilayah Persekutuan Kuala Lumpur, Putrajaya dan Labuan. Selain daripada itu, Malaysia juga mensasarkan sebanyak 30 peratus daripada sisa pepejalnya boleh dikitar semula melalui kesedaran awam berdasarkan konsep 3R iaitu mengurang, guna dan kitar semula (Mohd Naim et. al., 2022). Selain daripada itu, antara polisi yang selalu disarankan untuk diaplikasikan dalam kehidupan seharian kepada penduduk di Malaysia adalah kempen tidak menggunakan plastik beg ketika membeli barangan keperluan dan sebagainya (Mohd Na'im et. al., 2022).

Seterusnya, Negara Singapura pula mengamalkan dasar polisi pelan induk sifar sisa pepejal. Ia mensasarkan pada tahun 2030, hanya sebanyak 30 % sisa di hantar ke tapak pelupusan sisa pepejal. Selain itu, Singapura juga menekankan tanggungjawab pihak syarikat dengan memperkenalkan program *Extender Producer Responsibility* (EPR) di mana pihak syarikat akan bertanggungjawab untuk mengutip atau mengumpul semula sisa-sisa pepejal yang dikeluarkan oleh mereka untuk kegunaan para pengguna termasuk sisa elektonik (Asia Pacific Economic Cooperation, 2021). Seterusnya, Singapura melalui Agensi Alam Sekitar Kebangsaan (NEA) pula berperanan merancang, membangun dan menguruskan sisa pepejal samada umum atau

berbahaya. Ia turut meliputi fungsi perlesenan dan kawal selia untuk memastikan sisa dikumpulkan, dirawat dan dilupuskan dengan betul (NEA, 2022).

Negara Indonesia pula dalam polisi pengurusan sisa pepejalnya ada menyatakan terdapat beberapa penekanan terhadap elemen 3R, keperluan pengurusan sisa pepejal yang betul, pengurusan sisa berbahaya, pengurusan tapak pengurusan sisa yang baik serta penghasilan tenaga baru daripada sisa pepejal yang terkumpul (Suprapto, 2022). Selain daripada itu, menurut Purba (2019), beliau menyatakan bahawa pengkhususan sumber untuk membolehkan pihak berkuasa merancang polisi dan peraturan sebelum dikuatkuasakan oleh pihak berkuasa samada di peringkat pusat, bandar, daerah dan sebagainya. Seterusnya beliau juga menyatakan akan keperluan penentuan dasar dan polisi dilaksanakan terlebih dahulu sebelum disusuli dengan pelaksanaannya oleh pihak berkuasa di pelbagai peringkat pengurusan yang meliputi aspek-aspek kriteria, prosedur, norma dan piawaian berkaitan pengurusan sisa pepejal. Justeru itu, ketetapan polisi berkenaan sisa pepejal amat perlu untuk dipatuhi bagi memastikan kawalan penjanaan, guna semula, kitar dan dan pelupusan sisa pepejal dapat dilaksanakan secara optimum dan maksimum (Cruz, 2023).

4. Pelupusan Sisa Pepejal

Pelupusan sisa pepejal merujuk kepada negara-negara maju dan membangun adalah berbeza. Ia berkemungkinan besar berlaku akibat dari penekanan dan kawalan pelaksanaan samada ketat atau longgar yang turut menonjolkan tahap keprihatinan pemimpin dan pengurusan sesebuah negara. Selain daripada itu, menjadi lumrah dalam kawalan pelupusan sisa pepejal dengan menumpukan kepada aspek seperti mengurangkan, guna semula, kitar semula, penghasilan kepada tenaga baru dan penekanan kepada pendidikan terhadap masyarakat dan komuniti. Justeru itu, artikel ini akan melihat kepada perbezaan dan pendekatan yang digunakan oleh Negara-negara maju dan membangun.

Negara Sweden menekankan kepada pengeluar untuk bertanggungjawab dalam menjalankan kitar semula dan pelupusan terhadap produk-produk yang dikeluarkan kepada para pengguna Avfall Sverige, 2024). Seterusnya, Sweden juga paling terkehadapan dalam menukarkan sisa rumah kepada sumber tenaga baru boleh guna untuk manfaat semua pihak. Ia ditambah dengan tahap kesedaran awam yang sangat tinggi dalam menjayakan program guna semula sisa pepejal melalui sistem pengurusan yang baik dan tersusun. Selain daripada itu, negara Sweden berjaya melakukan penjimatan kewangan dengan menggunakan sisa pepejal sedia ada yang diimport dari negara lain daripada menggunakan bahan api fosil seperti arang batu dan sebagainya untuk menjana sumber tenaga elektrik, haba dan sebagainya (Wei S. L., 2023). Menurut beliau lagi, Sweden telah menetapkan sasaran untuk menjana 100 peratus tenaga baharu yang boleh diperbaharui pada tahun 2040. Seterusnya Negara Sweden telah mewujudkan sebanyak 38 buah iniserator (Sandhi & Rosenlund, 2024). Pada awal kewujudan isinerator ini, pada awal tahun 80an ia bergantung kepada bahan api fosil dan namun begitu telah beralih kepada bahan sisa pepejal dan biojisim bagi menghasilkan tenaga. Menurutnya lagi, tanggungjawab pihak berkuasa tempatan di Sweden, industri-industri dan komuniti setempat turut membantu bagi mengumpul sisa pepejal untuk dijadikan bahan bakar dalam proses penghasilan tenaga tersebut.

Selain daripada itu, Negara Jerman menerapkan unsur-unsur pengasingan sisa yang menjadi keperluan utama untuk mengawal pengeluaran sisa pepejal oleh penduduk atau masyarakat. Ia merangkumi tiga elemen utama iaitu kitar semula, penghasilan tenaga dari sisa tidak boleh dikitar semula dan pelupusan sisa (BMUV, 2023). Ia seterusnya membangun dan menggalakkan amalan kitar semula bagi mengingkatkan kesedaran di kalangan masyarakat. Tindakan tersebut

telah menghasilkan kadar pemulihan dan kitar semula yang tinggi di Negara Jerman di mana telah berupaya membantu menjimatkan sumber tenaga utama bagi menghasilkan tenaga, menyerlahkan sumbangan industri sisa kepada amalan ekonomi, memastikan bahan buangan dibuang dengan selamat tanpa menjejaskan alam sekitar, sisa organik terlebih dahulu menjalani proses rawatan biologi mekanikal bagi mengurangkan larut resap dan pelepasan gas di tapak-tapak pelupusan sisa (BMUV, 2023). Seterusnya Akta Pengurusan Sisa Negara Jerman telah diperkenalkan sejak 20 tahun yang lalu (Nelles et. al., 2016). Ia telah memperuntukkan tanggungjawab pelupusan kepada pengeluar dan memberikan gambaran kepada orang ramai akan keperluan mengasingkan sisa dan seterusnya menghasilkan sumber tenaga baru. juga membangunkan loji-loji bagi menghasilkan tenaga baru untuk sisa-sisa pepejal yang tidak boleh diguna atau dikitar semula. Oleh yang demikian, secara tidak langsung ia mengurangkan kebergantungan kepada tapak-tapak pelupusan bagi melupuskan sisa-sisa tersebut.

Negara Jepun pula telah mengorak langkah sejak dari awal lagi. Pada tahun 2012, *Ministry of Environment* telah memperkenalkan garis panduan pengurusan sisa pepejal dan teknologi kitar semula. Selain itu, ia juga telah bermula lebih awal lagi melalui *Basic Act for Establishing a Sound Material-Cycle Society* pada tahun 2000 dan *Waste Management and Public Cleansing Law* pada tahun 1970. Seterusnya, Negara Jepun mengaplikasi kaedah pelupusan sisa menggunakan insinerator di mana sisa akhir yang dilupuskan di tapak-tapak pelupusan sisa adalah amat sedikit (Sasaki & Kajima, 2020).

Seterusnya, negara Malaysia giat melaksanakan penekanan dalam meningkatkan kaedah kutipan sisa pepejal, peningkatan kitar semula dan memajukan infrastruktur bagi menjalankan rawatan sisa. Pelbagai usaha giat dijalankan bagi keperluan mengasingkan terlebih dahulu sisa-sisa pepejal bermula daripada rumah. Merujuk kepada Jabatan Pengurusan Sisa Pepejal Negara (JPSPN), 2025, bermula pada 2016, satu penekanan baru telah diperkenalkan dengan cuba menjana tenaga dari teknologi *waste to energy* dan penggunaan *anaerobic digestor* khusus untuk mengurangkan keberhasilan gas rumah hijau. Seterusnya, usahasama bersama keterlibatan pihak-pihak swasta dalam menguruskan sisa-sisa pepejal yang terhasil turut dilaksanakan melalui syarikat-sayarikat konsesi yang diberikan tanggungjawab sehingga ke tapak-tapak pelupusan sisa. Pada masa kini, sebanyak tujuh buah negeri yang telah menandatangani Akta Pengurusan Sisa Pepejal dan Pembersihan Awam (Akta 672) bagi menerima perkhidmatan pungutan sisa pepejal melalui tiga buah syarikat iaitu Alam Flora Sdn Bhd, SWM Sdn Bhd dan Environment Idaman Sdn Bhd (JPSPN, 2025).

Pendekatan yang dijalankan di Negara Singapura adalah dengan melalui penekanan terhadap pengurangan sisa-sisa pepejal yang di hantar ke tapak-tapak pelupusan sisa. Ia juga menekankan kawalan ketat dengan menguatkuasa dan melaksanakan undang-undang dalam pengurusan sisa pepejal serta menggalakkan kitar semula. Terkini, sistem pelupusan di Negara Singapura akan melalui proses pembakaran melalui insinerator dan sisa pembakaran akan d bawa ke tapak pelupusan sisa pepejal (NEA, 2024). Selain daripada itu, menurut NEA lagi, pihak berkuasa di Negara Singapura juga sedang giat menjalankan kajian-kajian tertentu bersama pihak universiti-universiti tempatan bagi menguji kesesuaian bahan akhir atau debu hasil pembakaran untuk digunakan sebagai bahan binaan dan produk lain yang bersesuaian bagi memenjangkan jangka hayat tapak pelupusan sedia ada yang dijangkakan akan penuh pada tahun 2035 sekiranya tidak ada tindakan susulan dibuat berkenaan dengan hasil pembakaran sisa pepejal tersebut.

Negara Indonesia pula menjalankan pelupusan sisa pepejal melalui proses pengumpulan, penempatan sisa di tempat pengumpulan sementara sebelum di bawa ke tempat pelupusan.

Menurut *Waste for Change*, 2022, sisa pepejal yang di bawa ke tempat pengumpulan sementara akan melalui proses pengasingan sisa mengikut jenis dan bahan. Penerapan konsep 3R diaplikasikan di sini dan sisa yang tidak boleh digunakan lagi akan terus di bawa ke tapak pelupusan sisa pepejal. Selain daripada itu, Negara Indonesia juga cuba mengenengahkan kaedah usahama bersama syarikat-syarikat swasta bagi melaksanakan projek *waste to energy* bagi menggunakan semula sisa pepejal untuk dijadikan tenaga baru dan sebagainya untuk manfaat semua pihak (Haqq dan Gultom, 2021). Seterusnya Negara Indonesia juga giat berusaha menjalankan kaedah 3R bagi menangani isu lambakan sisa pepejal di tapak pelupusan dan sebagainya (Rakhmawathi et. al., 2023).

Oleh yang demikian, proses pelupusan sisa pepejal yang paling popular dilaksanakan pada masa kini merujuk kepada negara maju dan Negara membangun adalah penggunaan tapak pelupusan sisa (NEA, 2022). Perbezaan yang timbul antara Negara maju dan membangun adalah dari segi jumlah sisa yang dilupuskan di tapak pelupusan sisa. Ia juga merujuk kepada sisa akhir samada selepas guna semula, kitar semula mahupun setelah ditukar terlebih dahulu fungsinya seperti penjanaan atau penghasilan sumber tenaga baru dan sebagainya (Avfall Sverige, 2024).

5. Kesimpulan

Setelah melibat perbandingan antara Negara-negara maju dan Negara-negara membangun dalam menguruskan sisa pepejal. Ia secara pandangan umumnya menunjukkan sisa pepejal akan sentiasa bertambah dari semasa ke semasa. Namun begitu, terdapat juga negara yang berjaya mengurangkan janaan sisa pepejal dalam setahun iaitu seperti Negara Sweden dan Jepun. Ia adalah melalui proses yang dijalankan di negara tersebut seperti pembakaran isinerator bagi penghasilan sumber tenaga baru, penguatkuasaan melalui polisi terkini dan lain-lain lagi. Selain daripada itu, dapat disimpulkan bahawa pelbagai usaha telah dijalankan oleh pihak berkuasa setiap negara masing-masing bagi melaksanakan pengurusan sisa pepejal yang baik. Di antara kaedah-kaedah yang dijalankan oleh negara-negara maju seperti Jepun, Jerman dan Sweden menerapkan kaedah seperti pengunaan isinerator, pengumpulan sisa pepejal bermula dari kediaman masing-masing, penerapan budaya 3R dan cuba untuk meminimumkan sisa pepejal yang di bawa ke tapak pelupusan (Arimura & Hibiki, 2024). Tindakan tersebut adalah turut sama dengan Negara-negara lain yang sedang membangun di Asia Tenggara seperti Malaysia, Singapura dan Indonesia. Selain daripada itu, terdapat beberapa perbezaan dalam kawalan, inisiatif dan aktiviti yang dilaksanakan. Pada umumnya, ia sedikit sebanyak melibatkan faktor kewangan, mentaliti masyarakat dan kekuatan undang-undang yang dijalankan merujuk kepada kemampuan dan keupayaan pihak berkuasa (Haqq & Gultom, 2021). Ini adalah kerana kos bagi pengurusan sisa pepejal yang berakhir dengan tapak pelupusan melalui kaedah yang bersesuaian akan berupaya mengurangkan pertambahan tapak-tapak pelupusan sisa baru dan sebagainya (Ichinose, 2024). Justeru itu, apa yang dilaksanakan di negara-negara maju untuk menguruskan sisa pepejal dengan baik boleh dijadikan panduan kepada negara-negara membangun bagi memastikan tahap kesejahteraan penduduk dan alam sekitar seiring dengan pembangunan dan kepesatan ekonomi sesebuah negara.

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ATTRACTIVENESS OF TVET PROGRAMS: FACTORS INFLUENCING STUDENTS' LEARNING ATTITUDES AT SUNGAI PETANI COMMUNITY COLLEGE

Wei Boon Quah[1*], Ezaida binti Ahmad[2]

[1]Hotel Operation Unit, Sungai Petani Community College, No. 77, Lengkok Cempaka 1, Pusat Bandar Amanjaya, 08000 Sungai Petani, Kedah, Malaysia

[2]Student Intake Unit, Sungai Petani Community College, No. 77, Lengkok Cempaka 1, Pusat Bandar Amanjaya, 08000 Sungai Petani, Kedah, Malaysia

*Corresponding author e-mail address: quah@kkspe.edu.my

Abstract

This study aims to identify the factors that influence students' attitudes towards selecting a Technical and Vocational Education and Training (TVET) institution for further education, specifically at Sungai Petani Community College (KKSP). A total of 92 students from four academic programs participated in the study. This study used a quantitative approach as the research method. A Google Form was used as the medium to distribute questionnaires to respondents. The instrument covered 6 sections of questionnaires, which included demography, parental influence, teachers, peers, career potential, social status, and students' attitudes toward TVET. Data analysis used in this study was descriptive and inferential statistical analyses (Pearson correlation and multiple regression). The findings showed that career potential was the most dominant factor influencing students' attitudes toward TVET ($r = .663$, $p < .01$), followed by peer influence ($r = .298$, $p < .01$) and teacher influence ($r = .225$, $p < .05$). However, parental influence and social status were not statistically significant. These findings suggested that prioritizing job opportunities, economic stability, and future security are the elements that affect students when making educational decisions. Therefore, graduate employability and strengthening industry partnerships should be emphasized by TVET institutions to ensure a relevant and up-to-date curriculum. This study highlighted some important implications for student recruitment strategies, curriculum development, and career guidance approaches in Malaysian TVET institutions.

Keywords: TVET; Career Potential; Peer Influence.

1. Introduction

Technical and Vocational Education and Training (TVET) has been recognised globally for its role in producing competitive, skilled labour. The increasing enrolment of students into TVET institutions in Malaysia shows that it has become a significant phenomenon in the landscape of national human capital development. This phenomenon aligns with international trends, where countries such as Germany, Switzerland, and South Korea have demonstrated that a well-structured TVET system anchored in industrial training can reduce youth unemployment, enhance technological innovation, and support sustainable economic growth (Nawi et al., 2024). Malaysia has also strengthened its TVET ecosystem through various government initiatives, including aggressive promotional campaigns, curriculum enhancements, and strategic collaborations with the industrial sector. This shift reflects a positive change in public perception of the TVET pathway, especially following the COVID-19 pandemic, which had previously impacted enrolment rates. As stated by Mohd Noor Shahudin, Senior Director of Academics at the Department of Polytechnic

and Community College Education (DPCCE), a total of 118,000 students enrolled in polytechnics and community colleges nationwide for the 2023/2024 academic session — an increase of nearly 20% compared to 90,000 students the previous year (Mohamed, 2023; Zainury, 2023). Furthermore, move to the context in Kolej Komuniti Sungai Petani (KKSP), the enrolment for KKSP has shown encouraging progress, with a consistent rise in student enrolment over the past two years — from 73 students in Session 2 2022/2023 to 68 students in Session 2 2023/2024 and surging to 104 students in Session 2 2024/2025. This increase raises a key question: what factors are driving this increase? Therefore, this study aims to identify factors such as career potential, peer influence, teacher influence, parental influence, and social status that affect students' attitudes towards selecting a TVET institution for further education. This study is expected to directly contribute to the development of more sustainable enrolment strategies at rural community institutions, while also enriching the existing literature on educational choice behaviour in the context of vocational education in Malaysia (Abdul-Aziz et al., 2020).

2. Literature Review

2.1. Parental Influence

In previous study by Mustafa and Lasmaya (2023) showed that students' decisions to pursue TVET are often influenced by parental roles as sources of motivation, career guidance, and educational direction. Additionally, parental career behaviour is shown to significantly shape students' self-efficacy in decision-making. In Chia et al.'s study (2021), the Analytic Hierarchy Process (AHP) has been used to identify parental influence as the most dominant factor in TVET selection. This aligned with Abdul-Aziz et al. (2020), where the study also mentioned that who family's role was emphasized in encouraging community college enrolment. In the study of Shaari et al. (2024), social norms superficially including family expectations, also play a role in this matter. As confirmed by Hamid and Othman (2024), the Theory of Planned Behaviour has been applied to highlight parental influence as a significant predictor of TVET enrolment intentions. In addition, Chia et al. (2023) and Foo and Jamil (2019) further reinforce that family and informal sources significantly impact student choices in the Malaysian context. However, studies conducted in Kenya and Ghana by Boateng et al. (2024) and Chola et al. (2023) revealed consistent patterns of paternal influence, suggesting familial impact as a cross-cultural factor in vocational decisions. Overall, these findings underscore that parental influence extends beyond emotional support to shape self-efficacy, educational aspirations, and vocational interest, indicating the importance of integrating family dynamics into policies aimed at strengthening TVET enrolment. Hence, the following hypothesis is proposed:

H1: There is a significant relationship between parental influence and students' attitudes toward selecting a TVET institution for further education.

2.2. Teacher Influence

Through teachers' pedagogical approaches, interpersonal skills, and levels of professional competency, the role of teachers in shaping students' inclination toward Technical and Vocational Education and Training (TVET) is highly significant. Furthermore, Omar et al. (2020) emphasized that the most crucial factor in establishing teaching effectiveness and boosting students' confidence in choosing TVET as a career path is teacher knowledge. Supporting this, student-centered teaching strategies were adopted by Malaysian TVET teachers, which foster critical thinking and self-motivation among students (Md Yunos et al., 2019). In addition, Salleh et al. (2022) further highlighted that mentoring roles and a conducive school environment shape

teacher competency within the Technological Pedagogical Content Knowledge (TPACK) framework. This matters, positively impacting students' learning experiences. Findings that align with Hamdan et al. (2021), who advocated for sustainable teacher training models suited for 21st-century educational demands. Next, student perceptions regarding the employability and relevance of TVET have been shaped by teachers, as it functions as a key information agent (Abdul-Aziz et al., 2020). Collectively, these studies underscore the importance of pedagogical strength, mentoring support, and teacher influence not only in developing student competencies but also in transforming vocational education into an appealing and strategic option, particularly for students from rural and underrepresented backgrounds. Thus, the following hypothesis is proposed:

H2: There is a significant relationship between teacher influence and students' attitudes toward selecting TVET institutions for further education.

2.3. Peer Influence

Peers are always viewed as a significant role in shaping students' attitudes and decisions towards their choice of educational pathways. This includes choosing Technical and Vocational Education and Training (TVET) as their study place. In the study of Abdul-Aziz et al. (2020), researchers highlighted that positive peer interactions serve as a strong motivating factor. Thus, by offering informal encouragement and emotional support, which in turn enhances students' interest in TVET and readiness to pursue community colleges. Added by Shaari et al. (2024), peer and community influence as the social norms that have a significant relationship with students' intentions to enrol in TVET. Similarly, peer influence has been identified as a key predictor in decision tree models, revealing that peers' perceptions and experiences can directly shape others' educational choices (Chia et al., 2021). In peer networks, unclear information is often shared among them regarding choosing education institutions; therefore, the importance of expanding TVET communication should be stressed (Omar & Mohd. Desa, 2023). Furthermore, peer-supported collaborative learning and informal experience sharing have been found to foster an encouraging social environment that increases students' confidence in exploring technical careers (Chia et al., 2021). Collectively, these findings suggest that peer influence is not merely supportive but a powerful catalyst for motivation, interest, and positive perception of TVET, especially among rural youth, and should therefore be actively incorporated into institutional communication and outreach strategies. Thus, the following hypothesis is proposed:

H3: There is a significant relationship between peer influence and students' attitudes toward selecting TVET institutions for further education.

2.4. Career Potential

For those who are seeking stable future employment, career potential is a key driver influencing students' decisions to pursue Technical and Vocational Education and Training (TVET). In Abdul-Aziz et al.'s study (2020), career prospects have been identified as the dominant "pull" factor for students enrolling in community colleges. Due to strong employability and immediate job opportunities in the industrial sector. Supported by Foo and Jamil (2019), researchers reinforce that students' decisions are shaped by individual preferences, institutional factors, and perceptions of job prospects, alongside external information and social cues. Aligning with this, the study from Amin et al. (2023) highlighted that the attractiveness of opportunities in technical and engineering fields was further bolstered by government efforts to elevate TVET's role in national human capital development. On the other hand, findings from Wafi et al. (2023) also

emphasize the integration of soft skills like leadership and entrepreneurship to improve graduates' adaptability in a dynamic job market. Meanwhile, Taha et al. (2022) debate a different perspective, which personal interests and personality traits are also significant, especially among students seeking fast-track, stable careers. These factors were from external employment pull versus internal personal drive that underscore the need for a holistic understanding of TVET enrolment motivations. Collectively, the evidence positions TVET as a high-impact platform that delivers career readiness, quick access to employment, and sustainable long-term growth. Thus, the following hypothesis is proposed:

H4: There is a significant relationship between career potential factors and students' attitudes toward selecting TVET institutions for further education.

2.5. Social Status

Social status plays a crucial role, particularly for those students with a socioeconomic background, in influencing students' inclination to pursue Technical and Vocational Education and Training (TVET) pathways. In the study done by Wang et al. (2025) found that students from low-income families are more likely to choose vocational education due to the perception of faster career entry and early income, which can alleviate financial burdens. However, this is reinforced by Pratama and Ridha (2019), who mentioned that a negative relationship exists between socioeconomic status and preference for traditional academic tracks, with lower-income students showing stronger interest in TVET. For those students who tend to plan for skill-based careers, the significant link between socioeconomic status and career planning will normally be the factors that affect economically disadvantaged students (Islamiyah et al., 2018). As added by Kabundula and Namushi (2023), socioeconomic factors are reported as the stronger predictors than psychological traits in determining vocational career choices. In Tüzel İşeri's findings (2019), further emphasized that students will pursue technical education as a pathway because students in low-income areas often have limited exposure to diverse career options. Thus, the following hypothesis is proposed:

H5: There is a significant relationship between social status factors and students' attitudes towards choosing TVET institutions for further education.

3. Methodology

This study was conducted at Kolej Komuniti Sungai Petani and involved students from the academic session 2/2024–2025. A total of 103 students from four academic programs were identified as the study population, namely those enrolled in the Certificate in Culinary Arts, Certificate in Hotel Operations, Certificate in Automotive Technology, and Diploma in Beauty Therapy programs. A quantitative approach was employed through the distribution of a questionnaire to the entire population (census sampling). The questionnaire was disseminated online via Google Form and shared with students through their respective class WhatsApp groups. Out of the 103 students, 92 provided complete responses, resulting in a response rate of 89.3%—a high and sufficient rate for statistical analysis. The questionnaire instrument was adapted and modified from a study conducted by Ali et al. (2024). It comprised seven main sections: Section A focused on students' demographic information; Section B included four (4) items on parental influence; Section C contained three (3) items measuring teacher influence; Section D assessed peer influence through three (3) items; Section E included three (3) items related to students' perceived job potential and career prospects; Section F evaluated students' social status using four (4) items; and Section G consisted of four (4) items assessing students'

attitudes toward TVET in general. A five-point Likert scale was used for measurement. Data collected were analysed using descriptive statistics to determine the mean, standard deviation, and response distribution, while inferential analysis (Pearson correlation and multiple regression) was used to examine the relationships and influence between the independent variables (parental influence, teacher influence, peer influence, social status, and career potential) and the dependent variable (students' attitudes toward TVET). 30 respondents were involved in the pilot test. Based on Cronbach's Alpha coefficient analysis, the result obtained was .779 for all 21 items across the questionnaire sections. According to Pallant (2020), a Cronbach's Alpha value between 0.7 and 0.8 indicates acceptable reliability.

4. Results and Discussion

A total of 92 students from Kolej Komuniti Sungai Petani provided complete responses to the questionnaire. The demographic data covered three key aspects: gender, ethnicity, and academic program. In terms of gender distribution, 54 respondents (58.7%) were female, while 38 respondents (41.3%) were male, indicating that female students formed the majority in this study. Regarding ethnic background, the majority of respondents were Malay, comprising 81 students (88.0%), followed by 10 Indian students (10.9%) and one Chinese student (1.1%), reflecting the general ethnic composition of the institution, which is predominantly Malay. In terms of academic programs, respondents were drawn from four main programs: Certificate in Culinary Arts (29 students, 31.5%), Certificate in Hotel Operations (22 students, 23.9%), Certificate in Automotive Technology (20 students, 21.7%), and Diploma in Beauty Therapy (21 students, 22.8%). The distribution across programs was relatively balanced, offering a representative overview of each academic area within the institution.

This study found that career potential is the most influential variable affecting students' attitudes toward selecting a TVET institution. This is supported by the Pearson correlation analysis, which showed a highly significant relationship ($r = .663$, $p = .000$) between this factor and students' attitudes. These findings are consistent with previous studies by Amin et al. (2023) and Wafi et al. (2023), which emphasized that job marketability and clear career pathways make TVET a primary choice among students, particularly in the context of national human capital development. Therefore, this tangible career outcome factor should be highlighted in TVET promotion strategies, especially in rural and low-income areas.

Additionally, this study also found that peer influence ($r = .298$, $p = .004$) and teacher influence ($r = .225$, $p = .031$) had significant relationships with students' attitudes toward TVET. These findings align with studies by Abdul-Aziz et al. (2020), Shaari et al. (2024), and Omar et al. (2020), which suggested that social relationships, such as peer encouragement and effective teacher guidance, positively impact students' interest and confidence in choosing TVET. In this context, student-friendly teaching approaches, hands-on learning, and peer experience-sharing appear to play crucial roles in shaping positive attitudes toward vocational pathways.

The study found that parental influence did not have a statistically significant relationship with students' attitudes toward choosing TVET institutions ($r = .162$, $p = .122$). This result contrasts with prior studies that consistently emphasized the influential role of parents in vocational decision-making. For example, Mustafa and Lasmaya (2023) and Chia et al. (2021) identified parents as key motivators in shaping students' confidence and intentions in selecting TVET, while Boateng et al. (2024) found that paternal support was the primary driver of enrolment among Ghanaian students. However, this study suggests that in the local context—specifically within Kolej Komuniti Sungai Petani—students may rely more on personal aspirations and social peer

influences rather than familial guidance. This divergence underscores the importance of contextual differences and suggests that while parental influence is important globally, it may not always translate uniformly across settings.

Similarly, the social status factor showed no significant correlation with students' attitudes toward TVET ($r = .039$, $p = .709$). This result challenges previous findings by Pratama and Ridha (2019) and Wang et al. (2025), who emphasized socioeconomic background as a key determinant of vocational inclination, especially among low-income students seeking quicker financial returns. In addition, Kabundula and Namushi (2023) highlighted socioeconomic status as a significant predictor in TVET enrolment models. Yet, this study reveals that such status may not strongly influence attitudes when students are exposed to other motivating factors such as job market demands or peer encouragement. Mohd Nawi et al. (2024) also argued that social perception can shift based on media and institutional strategies—indicating that broader societal views may diminish the direct impact of socioeconomic status on vocational attitudes.

Overall, the findings of this study suggest that students are more influenced by career-related and social factors from peers and teachers rather than traditional influences such as parents or socioeconomic background. Hence, TVET promotions should highlight career success stories, alumni involvement, and strengthened peer and teacher relationships as part of communication strategies. At the same time, policy interventions such as need-based scholarships, anti-stigma campaigns for vocational education, and community support must be implemented comprehensively to ensure long-term effectiveness.

Table 1. Summary of Pearson Correlation Analysis

		Parental Influence	Teacher Influence	Peer Influence	Career Potential	Social Status
Attitude	Pearson Correlation	.162	.225*	.298**	.663**	.039
	Sig. (2-tailed)	.122	.031	.004	.000	.709

Note. ** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

The results of the multiple regression analysis indicate that the model is statistically significant, with $F(5, 86) = 14.480$ and $p < .001$. This shows that all five independent variables collectively contribute significantly to variations in students' attitudes toward selecting a TVET institution. The R^2 value obtained was .457, meaning that 45.7% of the variance in student attitudes can be explained by the combination of the five factors studied: parental influence, teacher influence, peer influence, career potential, and social status.

However, when examined individually (refer to the coefficients table), only the career potential factor showed a significant influence on students' attitudes ($\beta = .625$, $t = 7.486$, $p < .001$). This is consistent with the findings of Amin et al. (2023) and Wafi et al. (2023), who highlighted that job marketability and career assurance are primary drivers that lead students to choose TVET as a future path. The study also supports the argument that quick and practical career opportunities are more relevant than traditional factors such as family influence.

Conversely, the factors of parental influence ($p = .934$), teacher influence ($p = .795$), peer influence ($p = .187$), and social status ($p = .932$) did not show statistically significant effects in the regression model. These findings contradict studies such as those by Mustafa and Lasmaya

(2023) and Shaari et al. (2024), which stressed social influences as strong predictors of educational pathway choices. This study has emphasized internal motivational drivers such as career security and readiness, as opposed to social conformity factors, which did not significantly predict students' attitudes toward TVET enrolment.

This discrepancy may be due to the differing demographic contexts of students, particularly in community institutions such as Kolej Komuniti Sungai Petani, where students tend to focus more on short-term outcomes and personal economic stability rather than external social influences. Therefore, this study suggests that TVET promotion should focus on delivering practical value, such as strong employment prospects, industrial training, and entrepreneurial skills—rather than relying solely on family or community influence.

In conclusion, these findings reflect the importance of career potential as a strategic element in enhancing student enrolment in TVET institutions, and support the need for policies that emphasize job security and close collaboration with industries as an effective foundation for TVET promotion.

Table 2. Summary of Multiple Regression Analysis Examining the Influence of Social Status, Career Potential, Parental Influence, Teacher Influence, and Peer Influence Factors on Students' Attitudes Toward TVET Enrolment

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.676[a]	.457	.426	.56357

Note. a. Predictors: (Constant), Social Status, Career Potential, Teacher Influence, Peer Influence, Parental Influence

ANOVA

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	22.995	5	4.599	14.480	.000[b]
Residual	27.314	86	.318		
Total	50.310	91			

Note. a. Dependent Variable: attitude
b. Predictors: (Constant), Social Status, Career Potential, Teacher Influence, Peer Influence, Parental Influence

Coefficients

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
(Constant)	1.027	.422		2.432	.017
Parental Influence	-0.008	.096	-0.009	-0.084	.934
Teacher Influence	0.025	.095	0.026	0.261	.795
Peer Influence	0.110	.128	0.129	0.329	.187
Career Potential	0.653	.087	0.625	7.486	.000
Social Status	-0.005	.064	-0.007	-0.086	.932

Note. a. Dependent Variable: attitude

5. Conclusion

This study aimed to identify the key factors that influence students' attitudes toward choosing Kolej Komuniti Sungai Petani (KKSP) as their preferred institution for further education, with a particular focus on social influences and career potential. The findings revealed that among all variables examined, career potential emerged as the most significant predictor of student attitude toward TVET enrolment, while peer influence and teacher influence also showed moderate and significant associations. In contrast, parental influence and social status did not yield significant effects within this study's context. These results emphasize that students are primarily motivated by practical considerations such as employability and career readiness, rather than traditional social or familial expectations. This reinforces the growing importance of outcome-driven narratives in promoting TVET as a viable and prestigious educational pathway, especially for students from economically vulnerable communities.

The findings of this study have important implications for TVET institutions, policymakers, and educators. Firstly, career pathways and employability outcomes should be prominently featured in TVET promotion strategies, including the use of real-world testimonials, alumni success stories, and stronger industry partnerships. Secondly, peer-based learning and teacher-led guidance must be optimized to influence attitudes positively, suggesting a need for more collaborative learning models, mentoring systems, and teacher capacity-building in communication and career advising. Lastly, although parental and social status factors were not statistically significant, their role should not be entirely dismissed—community-level engagement programs and family-inclusive awareness campaigns may still be effective in changing perceptions over time.

While this study provides insightful contributions, it is not without limitations. Firstly, the sample was limited to students from a single institution—Kolej Komuniti Sungai Petani—which restricts the generalizability of the findings to other regions or types of TVET institutions, particularly urban or private-based settings. Secondly, the data were collected cross-sectionally and thus do not account for long-term attitudinal changes or post-graduation outcomes. Future research should consider expanding the study across multiple colleges, incorporating longitudinal data, and exploring qualitative perspectives, such as in-depth interviews with students, parents, and instructors. Additionally, new variables such as digital literacy, parental education level, and exposure to career counselling could be integrated to build a more holistic understanding of TVET enrolment decision-making among Malaysian youth.

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LEADING FROM WITHIN: HOW WOMEN DIRECTORS AND TECHNOLOGICAL INNOVATION RESHAPE FIRM PERFORMANCE

Shah Rol bin Hussain*, Abdul Aziz bin Ishak

Commerce Department, Tuanku Sultanah Bahiyah Polytechnic, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: shahrol@ptsb.edu.my

Abstract

In the evolving landscape of corporate governance, gender diversity on boards is emerging as a strategic advantage. This conceptual paper explores how women directors enhance firm performance through their influence on technological innovation. Anchored in the Resource-Based View (RBV), it positions women directors as a valuable internal resource that strengthens innovation capabilities. By synthesising empirical findings and theory, the paper develops propositions that explain the role of women directors in reshaping technological innovation pathways in manufacturing firm performance. A conceptual framework is proposed to demonstrate the mediating role of technological innovation and align it with national priorities, such as the Twelfth Malaysia Plan, SDG 5 and 9, and the Malaysia MADANI framework. This study contributes by advancing RBV theory and offering a strategic governance model grounded in intangible assets. The implications highlight that technological innovation-driven firm performance can be built from within through inclusive leadership by women directors. This paper serves as a call to action for researchers, regulators, and business leaders to rethink board diversity beyond compliance and embrace its transformational potential.
Keywords: Board Gender Diversity; Technological Innovation; Firm Performance.

1. Introduction

Technological innovation has become a critical determinant of firm success, particularly in the evolving context of Malaysia's manufacturing sector. Firms are increasingly required to innovate in response to challenges such as limited technological adoption, operational inefficiencies, and rising domestic and global competition (World Economic Forum, 2023a). In this context, corporate governance, especially the composition of the board of directors, plays a vital role in driving firm performance. Within board structures, gender diversity is gaining recognition not only as a matter of equity but also as a driver of firm outcomes through more inclusive and innovation-oriented decision-making.

Despite national-level initiatives such as the Malaysian Code on Corporate Governance 2021, which recommends at least 30% women representation on boards (Securities Commission Malaysia, 2021) and the Twelfth Malaysia Plan's call for inclusive leadership, female participation at the board level in Malaysia remains below target (Economic Planning Unit, 2021). As of 2024, only 26% of board positions across all public-listed companies in Malaysia are held by women (MSWG, 2024). While this figure marks some progress, it also highlights the persistent underrepresentation of women in corporate decision-making roles. The implications of this imbalance extend beyond ethical considerations; it also limits the strategic potential of firms to benefit from the unique insights, values, and governance perspectives contributed by female board directors. A growing number of studies have demonstrated that board gender diversity is associated with better decision-making, improved risk oversight, and stronger firm performance

(Anita, 2024; Mohamed et al., 2022; Bacha & Azouzi, 2019; Post & Byron, 2015). However, a critical gap remains in understanding the mechanisms that link gender diversity to firm performance outcomes.

Although prior research has offered meaningful empirical insights, there remains a limited application of theory-driven frameworks that explain this internal process, particularly in emerging market contexts like Malaysia. The Resource-Based View (RBV), which conceptualizes firm success as stemming from internal resources that are valuable, rare, inimitable, and non-substitutable (VRIN), offers a relevant theoretical lens to examine the strategic role of women directors. Female board members contribute intangible yet distinctive value ranging from ethical reasoning to inclusive governance practices, which may serve as important enablers of a firm's technological innovation capacity.

Recent literature reflects a shift in the perception of board gender diversity from being viewed as a symbolic or compliance-driven measure to being recognised as a strategic resource that directly enhances firm performance. Studies by Kamble et al. (2023) highlight that women directors are increasingly recognised as catalysts for technological innovation readiness, ethical governance, and inclusive strategic thinking. These findings are especially pertinent in the context of Malaysian manufacturing firms, where technological innovation capabilities remain inconsistent and where inclusive governance reforms are still in progress.

Despite the growing empirical evidence supporting the benefits of gender-diverse boards, three significant research gaps can be identified. First, there is a notable lack of studies examining the mediating role of technological innovation in the relationship between board gender diversity and firm performance, and this leaves a significant theoretical and empirical gap in the Malaysian manufacturing context. Second, the RBV framework has been widely applied to innovation studies, but they are still limited in incorporating board composition, especially gender diversity, as a source of intangible strategic capital (Terjesen et al., 2016). This omission represents a critical theoretical blind spot in the literature.

These research gaps point to a specific problem: while Malaysia has made visible efforts to promote women in boardrooms, the underlying mechanisms, particularly how female directors influence firm performance through technological innovation, remain theoretically and empirically underexplored. This lack of clarity weakens the ability of researchers and practitioners to construct strategic frameworks that capture the full value of gender diversity in corporate governance.

The study reframes women directors not merely as ethical figures, but as innovation-enabling assets who possess distinctive human and social capital that contribute to a firm's performance. In doing so, the current study offers a framework that is not only theoretically robust but also practically aligned with Malaysia's national policy objectives. These include Sustainable Development Goals (SDG) 5 (gender equality), SDG 9 (industry, innovation, infrastructure), Twelfth Malaysia Plan (RMK12) (inclusive, high-tech industrial growth), and the MADANI Framework (*Inovasi*, *Keadilan*, *Daya Cipta*) promote innovation-driven and inclusive development. By integrating RBV with emerging governance practices and national aspirations, this current study has the potential to offer significant contributions to theory, policy, and managerial practice.

2. Literature Review

The literature on board gender diversity and technological innovation has expanded significantly over the past decade, particularly in relation to firm performance. However, a critical synthesis of this body of work reveals several persistent gaps, underscoring the need for a new conceptual approach. This section discusses two central constructs: board gender diversity as a strategic governance mechanism and technological innovation as a mediating enabler of firm performance. These themes are examined through the theoretical lens of the Resource-Based View (RBV), which allows for a more nuanced understanding of how intangible board attributes translate into competitive advantage.

Board gender diversity contributes to firm performance through multiple pathways. Female directors often bring diverse cognitive styles, greater emotional intelligence, and a broader stakeholder orientation to board deliberations. These characteristics enrich the decision-making process, improve ethical oversight, and promote more inclusive governance. For example, Post and Byron (2015), through a meta-analysis of firms in developed economies, found that boards with higher female representation were significantly associated with stronger financial performance. In the Malaysian context, Mohamed et al. (2022) demonstrated that companies with greater female board participation performed better on sustainability measures, highlighting the relevance of board inclusivity in emerging markets.

Beyond mere representation, prior studies have examined both quantitative and qualitative dimensions of board gender diversity. Quantitative measures include the proportion of women on boards and their independent director status (García-Sánchez et al., 2021). Meanwhile, qualitative studies have focused on committee participation, tenure, and engagement. For instance, women who hold roles in audit or innovation committees or participate actively in board meetings have been shown to influence innovation oversight and board effectiveness (Terjesen et al., 2016; Hafsi & Turgut, 2021).

From the RBV perspective, these contributions can be conceptualised as strategic resources. Unlike tangible assets such as capital or machinery, the competencies and insights brought by women directors are intangible, context-specific, and difficult to replicate, meeting the VRIN criteria of value, rarity, inimitability, and non-substitutability. Terjesen et al. (2016) argue that women contribute both cognitive diversity and moral capital, which enhance the board's ability to govern effectively and formulate strategic direction. These qualities position board gender diversity as a form of strategic capital that contributes to a firm's sustained competitive advantage.

At the same time, technological innovation has been identified as a dynamic organisational capability that enhances firm performance, particularly in sectors undergoing digital transformation. In the context of Industry 4.0, firms that effectively implement innovation strategies are more agile, productive, and competitive (Kamble et al., 2023). Technological innovation encompasses more than just R&D; it involves transforming new ideas into viable products, services, or operational processes. To measure this multifaceted capability, prior research has employed proxies such as R&D intensity (e.g., R&D expenditure relative to sales), patent filings and citations, and innovation efficiency indicators (e.g., products-sales ratio to R&D inputs). For example, Chen et al. (2021) shows that boards with more female directors significantly boost R&D performance, including innovation output and productivity, often via their enhanced roles in monitoring and oversight. Similarly, studies like those by Kamble et al. (2023) measure innovation outputs through metrics such as patent counts and new product revenue, demonstrating a strong link between board gender diversity and innovation success. These indicators collectively reflect

a firm's capacity to deploy internal knowledge and resources consistent with RBV theory as strategic assets that drive sustained competitive advantage.

Recent empirical findings suggest a positive association between board gender diversity and technological innovation outcomes. Chen et al. (2023) found that firms with gender-diverse boards showed higher R&D intensity, indicating that female directors often support innovation-led strategies. Hafsi and Turgut (2021) reinforce this by arguing that board diversity improves openness to change and tolerance for risk, both essential components of technological innovation.

Yet, despite these promising insights, many studies fall short of explaining how innovation acts as the mechanism through which board diversity influences firm performance. This lack of mediation-focused theorisation represents a critical research void. Existing studies tend to focus either on direct diversity-performance links or general innovation outcomes, with few offering a clear, theory-driven model explaining the indirect effects. Additionally, there is limited alignment between research findings and policy frameworks such as MCCG 2021, SDG 5 and 9, or RMK12. Bridging this divide is essential for producing research that not only advances theory but also informs policy and practice.

To address these gaps, this study offers an integrated conceptual model that links governance reform, specifically board gender diversity, with technological innovation and firm performance, all situated within the RBV framework. The table below summarises how key elements of RBV theory are mapped to operational constructs used in this study, drawing on recent empirical findings.

Table 1. RBV Theoretical to Empirical Mapping Matrix

RBV Construct	Abstract Element	Operational Proxy	Source
Valuable	Strategic decision-making diversity	Percentage of women on boards	García-Sánchez et al. (2021)
Rare	Limited gender representation	<30% female board participation	MSWG (2024)
Inimitable	Inclusive leadership experience	Ethical oversight and governance	Hafsi & Turgut (2021)
Non-substitutable	Innovation orientation and board capital	R&D investment and innovation output	Chen et al. (2023)

3. Methodology

As a conceptual paper, this study does not involve empirical data collection. Instead, it adopts a structured literature synthesis approach, which is widely recognised in theory-building research and commonly used in high-impact journals such as the Academy of Management Review and Journal of Business Research. This method enables the formulation of theoretically grounded propositions through the critical integration of relevant literature.

The first step involved defining the research scope and keywords. The study focused on literature at the intersection of corporate governance, gender diversity, technological innovation, and firm

performance, particularly in the context of Malaysian manufacturing firms. Keywords included "Board Gender Diversity," "Female Directors," "Resource-Based View (RBV)," "Technological Innovation," "Innovation Capability," "Firm Performance," "Corporate Governance," "Malaysia," and "Manufacturing Firms." Boolean operators were used to enhance search accuracy.

Next, sources were selected from reputable academic databases such as Scopus, Web of Science, Emerald Insight, SpringerLink, ScienceDirect and Google Scholar. Only peer-reviewed journal articles published between 2015 and 2024 were included, with preference given to Q1–Q3 journals. Policy reports from institutions like the Securities Commission Malaysia and the World Economic Forum were also incorporated.

Articles were then screened and coded in two stages. Abstracts were reviewed for relevance, followed by full-text evaluations for theoretical depth, methodological rigour, and alignment with the study's objectives. The literature was categorised based on key variables (e.g., board diversity, technological innovation), construct relationships (direct, mediating, or moderating), and theoretical frameworks used. The coded studies were grouped into thematic clusters under three main constructs: board gender diversity, technological innovation, and firm performance. This thematic organisation facilitated the identification of consistent patterns and relationships across disciplines.



Figure 1. Flowchart of Conceptual Paper Protocol

From this synthesis, two research propositions were developed:

P1: Board gender diversity positively influences firm performance.
P2: Technological innovation mediates the relationship between board gender diversity and firm performance.

Finally, a conceptual model was constructed in Figure 3.2 to visually represent the hypothesised relationships. The model situates technological innovation as the mediating variable between board gender diversity and firm performance, framed within RBV theory and aligned with policy imperatives such as MCCG 2021, SDG 5 and 9, RMK12 and MADANI Framework.

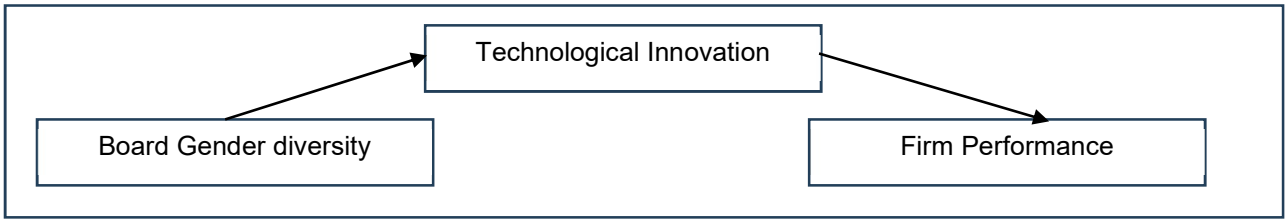


Figure 2. Conceptual Paper

4. **Implications and Contributions of the Study**

This study makes a significant theoretical contribution by extending the RBV to incorporate board gender diversity as a strategic internal resource that enhances firm performance through technological innovation. While RBV has traditionally emphasised tangible assets and technical know-how, this paper reconceptualises women directors, especially in the manufacturing context, as intangible but critical assets that support technological innovation readiness. By doing so, the current study enriches RBV literature with a governance perspective that is often overlooked in emerging markets like Malaysia.

The proposed model advances the corporate governance literature by emphasising the mediating role of technological innovation. Rather than assuming a direct causal link between board gender diversity and firm performance, the model provides a theory-led, causally nuanced explanation that acknowledges internal innovation capabilities as the true performance drivers. This contributes to a deeper understanding of how intangible board capital operates within the firm to produce tangible outcomes.

On a practical level, the study offers a valuable framework for corporate decision-makers. It encourages firms to move beyond compliance-based gender quotas and instead adopt strategic approaches to board appointments. Female directors with backgrounds in R&D, digital transformation, or innovation strategy can bring immediate value to firms, particularly those navigating technological shifts and firm performance transitions in the post-pandemic economy.

The proposed framework not only contributes to the academic understanding of board gender diversity and innovation but also aligns with several national and global development agendas. First, it advances Sustainable Development Goal 5 (Gender Equality) by highlighting the strategic value of women's participation in corporate leadership, particularly their contribution to ethical governance and innovation-oriented decision-making (United Nations, 2015). This supports ongoing efforts to elevate women into decision-making roles, as recommended by the Malaysian Code on Corporate Governance (MCCG 2021), which sets a 30% minimum target for female board representation (Securities Commission Malaysia, 2021).

Second, the study contributes to SDG 9 (Industry, Innovation, and Infrastructure) by positioning technological innovation as a core mechanism linking governance diversity to firm competitiveness. By identifying innovation as a mediating variable, the study provides strategic insight into how Malaysian firms, especially in the manufacturing sector, can strengthen industrial

capabilities through inclusive governance and internal knowledge resources (Kamble et al., 2023; World Economic Forum, 2023b).

Moreover, the framework supports Pillars 1 and 4 of the Twelfth Malaysia Plan (RMK12), which promote an inclusive, high-tech, and innovation-driven economy. Pillar 1 advocates for restructuring the economy to be more progressive and inclusive, while Pillar 4 encourages the advancement of green technology and future-proof industrialisation (Economic Planning Unit, 2021). This study's focus on leveraging female board members' strategic capital to drive innovation resonates with both goals.

Finally, the study echoes the values of the MADANI framework, particularly Inovasi (innovation), Keadilan (justice/equity), and Daya Cipta (creative empowerment). By reframing women directors as enablers of innovation and inclusive governance, the research supports the creation of ethically grounded, innovation-led firms aligned with MADANI's nation-building aspirations (Prime Minister's Office of Malaysia, 2023).

The study also lays the groundwork for future academic inquiry. The conceptual model can be empirically tested, refined across sectors, or extended through cross-country comparisons in ASEAN and other emerging economies. It opens a pathway for research that integrates governance, innovation, and strategic performance in contexts where intangible resources are central to long-term competitiveness.

5. Limitations and Future Research

Despite offering a theoretically robust and policy-aligned framework, this study has several limitations. As a conceptual paper, it does not empirically validate the proposed relationships, which may limit its immediate applicability. Furthermore, the model is situated within the Malaysian manufacturing context and may not be generalisable to other sectors or economies. The exclusive reliance on the RBV may also restrict theoretical plurality, overlooking alternative explanations from institutional or behavioural theories. Lastly, potential publication bias in the reviewed literature and the assumption of causal pathways without empirical backing are acknowledged. These limitations present opportunities for future research to empirically test and extend the proposed framework across diverse contexts and theoretical paradigms.

Future research should undertake longitudinal studies on Malaysian manufacturing firms to examine how gender-diverse boards influence innovation trajectories and long-term performance. This is particularly relevant in light of ongoing governance reforms under RMK12 and MADANI.

Comparative sectoral analysis spanning services, finance, and digital industries can determine whether the technological innovation-enabling impact of board gender diversity is consistent or varies by industry context. Additionally, in-depth qualitative research, such as interviews or ethnographic studies, could offer richer insights into how women influence boardroom dynamics, innovation culture, and strategic outcomes.

Future studies should also explore intersectional factors, including how the effects of gender director combine with other attributes like tenure, expertise, or independence. Finally, cross-national studies across ASEAN could contribute to building a regional governance index that integrates gender inclusivity, innovation, and strategic capability.

6. Conclusion

This study presents a novel, theory-driven framework that positions board gender diversity as a strategic internal resource within the RBV, capable of enhancing firm performance through its influence on technological innovation. By integrating governance, technological innovation, and public policy, the study redefines the role of women directors not as tokens of compliance but as powerful contributors to organisational technological innovation and firm performance. In the context of Malaysia's economic transformation and global moves towards inclusive governance, this framework offers timely guidance. It supports national development goals, aligns with MCCG 2021 and RMK12, SDG5 and 9 and operationalises the MADANI principles. More importantly, it offers a flexible, research-driven model that can guide firms in building innovation capabilities from within. The study calls on scholars to empirically validate and refine this framework, on corporate leaders to embed inclusive technological innovation strategies in their governance models, and on policymakers to go beyond quotas towards systemic reform. To build competitive, resilient, and future-ready firms, leadership must evolve—not just from the top, but from within.

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KAJIAN KEBERKESANAN ALAT BANTUAN MENGAJAR *FUEL INJECTION SYSTEM TEACHING KIT* (FISTKIT) KEPADA PELAJAR SIJIL SERVIS KENDERAAN RINGAN (SKR) KOLEJ KOMUNITI KEPALA BATAS

Abu Hassan Jabar bin Abu Bakar

Kolej Komuniti Kepala Batas, 13200 Kepala Batas, Pulau Pinang, Malaysia

Corresponding author e-mail address:abu.hassan@kkkba.edu.my

Abstrak

FISTKit merupakan alat bantuan mengajar yang direka bagi membantu pensyarah melakukan demonstrasi simulasi operasi sistem suntikan bahan api petrol. FISTKit dapat menunjukkan secara langsung kepada pelajar bagaimana prinsip sistem suntikan bahan api berlaku. Rekabentuk FISTKit ini juga dibangunkan dengan mengambilkira ruang pelaksanaan proses PdP yang kondusif kerana Sesi PdP yang melibatkan amali memerlukan pelajar untuk berinteraski secara efektif bagi mencapai Hasil Pembelajaran Kursus. *FISKiT* dicipta dengan menggunakan gabungan peralatan komponen sistem suntikan bahan api kenderaan yang terpakai yang telah dibaikpulih dan disusun mengikut kedudukan sebenar dalam kenderaan di atas kerangka mudah alih. Pada kenderaan sebenar semua komponen Sistem suntikan bahan api kenderaan berselindung di sebalik komponen kereta yang lain. Dengan menggunakan FISTKit, pelajar dapat melihat dengan lebih jelas konsep semburan bahan api yang berlaku di dalam sistem enjin pembakaran dalam (Internal Combustion Engine). Kajian ini dijalankan melalui soal selidik kepada seramai 56 orang pelajar SKR tentang penggunaan FISKIT dan keberkesanannya terhadap proses pengajaran dan pembelajaran di dalam kelas.
Katakunci: FISTKit; Sistem suntikan bahan api; Proses pengajaran dan pembelajaran.

1. Pengenalan

Modul Sistem Pengurusan Enjin menawarkan para pelajar dengan pengetahuan dan kemahiran secara teori dan amali mengikut proses kerja sebenar kaedah penyelenggaraan yang melibatkan sistem enjin pembakaran dalam dengan menggunakan peralatan dan kemahiran pelajar. Salah satu dari modul tersebut mendedahkan para pelajar dengan kerja-kerja penyelenggaraan sistem suntikan bahan api petrol di mana pelajar mampu melaksanakan kerja-kerja menguji dan memeriksa sistem suntikan bahan api petrol. Pelajar juga dikehendaki untuk mengenali proses kendalian aliran bahan api petrol melalui Fuel Pump dan menetapkan kadar suntikan serta mekanisme Fuel Injector. Oleh itu, satu alat bantu mengajar telah dibangunkan bagi memudahkan pensyarah dalam penyampaian PdP kepada pelajar Sijil Servis Kenderaan Ringan (SKR) Kolej Komuniti Kepala Batas. Setelah itu, satu kajian tentang keberkesanan alat bantu mengajar FISKIT ini telah dijalankan kepada pelajar. FISKIT adalah singkatan bagi Fuel Injection System Kit. Ianya adalah sebuah produk inovasi yang dibangukan berbentuk alat bantu mengajar bagi subjek Sistem Pengurusan Enjin. Komponen telah dilabelkan serta telah disertakan dengan penerangan padanya. Dengan adanya FISKIT ini, proses pengajaran dan pembelajaran menjadi lebih mudah kerana pelajar boleh melihat komponen-komponen dan mengetahui cara kerja Sistem Suntikan Bahan Api Kenderaan pada kenderaan sebenar.

1.1 Pernyataan Masalah

Sebelum pembangunan FISTKit, terdapat beberapa masalah yang dikenal pasti dalam proses pengajaran dan pembelajaran sistem suntikan bahan api petrol, yang menyebabkan pelajar kurang memahami dan sukar melaksanakan kerja amali dengan baik:

Ketiadaan model sistem suntikan bahan api petrol yang diasingkan daripada ruang enjin (engine bay), menyukarkan pelajar untuk melihat keseluruhan sistem secara berasingan.

Komponen-komponen sistem bahan api petrol adalah terpisah antara satu sama lain, menyebabkan pensyarah perlu menunjukkannya tanpa menjelaskan kesinambungan proses antara komponen tersebut.

Kekangan masa dan bilangan unit sistem suntikan bahan api petrol yang terhad menghalang peluang pelajar untuk berinteraksi dengan sistem secara individu.

Penggunaan komponen yang berulang kali meningkatkan risiko kerosakan dan kehilangan, serta kos penyelenggaraan.

Pelajar hanya merujuk gambar rajah dalam nota kuliah dan berkumpul di sekitar ruang enjin untuk mendengar penjelasan, menyebabkan mereka tidak dapat memahami sepenuhnya aplikasi setiap komponen secara keseluruhan.

Pelaksanaan amali oleh pelajar menggunakan komponen-komponen yang berasingan, menyukarkan pemahaman tentang aliran proses.

1.2 Objektif Kajian

a. Membangunkan Alat Bantu Mengajar FISKIT.
b. Mengkaji keberkesanan FISKIT kepada pelajar Sijil Servis Kenderaan Ringan (SKR) Kolej Komuniti Kepala Batas

2. Kajian Literatur

Alat Bantuan Mengajar adalah salah satu teknik penyampaian di dalam pengajaran dan pembelajaran untuk membantu pelajar memahami sesuatu topik dengan lebih mudah. Alat Bantuan Mengajar berfungsi sebagai alat yang boleh menimbulkan minat pelajar untuk belajar.

Alat Bantuan Mengajar dapat mambantu guru teknikal umumnya dalam menerangkan sesuatu perkara dan konsep isi kandungan pembelajaran dengan lebih tepat berbanding secara lisan. Banyak masalah yang timbul terutamanya masalah di dalam teknik penyampaian yang memberi kesan kepada pemahaman pelajar di dalam kelas. Penyelesaian kepada masalah itu adalah Alat Bantuan Mengajar (Abdul Rahim, 1992). ABM dapat menyelesaikan pelbagai masalah dalam kaedah pengajaran guru yang sentiasa berubah mengikut peredaran zaman. Dalam penyampaian dan pengajaran di dalam kelas, salah satu faktor utama menjadi penghalang kepada pemahaman pelajar adalah tumpuan pelajar. Tumpuan pelajar inilah yang menjadi penghalang kepada penyampaian berkesan. Tetapi, dengan adanya Alat Bantuan Mengajar, faktor kewujudan masalah tumpuan pelajar ini dapat diselesaikan (Ashaari, 1999).

3. Metodologi Kajian

Pembangunan inovasi FISKit melibatkan beberapa fasa utama:

Mengenalpasti Masalah: Fasa awal melibatkan pengenalpastian isu-isu dan kekangan dalam kaedah pengajaran sistem suntikan bahan api petrol sedia ada.

Reka Bentuk Model: Model FISKit direka menggunakan perisian Autodesk Inventor dan Mastercam. Proses ini melibatkan reka bentuk struktur dan susun atur komponen sistem suntikan bahan api petrol secara bersepadu.

Fabrikasi dan Pendawaian: Setelah reka bentuk dimuktamadkan, proses fabrikasi rangka inovasi dilakukan. Ini diikuti dengan proses pendawaian komponen inovasi untuk memastikan fungsi yang betul.

Pelaksanaan dan Penggunaan Inovasi: FISKit kemudian diintegrasikan ke dalam proses PdP. Pensyarah menggunakan FISKit untuk menerangkan prinsip suntikan bahan api petrol, menunjukkan simulasi, menjelaskan fungsi setiap komponen dan hubung kaitnya, serta mendemonstrasikan bentuk semburan bahan api petrol pada setiap Fuel Injector. Pelajar pula merujuk nota dan model FISKit untuk meningkatkan kefahaman dan mengenalpasti kedudukan komponen.

Analisa Keberkesanan: Penilaian keberkesanan FISKit dilakukan melalui pengedaran soal selidik kepada pelajar dan pensyarah, serta analisis markah kuiz pelajar sebelum dan selepas inovasi diaplikasikan dalam PdP. Soal selidik pelajar menumpukan kepada aspek Hasil Pembelajaran Kursus, manakala soal selidik pensyarah memfokuskan kepada skop pembangunan inovasi. Markah kuiz pelajar dianalisis untuk menilai peningkatan pemahaman teori.

3.1 Rekabentuk

Dalam rekabentuk ABM sistem suntikan bahan api ini, terdapat beberapa elemen penting yang perlu dipertimbangkan untuk memastikan fungsi yang efektif dan pemahaman yang baik bagi pelajar. Berikut adalah penerangan mengenai dua komponen utama serta paip sambungan yang diperlukan:

i. Pam bahan api:
   Fuel pump berperanan untuk mengangkut bahan api dari tangki ke sistem suntikan. Ia memastikan bahawa bahan api sampai dengan tekanan yang tepat untuk proses pembakaran yang efisien. Pastikan ukuran dan kapasiti pam bahan api sesuai untuk mengendalikan aliran bahan api yang diperlukan.

ii. Penyuntik bahan api:
   Penyuntik bahan api bertugas untuk menyuntik bahan api ke dalam ruang pembakaran pada tekanan dan sudut yang tepat. Ia memastikan campuran bahan api dan udara adalah optimum untuk pembakaran.

iii. Paip Sambungan:
   Paip sambungan diperlukan untuk menghubungkan fuel pump dan fuel injector, serta memastikan aliran bahan api yang lancar tanpa kebocoran. Pastikan paip yang digunakan mempunyai diameter yang sesuai dan tahan terhadap tekanan tinggi. Penempatan paip juga harus dipertimbangkan untuk memudahkan akses dan pengurusan dalam ruang yang terhad.

3.2 Keseluruhan Rekabentuk

Reka bentuk keseluruhan sistem ini perlu mempertimbangkan kesesuaian ukuran komponen serta keperluan untuk pembelajaran dalam kelas. Pastikan setiap komponen dapat dilihat dan diakses dengan mudah oleh pelajar. Uji sistem setelah pemasangan untuk memastikan ia berfungsi dengan baik, sekaligus memberi peluang kepada pelajar untuk memahami mekanisme dan interaksi antara setiap komponen dengan lebih jelas. Dengan cara ini, pelajar dapat memperoleh pengalaman praktikal yang berguna dalam memahami sistem suntikan bahan api secara keseluruhan.

3.3 Pembangunan

Membangunkan alat bantu mengajar bagi sistem suntikan bahan api kenderaan adalah satu langkah yang sangat berharga untuk meningkatkan proses pengajaran dan pembelajaran. Berikut adalah langkah proses kerja fabrikasi yang dilakukan:

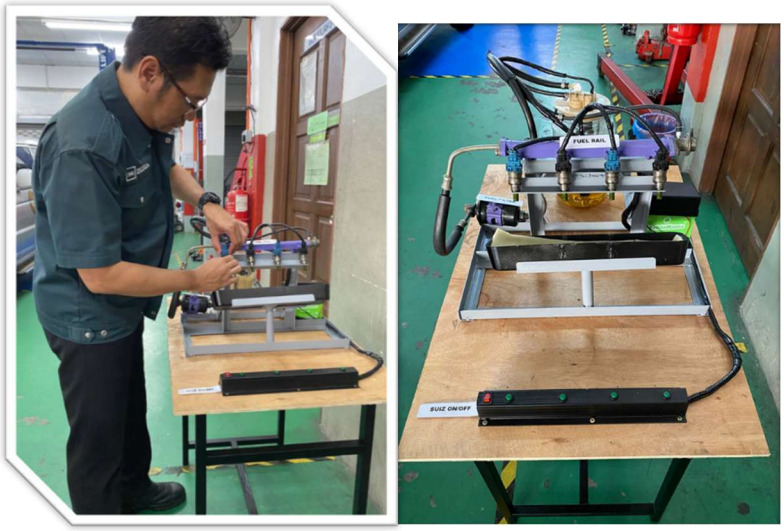
i. Pembaikan Komponen Terpakai:
Pam Bahan Api: Periksa dan pastikan ia berfungsi dengan baik.
Paip Sambungan: Pastikan tiada kebocoran dan sesuai dengan saiz komponen lain.
Penyuntik Bahan Api: Uji penyuntik untuk memastikan aliran bahan api yang tepat.
Suis dan Bateri: Pastikan suis berfungsi dengan baik dan bateri mencukupi untuk menyokong sistem.

ii. Penyediaan Rangka:
Pemilihan Bahan: Sediakan besi yang sesuai untuk dijadikan rangka. Pilih bahan yang cukup kukuh untuk menampung semua komponen.
Reka Bentuk Rangka: Rancang reka bentuk rangka yang membolehkan pemasangan semua komponen dengan kemas dan mudah diakses.

iii. Bina braket:
Reka bentuk braket untuk setiap komponen agar dapat dipasang dengan selamat pada rangka. Pasang braket dengan menggunakan skru atau las, memastikan setiap komponen terpasang dengan baik dan stabil.

iv. Pelabelan Komponen dan Aliran Bahan Api:
Gunakan label yang jelas untuk setiap komponen (pam, penyuntik, dan lain-lain) agar pelajar dapat mengenal pasti dengan mudah. Tandakan laluan aliran bahan api secara jelas agar pelajar dapat memahami proses dan interaksi antara komponen.

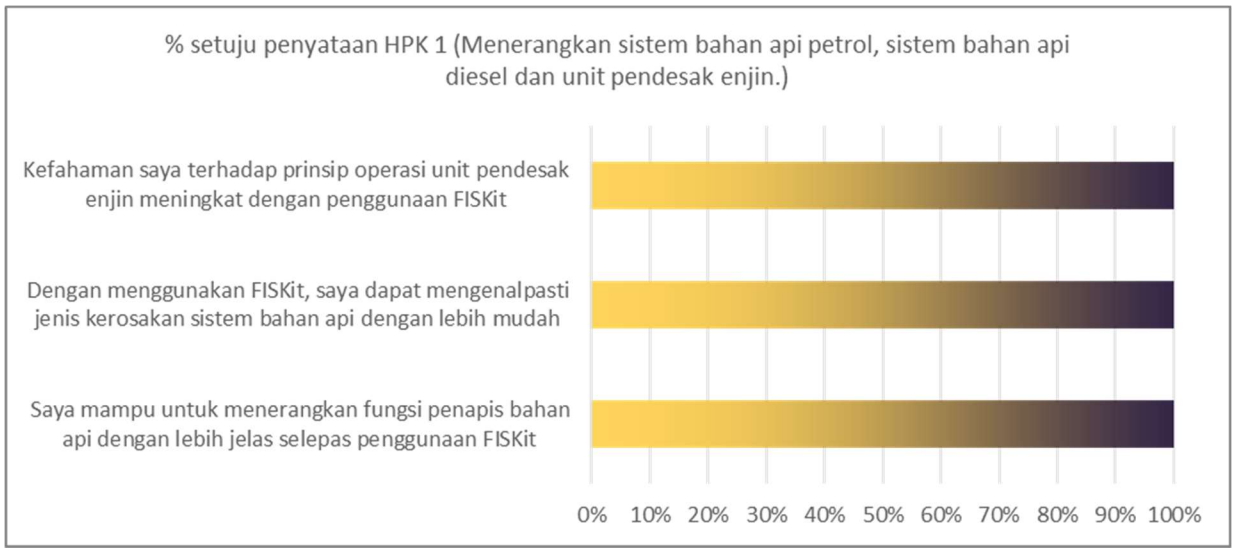
v. Pengujian dan Penilaian
Setelah semua proses selesai, lakukan pengujian untuk memastikan setiap komponen berfungsi dengan baik.

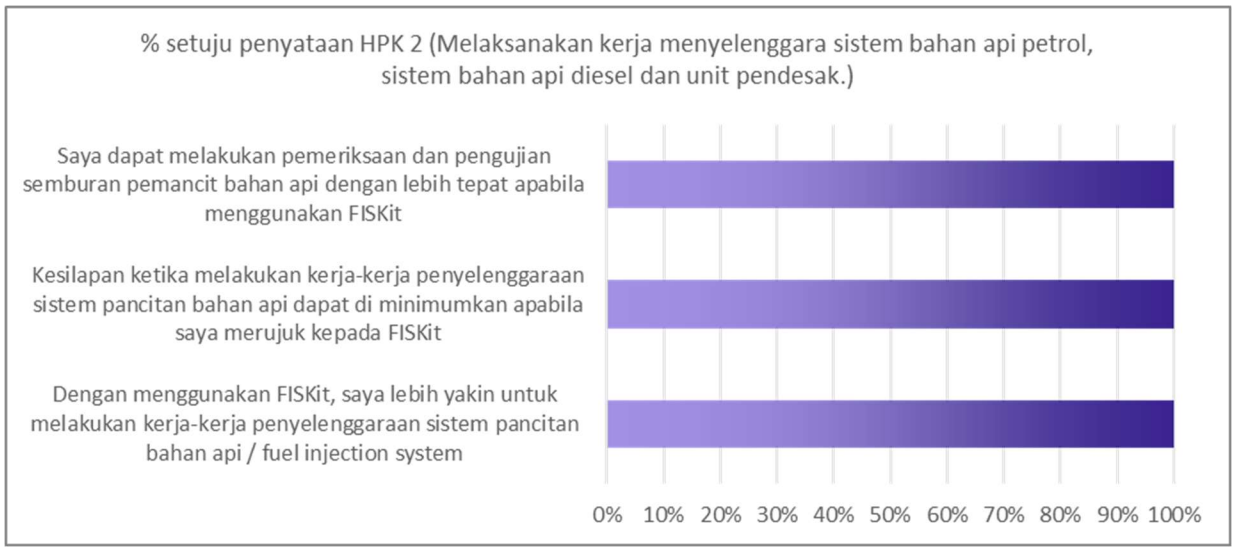


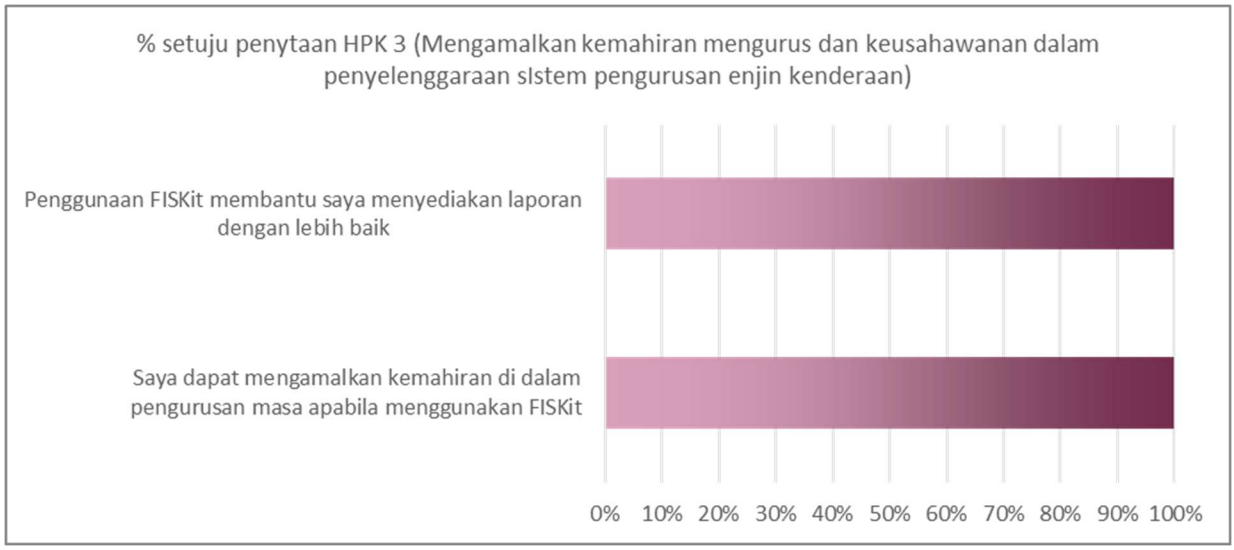
Rajah 1. Proses pembangunan FISKit

4. Analisis

Analisis keberkesanan inovasi FISTKit dijalankan berdasarkan dapatan soal selidik pelajar dan pensyarah, serta perbandingan markah kuiz pelajar sebelum dan selepas penggunaan inovasi. Analisis Dapatan Soal Selidik pelajar yang diedarkan kepada pelajar menunjukkan bahawa 100% pelajar bersetuju dengan penyataan dalam soal selidik. Ini mencerminkan persepsi positif pelajar terhadap keberkesanan FISTKit dalam meningkatkan kefahaman mereka terhadap sistem suntikan bahan api petrol. Keputusan soal selidik adalah seperti gambarrajah dibawah:







Rajah 2. Keputusan soal selidik pelajar

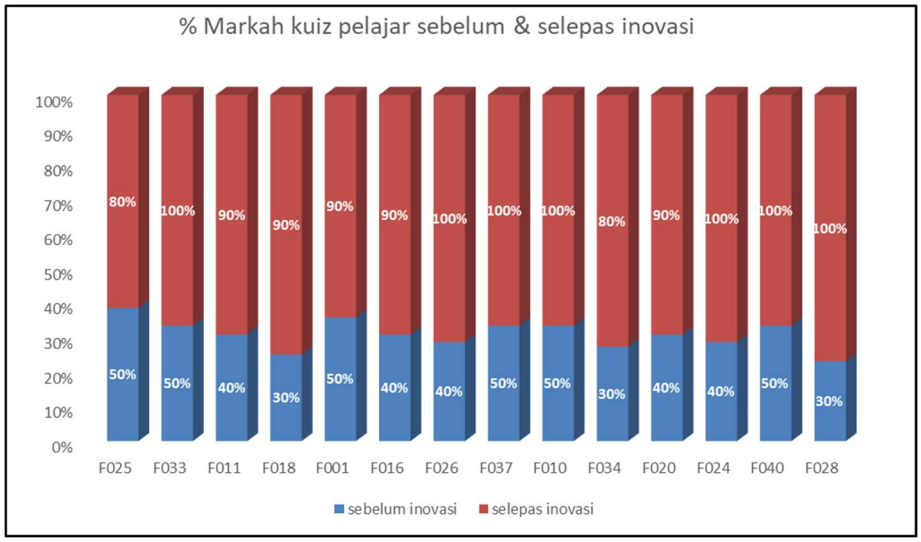
Analisis Dapatan Soal Selidik Pensyarah yang diedarkan kepada pensyarah juga menunjukkan bahawa 100% pensyarah bersetuju dengan penyataan dalam soal selidik. Ini menandakan bahawa pensyarah melihat FISTKit sebagai alat bantu mengajar yang berkesan dan memberikan impak positif dalam penyampaian PdP.



Rajah 3. Keputusan soal selidik pensyarah

Analisis Dapatan Pencapaian Markah Kuiz Pelajar Sebelum & Selepas Inovasi Analisis terhadap keputusan markah kuiz pelajar sebelum dan selepas inovasi menunjukkan peningkatan yang signifikan.

i. Sebelum inovasi, purata pencapaian markah pelajar dalam kuiz adalah 45%.
ii. Selepas penggunaan inovasi FISTKit semasa PdP, purata pencapaian markah kuiz pelajar meningkat kepada 80%.



Rajah 4. Markah kuiz pelajar

Berdasarkan analisis yang dilakukan, inovasi FISTKit telah memberikan kesan positif yang ketara kepada tahap pencapaian hasil pembelajaran kursus pelajar. Penggunaan inovasi ini juga telah berjaya menambah kepelbagaian kaedah penyampaian PdP yang lebih kondusif.

Impak Penghasilan Inovasi Inovasi FISTKit memberikan impak yang menyeluruh dalam beberapa aspek:

i. Kos: Kos untuk mendapatkan alat ganti yang hilang atau rosak dapat diminimumkan kerana pelajar dapat mengenalpasti kedudukan dan bilangan komponen yang ada pada sistem suntikan bahan api petrol dengan merujuk kepada inovasi.
ii. Masa dan Proses: Pensyarah dapat melaksanakan pembelajaran amali dengan lebih produktif kerana tidak perlu membuka dan memasang komponen sistem suntikan bahan api petrol setiap kali sesi penerangan amali. Inovasi ini juga mampu meningkatkan kemahiran psikomotor pelajar dalam menyelesaikan masalah.
iii. Kefahaman: Pemahaman pelajar tentang prinsip aliran bahan api petrol, aplikasi Fuel Pump dan Fuel Filter, serta fungsi Fuel Injector dapat ditingkatkan. Inovasi ini memudahkan pelajar memahami proses aliran bahan api dari Fuel Pump sehingga ke Fuel Injector.
iv. Susun Atur: Inovasi ini mempamerkan susun atur komponen yang jelas, menjadikan pelajar lebih cekap ketika melaksanakan aktiviti amali.

5. Kesimpulan

Inovasi FISTKit telah terbukti sangat berkesan dalam meningkatkan pemahaman dan kemahiran pelajar dalam bidang penyelenggaraan sistem suntikan bahan api petrol. Model ini berjaya

mengatasi masalah kekurangan model, komponen yang terpisah, dan kekangan masa yang dihadapi dalam kaedah PdP tradisional. Analisis data menunjukkan peningkatan ketara dalam pencapaian markah kuiz pelajar dan penerimaan positif daripada kedua-dua pelajar dan pensyarah. Impak inovasi ini melangkaui aspek akademik, meliputi penjimatan kos, pengurangan risiko, pengoptimuman masa, peningkatan kefahaman, dan pemupukan kemahiran psikomotor. FISTKit juga menjadi pemangkin kepada kepelbagaian kaedah PdP yang lebih konstruktif dan berinovasi.

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TRANSFORMING LIBRARY ACCESS IN TVET: A TAM-BASED EVALUATION OF THE AL-KHAWARIZMI 360° VIRTUAL TOUR INNOVATION

Azhani binti Ariffin*, Nurul Ashikin binti Rahmad

Politeknik Tuanku Sultanah Bahiyah, 09090 Kulim, Kedah,Malaysia

*Corresponding author e-mail address: azhani@ptsb.edu.my

Abstract

This paper presents the development and evaluation of the Al-Khawarizmi Virtual Tour: The Knowledge Portal, an immersive 360° digital library platform implemented at Politeknik Tuanku Sultanah Bahiyah (PTSB), Malaysia. As the first of its kind among Malaysian polytechnics, the platform addresses the declining trend in physical library engagement by providing seamless, remote, and sustainable access to library services. Guided by the Technology Acceptance Model (TAM), the study assessed user perceptions on usefulness, ease of use, enjoyment, behavioural intention, and actual use. A mixed-method approach was adopted through surveys, interviews, and usage data. Results revealed strong acceptance across TAM dimensions, a 60% reduction in staff workload and enhanced access for over 1,200 users within the first two months. Aligned with SDG 4 and SDG 13, and National Education policies, this innovation represents a transformative pathway in bridging digital skills, technology, and sustainability in TVET ecosystems.
Keywords: Virtual Library Tour; 360 Digital Platform; Technology Acceptance Model (TAM).

1. Introduction

In the digital age, traditional library services are rapidly evolving to meet the needs of a more tech-savvy, sustainability-conscious generation. For Malaysian polytechnics, particularly within the Technical and Vocational Education and Training (TVET) sector, this evolution is vital to remain competitive and relevant in a globalised education landscape. The shift from physical to digital services has been accelerated by the COVID-19 pandemic, which significantly reduced student attendance in physical libraries.

A particularly pressing concern has been the steady decline in library usage trends. Data from the Library Management System reflects a significant drop in physical library attendance before and after the COVID-19 pandemic. In 2019, the number of visitors recorded was 40,029, which sharply declined to 10,117 in 2020 and further dropped to its lowest point of 3,686 in 2021. Although post-pandemic years have seen gradual recovery, with attendance increasing to 18,606 in 2022, 27,540 in 2023, and 35,060 in 2024, these figures have yet to return to pre-pandemic levels.

More concerning is the drastic reduction in physical book loans, which dropped from 599 in 2019 to 49 in 2023, before slightly increasing to 183 in 2024. These numbers reflect a clear shift in user behaviour, with a growing preference for online and digital reading materials (Ahmad et al., 2022). As such, it becomes crucial for libraries to implement innovations such as the Al-Khawarizmi Virtual Tour, which offers users remote access to library facilities and resources without the need for physical presence. This initiative not only helps students familiarise themselves with library

services more effectively but also ensures that the library remains relevant in an increasingly digital educational landscape.

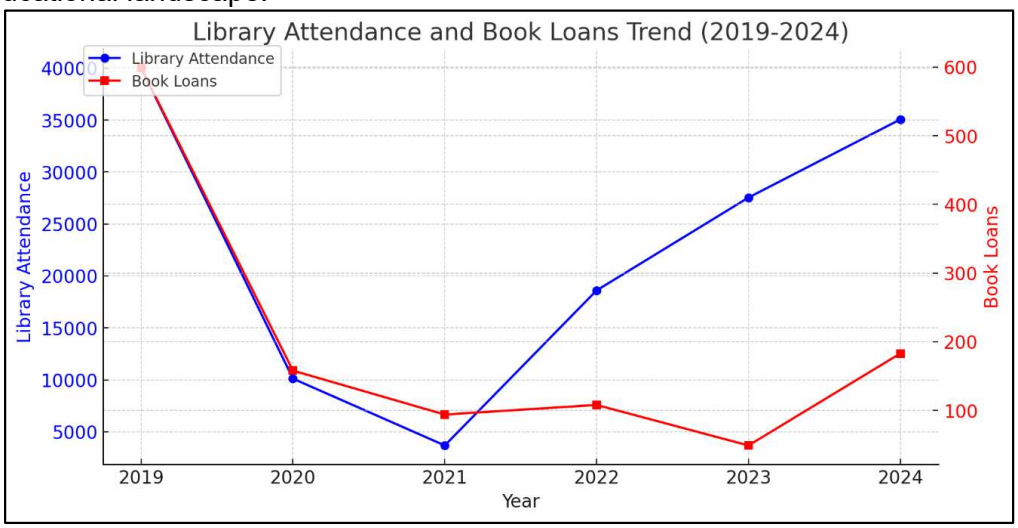


Fig. 1. Trends in Physical Library Visits and Book Loans (2019–2024)

Politeknik Tuanku Sultanah Bahiyah (PTSB) observed a drastic decline in physical library usage from 40,029 visits in 2019 to merely 3,686 in 2021. Although there was a moderate rebound in 2023 and 2024, it became clear that user preferences had permanently shifted towards digital and self-service modes of information access.

To counteract this trend, the library required an intervention that was not only accessible but also engaging for its predominantly Gen Z user base. While options like standard video walkthroughs lack interactivity and dedicated mobile applications can face barriers in development cost and user adoption, an immersive 360° virtual tour presents a compelling alternative. This technology offers a self-directed, exploratory experience that simulates physical presence, thereby fostering greater user autonomy and motivation.

Despite the potential of such technologies, their adoption within Malaysian polytechnic libraries remains minimal, and their effectiveness has been largely under-evaluated using formal academic frameworks. This study aims to fill that gap. The primary objectives of this research are:

i. To evaluate the user acceptance of the Al-Khawarizmi 360° Virtual Tour based on the Technology Acceptance Model (TAM).
ii. To assess the organizational impact of the innovation on operational efficiency, cost, and staff workload.
iii. To analyze the platform's alignment with national digitalization policies and Sustainable Development Goals (SDGs)

To address these challenges, Al-Khawarizmi Virtual Tour: The Knowledge Portal was conceptualised and developed. This innovation leverages immersive 360-degree virtual technology to simulate a full library experience, allowing users to navigate various zones, access orientation materials, and connect directly with e-resources such as KOHA and digital books. The initiative is aligned with broader national agendas, including the Digital Economy Blueprint, National STI Policy, Green Technology Master Plan, and TVET empowerment programmes under the Ministry of Higher Education.

The paper fits within the theme of iCie-TVET 2025, Transformative Pathways: Bridging Skills, Technology, and Sustainability in TVET, by demonstrating how digital innovation can serve as a scalable, sustainable, and user-friendly solution to revitalise key support services within the TVET learning ecosystem, particularly in the education domain.

2. Literature Review

The application of virtual tours in education is gaining momentum globally, especially in enhancing user engagement and facilitating remote access. Virtual reality (VR) and 360-degree immersive technologies have been widely used in sectors such as tourism, healthcare, and retail to simulate real-world experiences (Rahimizhian et al., 2020). In the education domain, particularly in TVET and higher learning institutions, such technologies offer students the opportunity to explore environments otherwise limited by time, geography, or access.

However, despite its potential, adoption within Malaysian library services has remained minimal. Most institutions still rely on traditional modes of library induction, such as printed guides, physical walk-throughs, and staff-led briefings. According to Arrasyid et al. (2020), immersive learning fosters autonomy and increases users' motivation to explore educational environments. Libraries can greatly benefit from this, especially when engaging Gen Z learners who are highly responsive to digital interfaces.

The Technology Acceptance Model (TAM), developed by Davis (1989) and later refined by Venkatesh et al. (2003), has been widely applied in evaluating user acceptance of digital platforms. The core constructs of TAM—Perceived Usefulness (PU), Perceived Ease of Use (PEU), and Behavioural Intention (BI)—provide a strong foundation for assessing how users interact with and adopt emerging technologies. For this study, additional constructs such as Perceived Enjoyment (PE) and Actual Use (AU) were also considered to gain a holistic understanding of user experience and adoption.

3. Methodology

This study adopted a mixed-method approach to assess the effectiveness of the virtual tour using the TAM framework. The methodology combined quantitative and qualitative data collection tools to ensure comprehensive insights.

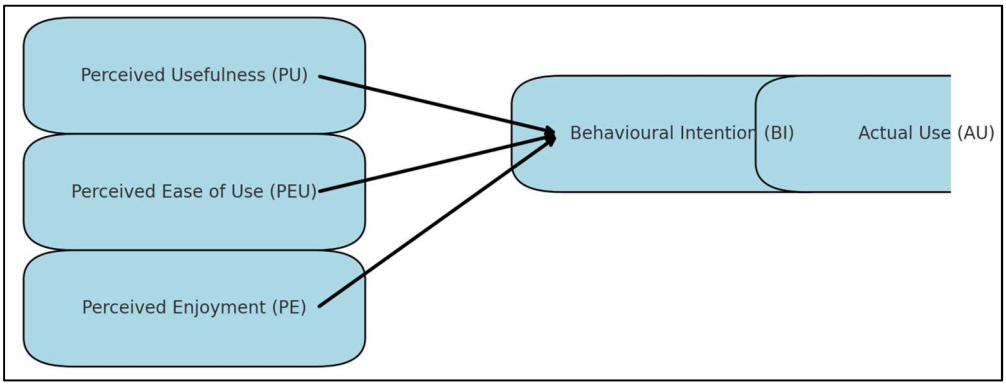


Fig. 2. The Adapted Technology Acceptance Model (TAM) Framework. The model illustrates the hypothesised influence of Perceived Usefulness (PU), Perceived Ease of Use (PEU), and Perceived Enjoyment (PE) on users' Behavioural Intention (BI) to use the virtual tour, which in turn affects Actual Use (AU)

3.1 Platform Development

The virtual tour was created using the Marzipano viewer, an open-source platform that allows seamless integration of 360-degree imagery. The content was captured using the Insta360 ONE R camera, covering all key zones in the Al-Khawarizmi Library: circulation desk, reference areas, discussion rooms, computer labs, and special collections. Each hotspot embedded in the tour links to informative audio narration, PDF guides, or external systems such as KOHA for catalogue search and user accounts.

3.2 Survey Instrument

A structured questionnaire based on the TAM constructs was distributed to 120 respondents recruited via convenience sampling from the Politeknik Tuanku Sultanah Bahiyah (PTSB) community. The participant pool comprised of students, academic staff, and administrative personnel, representing a diverse range of user perspectives. The instrument, adapted from previously validated TAM studies, included 25 items on a 5-point Likert scale, measuring the following:

i. Perceived Usefulness (PU)
ii. Perceived Ease of Use (PEU)
iii. Perceived Enjoyment (PE)
iv. Behavioural Intention (BI)
v. Actual Use (AU)

3.3 Interviews and Observations

To complement survey data, semi-structured interviews were conducted with 10 key stakeholders, including librarians, academic advisors, and ICT personnel. Observational data were collected over a period of one semester to track platform traffic, interaction duration, and user pathways. The qualitative data gathered from interviews were subsequently transcribed and analyzed using thematic analysis to identify recurring patterns and themes related to the virtual tour's usability and institutional impact.

4. Results and Discussion

Survey analysis revealed strong user acceptance across all TAM dimensions:

Table 1. User Feedback on Al-Khawarizmi Virtual Tour based on TAM Constructs

Category	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Perceived Usefulness	2%	4%	2%	34%	58%
Perceived Ease of Use	1%	3%	8%	31%	58%
Attitude Toward Using	1%	2%	6%	28%	63%
Behavioral Intention to Use	1%	2%	5%	27%	65%

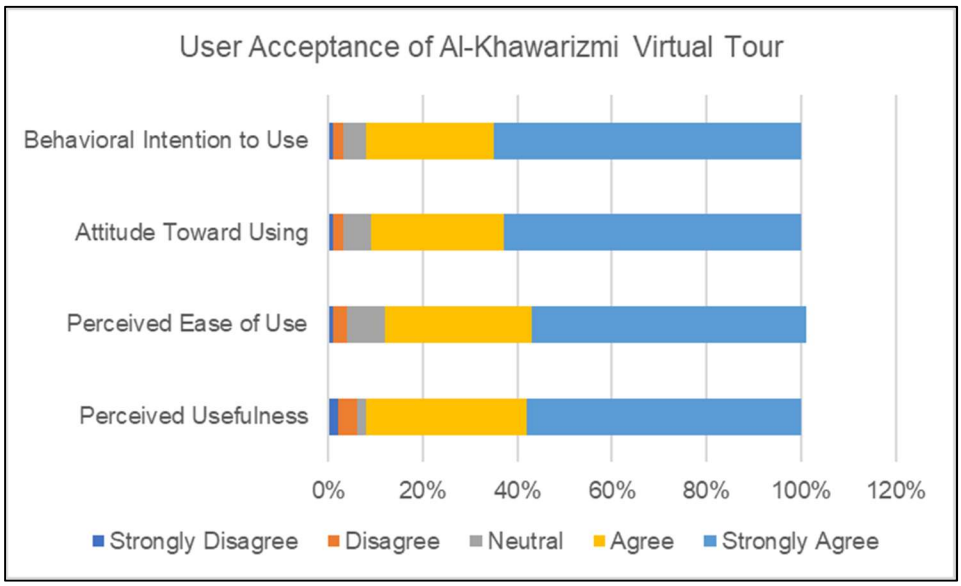


Fig. 3. User acceptance of Al-Khawarizmi Virtual Tour

i. Perceived Usefulness (PU): 92% of respondents agreed that the virtual tour improved their understanding of library functions and helped them use available services more effectively.
ii. Perceived Ease of Use (PEU): 89% agreed that the interface was intuitive and navigation was smooth, even for first-time users with a minimal technical background.
iii. Perceived Enjoyment (PE): 91% reported that exploring the virtual library was enjoyable and engaging, motivating them to spend more time interacting with library content.
iv. Behavioral Intention (BI): 92% indicated a strong likelihood of recommending the platform to peers and using it again in future.
v. Actual Use (AU): Platform analytics confirmed over 1,200 unique visits within two months post-launch, with an average session time exceeding three minutes per user.

The correlation analysis showed a significant positive relationship between PU, PE, and BI ($r=0.68$, $p<.01$), and between BI and AU ($r=0.55$, $p<.05$), supporting the predictive capacity of the TAM framework in this context.

4.1 Organisational Impact

The implementation reduced the need for physical library briefings by 60%, freeing up over 40 staff-hours per semester. It also reduced printing costs by eliminating the need for orientation brochures. The initiative contributed directly to KPI 15 under the JPPKK Strategic Plan, which promotes digital transformation in TVET support services.

4.2 Operational Cost Reduction and Cost-Efficiency Impact

A key institutional benefit of the Al-Khawarizmi Virtual Tour project lies in its impact on operational cost efficiency. Unlike many higher education institutions that engage external vendors for virtual tour development, often at rates between RM2,400 to RM4,000 annually, PTSB implemented an in-house model using the open-source Marzipano platform. This not only reduced capital expenditure but also eliminated ongoing licensing or hosting costs, as shown in Table 1 below.

Table 2.Cost-Efficiency Comparison of Virtual Tour Implementations in Malaysian Higher Education Institutions

HEIs	Website	Platform Used	Development/ Hosting Cost
Perpustakaan Awam Johor	https://ppaj.johor.gov.my/en/ppaj-virtual-tour/	Thinklink	RM4000/ year (External vendor)
Perpustakaan UiTM	https://library.uitm.edu.my/ptar-virtual/uitm-library-virtual	Pannellum	FREE
Perpustakaan UTHM	https://ptta.uthm.edu.my/using-the-library/lets-explore-ptta/pttas-virtual-tour.html	Metareal	RM1116/ year (External vendor)
UPM	https://virtualtour.upm.edu.my	3D Vista Virtual Tour Pro	RM2400 one off (External vendor)
PTSB	https://virtualtour.ptsb.edu.my	Marzipano (Open source)	FREE (Internal Team)

4.3 Environmental and Sustainability Contributions

The project supports multiple SDGs:

i. SDG 4 – Quality Education: By democratising access to library services.
ii. SDG 13 – Climate Action: By reducing reliance on print materials and physical transportation.

It also aligns with the National Green Technology Policy and the National STI Policy (2021–2030), specifically STI 4, which emphasises inclusive innovation and technology-driven service delivery.

4.4 Institutional Branding and Visibility

The virtual tour has been adopted as an official orientation tool and promotional material during open days and stakeholder visits. Its success has prompted management to expand virtual documentation to all key facilities at PTSB, including workshops, labs, and academic blocks.

4.5 Theoretical Implications

Beyond the institutional impacts, these findings have notable implications for the Technology Acceptance Model (TAM) within the TVET context. The strong positive response to Perceived Enjoyment (91% agreement) suggests that for immersive educational tools, this hedonic factor is a powerful driver of behavioral intention, potentially on par with the model's core constructs of usefulness and ease of use. This highlights the importance of user engagement and experience design in implementing new technologies for digital-native learners.

5. **Limitations and Future Research**

This study has several limitations. The findings are derived from a single institution, which may limit the generalizability of the results to other TVET contexts. Furthermore, the usage data were collected over a two-month period and reflect initial adoption rather than long-term, sustained use.

Future research could build onthis work by conducting a longitudinal study to track user engagement over several semesters. A comparative analysis across multiple polytechnics could also provide broader insights into the scalability of such innovations. Finally, exploring the technical integration of the virtual tour with Learning Management Systems (LMS) could reveal new pathways for embedding digital library resources directly into the curriculum

6. Conclusion

The Al-Khawarizmi Virtual Tour exemplifies how immersive technology can transform traditional library services into a flexible, scalable, and sustainable tool for enhancing educational support in Technical and Vocational Education and Training (TVET). Its high acceptance among users and measurable institutional benefits demonstrate the viability of similar innovations across Malaysia's polytechnic system and beyond. This model showcases a practical and impactful pathway in bridging technology, skill development, and sustainability, core beliefs of the iCie-TVET 2025 theme.

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DEVELOPMENT OF AN IOT-BASED HOME ENERGY MONITORING SYSTEM (HEMS) WITH CIRCUIT FAULT DETECTION FOR RESIDENTIAL APPLICATIONS

Pimpa a/p Soowan*, Zarina binti Ismail, Hasnita binti Ramli

Electrical Engineering Department, Tuanku Sultanah Bahiyah Polytechnic, 09000 Kulim, Kedah, Malaysia

*Corresponding author e-mail address: pimpa@ptsb.edu.my

Abstract

The growing demand for energy efficiency and real-time electrical monitoring in residential settings has accelerated the adoption of Internet of Things (IoT) technologies. Traditional home electrical systems often lack detailed energy tracking and fault detection capabilities, making it challenging for homeowners to manage consumption and ensure electrical safety. Recent advancements in microcontroller-based platforms and wireless communication have enabled the development of smart monitoring systems at a competitive cost. This study presents the development of an IoT-based home energy monitoring system using the ESP32 microcontroller. The system employs the PZEM-004T sensor module to measure key electrical parameters such as voltage, current, frequency, power factor, and energy consumption. Additionally, ZMPT101B voltage sensors are used to monitor voltage across individual circuit breakers, enabling precise circuit-level analysis. All data is transmitted via Wi-Fi and visualized through a Node-RED dashboard, allowing homeowners to monitor their home's electrical usage in real time. The system also features remote fault detection and isolation: when a fault is detected in any circuit, users are alerted and can remotely disconnect the affected circuit through the dashboard interface. By combining low-cost hardware with intelligent IoT integration, this system enhances home energy efficiency, safety, and user convenience.
Keywords: PZEM-004T; Node-RED; Real-time

1. Introduction

Energy monitoring in residential settings has become increasingly important as households aim to reduce energy waste, improve safety, and manage electricity bills more effectively. Traditional electrical distribution systems typically lack real-time visibility into energy consumption patterns, making it difficult for homeowners to identify inefficient appliances or sudden increases in usage. By continuously tracking electrical parameters such as voltage, current, frequency, power factor, and total energy consumption, a smart monitoring system can provide valuable insights to promote energy-saving behaviour and support more accurate billing estimations. In addition to consumption tracking, fault detection plays a critical role in ensuring home electrical safety. Overvoltage, undervoltage, or abnormal load conditions in individual circuits can pose serious risks, including equipment damage or fire hazards. Malaysia has experienced a significant increase in fires caused by electrical short circuits, recording 2,030 structural fires in 2024, a sharp rise from 1,264 incidents in 2023, with the majority occurring in residential landed homes ("Malaysia Records Highest Number of Fires Caused by Short Circuits in Past Three Years," 2025). Notable cases include a fire in March 2025 at Sarawak General Hospital's laboratory in Kuching, which was caused by overloaded wiring that triggered a short circuit ("Electrical Short Circuit Causes Minor Fire at Sarawak General Hospital Lab," 2025), and a February 2025 tragedy

in Melaka where aged electrical wiring led to a fire that claimed the lives of five family members ("Short Circuit Suspected in Melaka Fire That Killed Five," 2025)

Early detection and response are essential. Real-time monitoring and analysis of power consumption in home energy usage is an important part of energy management. The monitoring interface allows users to observe energy consumption in real time and analyse trends over time, encouraging more conscious energy usage (El-Khozondar et al., 2024). Anis et al., 2024 in their study proposes the development of a smart power distribution box that leverages Internet of Things (IoT) technology to provide real-time monitoring and automated fault detection within low-voltage electrical systems. The system is designed to address inefficiencies in conventional distribution boards by enabling proactive fault isolation and remote system supervision. Electrical parameters and fault conditions were transmitted via Wi-Fi to a cloud platform, allowing users to visualize data and control circuit breakers through a web or mobile dashboard. Shaban & Alsharekh, (2022) developed a smart low-voltage distribution panel board that utilizes Internet of Things (IoT) connectivity and machine learning to monitor and manage household energy consumption in real time. The system integrates voltage and current sensors with a microcontroller and Wi-Fi module, using the Blynk IoT platform for data visualization and remote access. For predictive analysis, the authors applied Gaussian Support Vector Machine (SVM) regression to be the most effective for accurate load forecasting. Nguyen & Nguyen, (2023) in their study develops an IoT-based smart electric meter that enables real-time electricity monitoring, remote appliance control, and automatic bill calculation. The system enhances transparency and efficiency by displaying data on the Blynk app, an LCD screen, and Google Sheets.

By reducing the risk of electrical fires and promoting safe energy practices, the system enhances the safety and sustainability of urban and residential living environments. The system promotes efficient energy use by providing real-time monitoring and cost tracking, helping users reduce unnecessary consumption. It supports access to modern energy services by enabling smart infrastructure that prevents energy waste and ensures safety in electrical distribution. This project aims to use Internet of Things (IoT) technology to develop an IoT-based home energy monitoring system with circuit fault detection for a single-phase residential application. The objective of this project is to design a real-time energy monitoring system and fault detection capabilities that are incorporated in the distribution box. The PZEM-004T sensors will measure in real-time the value of important parameters such as voltage, current, power, energy, frequency, and power factor. ZMPT100B voltage sensors were utilized to detect voltage abnormality in the circuit. In case of abnormality, such as potential overload in the circuit, voltage drop, or surge, the homeowner will be notified through a Telegram message. In addition, to ensure energy is utilized optimally, the system calculates utility costs monthly in real time. Daily energy usage is also displayed for user reference and consumption awareness.

2. Methodology

Leveraging the capabilities of IoT, this system is designed to detect current, voltage, energy, and power values using the PZEM-004T sensor. The data read by the sensor is sent to EMQX Cloud via a Wi-Fi connection. The data stored in the cloud is visualized through a Node-RED dashboard. In the event of a potential overload, tripped circuit, voltage sag, or surge, a notification is automatically sent to the homeowner via the Telegram app. In addition to displaying data on the dashboard, Node-RED is also designed to have switches that can be activated to send a control signal to isolate the faulty circuit by activating a relay. Besides that, the ESP32 also displays the sensor data in real-time on the LCD. Fig. 1 shows the structure of the HEMS proposed.

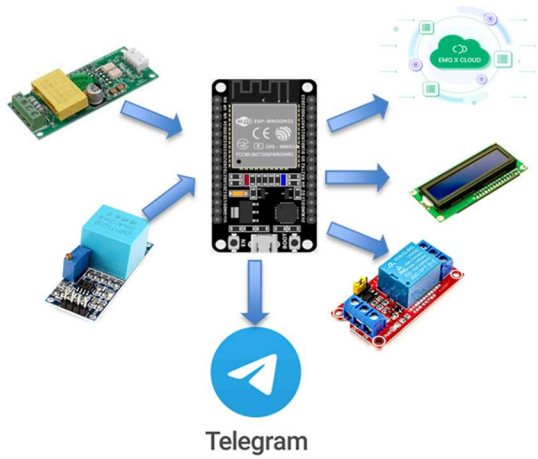


Fig. 1. Overview structure of the proposed HEMS

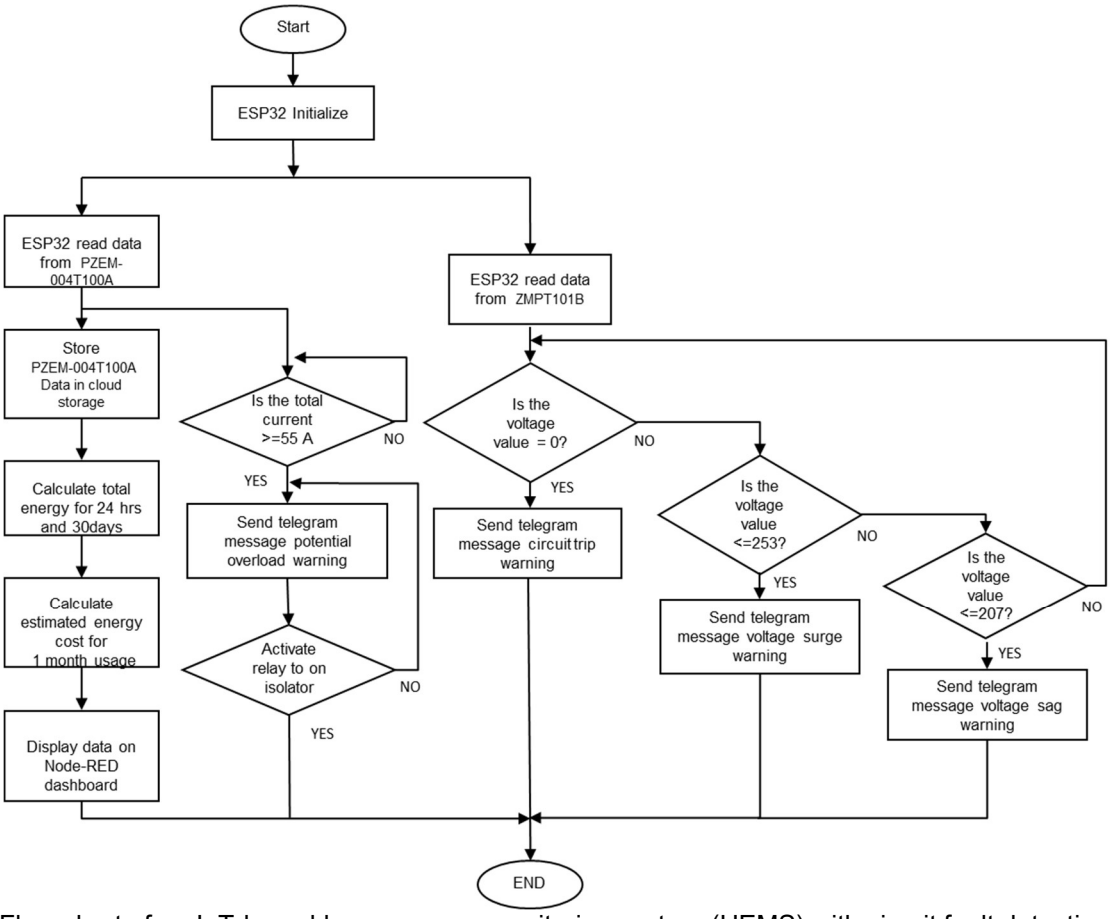


Fig. 2. Flow chart of an IoT-based home energy monitoring system (HEMS) with circuit fault detection.

Figure 2 illustrates the overall system flowchart, outlining the key processes involved in the monitoring and protection operation. As shown in the diagram, the system continuously measures electrical parameters at the main distribution board using integrated sensor modules. These measurements are processed and transmitted wirelessly for real-time analysis and visualization.

The system is designed to detect critical electrical conditions and issue timely alerts in the event of anomalies. It acts as an additional layer of protection, working alongside existing safety devices such as the Miniature Circuit Breaker (MCB) and Residual Current Circuit Breaker (RCCB). While these conventional protective devices perform their intended functions effectively, they do not offer real-time feedback or status visibility. By incorporating intelligent monitoring features, this system addresses the limitations of traditional protection equipment, enabling users to remotely access the operational status of the distribution board. This integration of real-time monitoring with automated fault response enhances both energy management and electrical safety in residential environments.

The PZEM-004T sensor is used to measure the total energy consumption, while the ESP32 microcontroller transmits this data to the EMQX Cloud, where it is stored for further processing. Using a Node-RED dashboard, the collected data is visually presented in real-time. The system continuously calculates the total energy used over 24 hours, as well as the cumulative energy consumption over 30 days. These values are displayed clearly on the dashboard interface. Based on the energy usage, the system estimates the monthly electricity cost, providing users with better insight into their energy expenses. In addition to monitoring energy, the system is also designed to detect voltage sags and surges, utilizing real-time data from the ZMPT101B voltage sensor for anomaly detection and alert generation.

The Energy Commission has mandated the use of MS IEC 60038:2006 – IEC Standard Voltages as the reference for nominal voltage levels in newly implemented low-voltage supply systems in Malaysia. According to this standard, the nominal voltage is 230/400V, with a tolerance range of +10% to -6% at a frequency of 50 Hz ±1% (Department of Standards Malaysia., 2006). As such, any supply voltage between 216.2V and 253V is within the normal operating range. Voltages that exceed or fall below this range are deemed potentially harmful to electrical appliances. When such conditions are detected, the system will automatically send a warning notification via the Telegram app to alert the homeowner of the anomaly.

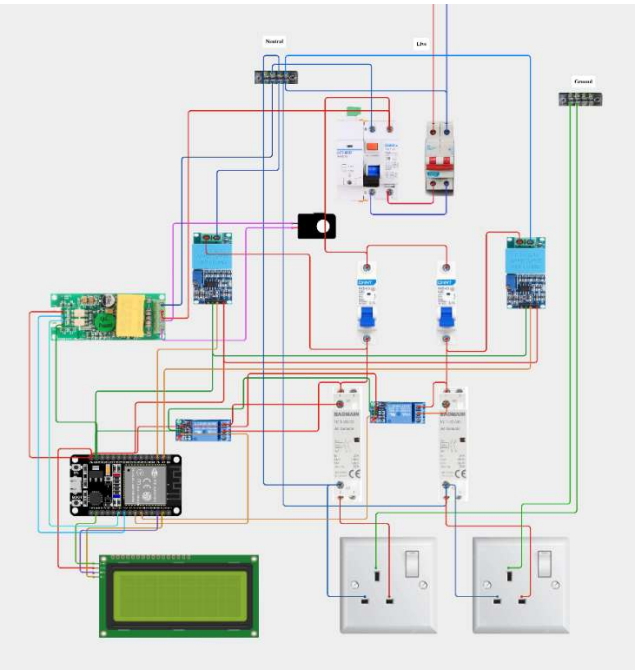


Fig.3 Hardware circuit design diagrams of HEMS

The circuit design for the Home Energy Management System (HEMS) is illustrated in Fig. 3. The devices involved in this system include the ESP32, RCCB (residual current circuit breaker), main switch, MCB (miniature circuit breaker), isolator, PZEM-004T, ZMPT101B, LCD display, and relay module. In this system configuration, there are two MCB outputs connected to separate load circuits, enabling individual circuit control and monitoring.

Table 1. GPIO Pin Connection

	Input/output	ESP32 GPIO Pin	Pin Mode	Note
1	PZEM-004T	17	Output	Measure voltages, Current, Power, Energy, Power Factor and Frequency
		16	Input	
2	ZMPT101B	36	Input	Measure Voltages
		39	Input	
3	Relay	18	Input	As switches, turn On and Off
		19	Input	
4	LCD (16x2)	21	Output	Display data to the LCD
		22	Output	

Table 1 shows the GPIO pin connections between the ESP32 and all connected sensors. GPIO pins 17 (Tx) and 16 (Rx) are used to interface with the PZEM-004T sensor, which measures voltages, current, power, energy, power factor, and frequency of the power supply to the main distribution board. The ZMPT101B1 and ZMPT101B2 voltage sensors are connected to GPIO pins 36 and 39, respectively, to monitor voltage levels across each circuit breaker. GPIO pins 18 and 19 function as input control signals for the relay module, enabling the system to activate an isolator and disconnect a circuit breaker from the load when necessary. An LCD is connected to GPIO pins 21 and 22 to display real-time measurement data.



Fig.4. Prototype of hardware proposed for IoT-based HEMS

To enable communication between the hardware, sensors, and the MQTT broker in the Home Energy Management System (HEMS), the Arduino IDE software is used. (Mallahi et al., 2022). The hardware prototype designed for HEMS is shown in Fig. 4. The code for the system is compiled and uploaded to the ESP32 microcontroller. The system visualizes data from related sensor nodes on ESP32 using Node-RED.

3. Results and Discussion

To assess the accuracy of the sensor readings, five different types of electrical loads were used during the testing phase. The recorded sensor values are presented in Table 2. This evaluation aims to determine the sensor's accuracy by comparing the measured values against the rated specifications of each load.

Table 2. Measured values against the rated specifications of load

Load	Rating (W)	Condition	Volt	Ampere	Watt	Error
Lamp	9	ON	240.0	0.08	9.30	3.33%
Lamp	11.5	ON	239.2	0.07	11.70	1.74%
Air Fryer	1500	ON	234.0	6.67	1562.00	4.13%
Iron	1000	ON	236.7	4.14	976.60	2.34%
Hair dryer	2000	ON	233.5	7.70	1812.00	9.40%
				Average Error		4.19%

The percentage error is calculated using the equation below (Satria et al., 2022).

$$Er(\%) = \left|\frac{True\ value - Read\ value}{True\ value}\right| x100\% \quad (1)$$

$$\%\ Average\ Accuracy = \frac{\sum \%\ Accuracy}{n} \quad (2)$$

$$\%\ Average\ Error = \frac{20.95\%}{5} = 4.19\%$$

Power accuracy = 100% - 4.19% = 95.81%

Based on data from Table 1, the accuracy of the sensor measurement is 95.81%.

The protection device was tested to verify the proper operation of Isolator 1 and Isolator 2 during relay activation and deactivation. The results of the test are presented in Table 3.

Table 3. Result of testing on an activated and deactivated isolator

Button Press	Isolator1	Isolator 2
"Isolator 1 ON"	ON	OFF
"Isolator 1 OFF"	OFF	OFF
"Isolator 2 ON"	OFF	ON
"Isolator 2 OFF"	OFF	OFF

The data received from the ESP32 sensor node is displayed on a custom-designed dashboard interface, as illustrated in Fig.5. This data is recorded and visualized in the form of graphs on the dashboard screen.

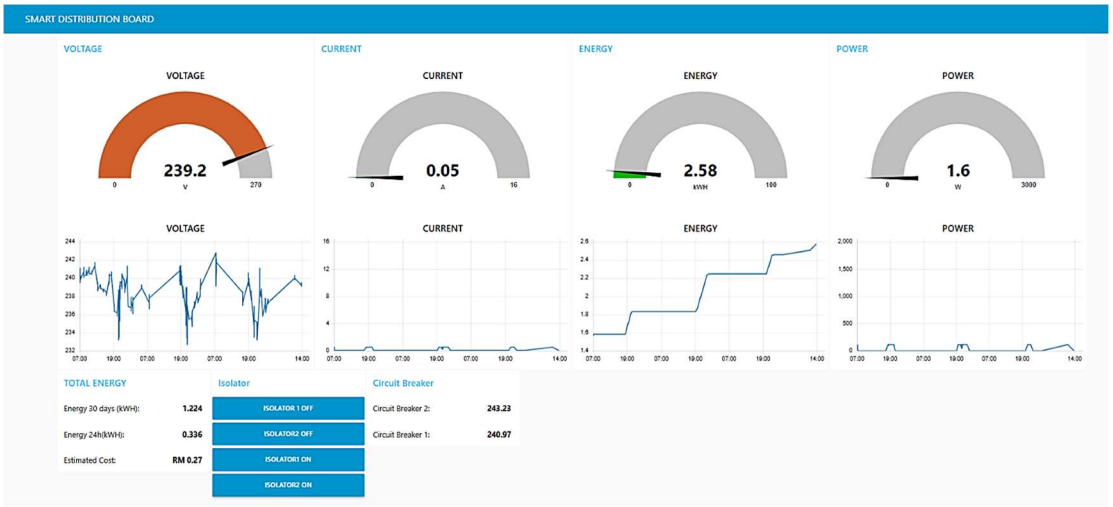


Fig.5. The dashboard is designed to display the system's results in real time.

The dashboard display provides users with real-time information on voltage, current, energy, and power consumption. It also shows the total energy usage, enabling users to estimate their daily and monthly electricity costs. Additionally, the system displays the voltage levels at each circuit breaker, allowing users to detect any abnormalities or irregularities in the power supply. The dashboard is also equipped with a control button that allows users to remotely disconnect the circuit by activating the isolator for safety or fault isolation purposes. The system is designed to send real-time notifications to users via the Telegram application in the event of a circuit trip. In addition to trip alerts, it also provides warnings about abnormal voltage conditions, such as voltage sags or surges, offering users timely information for effective monitoring and preventive action. The Telegram application notification is shown in Fig. 6. In addition to sending notifications, the system continuously displays real-time data on an integrated LCD screen for on-site monitoring, as shown in Fig.7.



Fig. 6. Telegram app notifications



Fig.7. Sensor data displays on LCD screen

Monthly energy consumption is systematically recorded, and the total usage is presented on the dashboard interface. The calculation of energy cost is based on the tariff rates (per kWh) specified by the utility provider, Nur Power. The detailed cost calculation structure is illustrated in Table 2.

Table 2. Nur Power tariff block structure

Block	Block Tariff (kWh)	Rate (RM)
1	200	0.2180
2	100	0.3340
3	300	0.5160
4	300	0.5460
5	>900	0.5710



Fig. 8. Estimation cost of energy consumption

Based on the measurements displayed on the dashboard, the total energy consumed is 1.224 kWh. Using the energy cost from block 1, where each unit is priced at RM 0.2180, the manually calculated total energy cost amounts to RM 0.266832. The system rounds this value to RM 0.27, using two decimal places as appropriate for standard billing practices, as shown in Fig. 8.

4. Conclusion

This study successfully demonstrates the development of a smart energy monitoring and protection system using the ESP32 microcontroller integrated with various sensors and IoT technologies. The system is capable of real-time monitoring of key electrical parameters such as voltage, current, power, energy consumption, and power factor. Sensor accuracy was validated through testing with multiple electrical loads, and the results confirmed reliable performance within acceptable error margins.

A user-friendly dashboard was designed to display live data, including energy usage and cost estimates based on utility tariff blocks. In addition to real-time visualization, the system enhances safety by sending instant notifications via Telegram in the event of circuit trips or abnormal voltage conditions such as sags or surges. It also enables remote disconnection of circuits through relay-controlled isolators, further improving fault response and energy management capabilities.

Overall, the integration of IoT, energy tracking, and automated protection mechanisms presents a comprehensive solution for household electrical monitoring, cost optimization, and safety enhancement. This system lays the groundwork for scalable applications in smart grid and home automation environments.

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A PROTOTYPE MOBILE ROBOT LEARNING KIT FOR MECHATRONICS STUDENTS IN MALAYSIAN POLYTECHNICS

Neoh Hock Seng

Mechanical Engineering Department, Politeknik Tuanku Sultanah Bahiyah, 09000, Kulim Hi Tech Park, Kulim, Kedah, Malaysia

Corresponding author e-mail address: neoh@ptsb.edu.my

Abstract

This paper proposes a low-cost solution to address the problem of the lack of mobile robot learning kits for Mechatronics students in Malaysian polytechnics, particularly in the subjects of PID control and line following. This learning kit is built around the Raspberry Pi 4 microcontroller and the OpenCV libraries. The control algorithms were written in Python. As an added feature, it displays live video feeds during the line-following control. The magnitudes of the control parameters, error, and motor speeds can be stored as data files and displayed graphically for future analysis and review. The integration of control theory, vision systems, and programming creates an updated multidisciplinary learning experience for Mechatronics students. The combination of hands-on learning and theoretical understanding would enhance engineering education in line with the requirements of Industry 4.0.
Keywords: Line Following; Vision; PID.

1. Introduction

The integration of vision systems in line-following robots for educational purposes has been actively used recently. It has been increasingly used as an alternative to teach students how to use mobile robots for line-following tasks, which thus far have been traditionally reliant on infrared sensors (Devi et al., 2024).

A low-cost mobile robotics platform (Oguten, S., Kabas,2001) was developed to perform heuristic optimization of PID controllers. The line-following task was facilitated with reflective sensors. It did not include vision-based sensing or GUI-based parameterizations. A lightweight and durable mobile robot (Pavon et al., 2023) was developed utilizing PID-based algorithms for line following. However, no GUI was designed to modify the control gains. The Webots simulator in Python implemented line-following by a virtual mobile robot. OpenCV libraries were used (Maarif et.al., 2020) for this purpose. Various line configurations were successfully detected for the line following tasks. However, no real-world line following was performed for comparison. Line following was not confined to differential drive mobile robots. Other platforms, such as a four-legged robot (Asfora, 2021), were used for the same purpose. It utilized colour vision-based PID control and is simple to reproduce for educational purposes.

In Malaysia, a low-cost differential mobile robot equipped with a webcam was built for line-following tasks (Ismail et al., 2009). The mobile robot detected white lines on a green floor surface. An image segregation method was used to ensure that the necessary information was provided to the robot's controller. This ensured that the vision system performed well in varying lighting conditions.

Artificial intelligence has also been incorporated to enable line-following mobile robots to be used as teaching tools. For instance, fuzzy logic (Aji et al., 2023), neural networks (Leal et al., 2025),

and deep learning (Alshammari et al., 2022) are popular artificial intelligence architectures applied in line-following control. Fuzzy logic enables the encoding of inputs such as line error and angle deviations into a set of rules that can be used to control the turning actions of the mobile robot to follow the path of the line. Neural networks and deep learning learn to map sensor inputs to motor outputs by adjusting the weights during training. This ensures robust performance in tracking unfamiliar paths.

Despite the worldwide growing adoption (Brigido & Oliveira, 2025) of vision systems in line-following mobile robots for educational purposes, there is currently no adoption of their use in mechatronics programs at Malaysian polytechnics. There is no published evidence or syllabi to demonstrate their use. The primary challenge for polytechnic students is to build vision-based line-following mobile robots for educational purposes. This paper addresses this problem by proposing a low-cost, modular line-following mobile robot learning kit that is simple to build and can be reused for mechatronics students in Malaysian polytechnics. The following sections will explain their functionalities.

2. Methodology

Figure 1 shows the physical structure of the mobile robot. Its chassis consists of two plastic bases. The bottom base supports two DC motors at its back. At the front, there is a roller that acts as the front wheel. The upper base supports the Raspberry Pi 4 microcontroller and contains the L293 H-bridge motor controller, as well as a 9V battery pack. Two 3.7-volt lithium-ion batteries power the Raspberry Pi 4. The C615 Logitech webcam is fixed to a long plastic plate that is attached to the front bracket of the bottom base. The webcam's wire is attached to the USB port of the microcontroller.

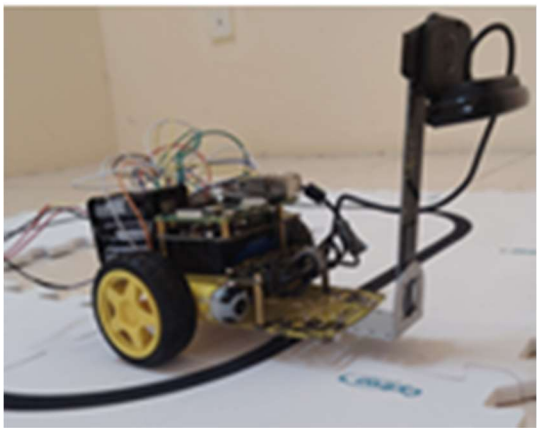


Fig. 3. Mobile Robot

The relatively high position of the webcam (12.5 cm above the floor surface) ensures that the track on the floor is visible within its field of view. Figure 2 shows this clearly.



Fig.2. Field of View of the Track

The software design, implemented in Python, is the heart of the line-following mobile robotics system. It is modular in design, consisting of a camera streaming module, a PID control algorithm, and a speed controller. The camera streamer enables the webcam to capture video and perform frame extraction. The PID controller controls the steering behaviour along the line based on proportional, integral, and derivative gains. The speed control module adjusts the speed of the DC motors based on pulse-width modulation techniques. Figure 3 illustrates the integrated control system of the line-following mobile robot.

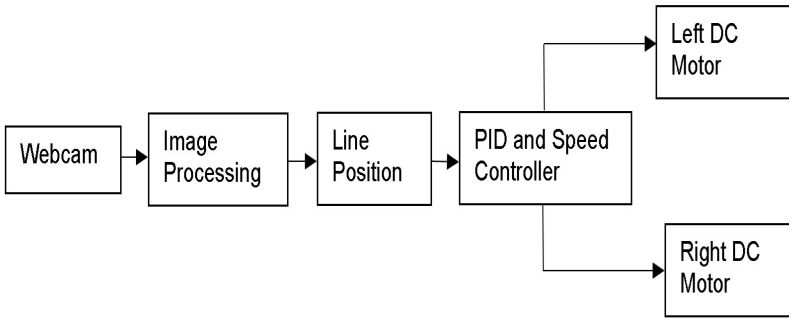


Fig.3. Line-Following Control System

Figure 4 shows a screenshot of the live video stream of the line, along with the gradient values of the line's edges during testing operations. The gradient values show the abrupt change in pixel intensities between the dark and light regions. The two peaks on the right side of the figure depict them. The positions of these peaks are used to determine the centre position of the line. At the bottom of the figure, it can be seen that a Graphical User Interface (GUI) has been developed to initiate and terminate the mobile robot's operations. It is indicated by the ‘Start,’ ‘Stop,’ and ‘Exit’ buttons.

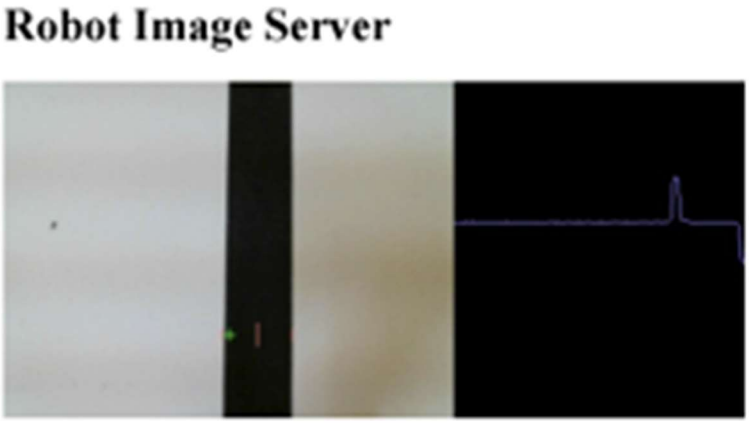


Fig.4. Video Streaming and GUI

The PID control algorithm ensures that the mobile robot steers along the line on the floor surface. The average value of the horizontal position of both peaks is the centre position of the line. The middle pixel position value of the field of view is subtracted from the centre pixel value of the track. The difference between these two-pixel values constitutes the error from the centre of the track, as shown in Figure 5.

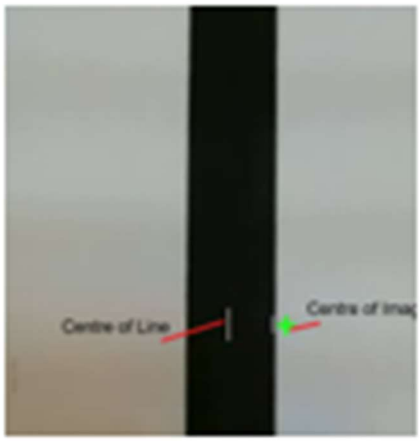


Fig.5. Error

The error value is sent to the PID algorithms for processing. The magnitude of the proportional, integral, and derivative gains will determine the outputs that will steer the mobile robot along the line. Equation (1) shows the PID control algorithm.

$$y(t) = K_p * e(t) + K_i * \int e(t) + K_d * de(t)/dt \quad (1)$$

In which:

y(t) = Control signal (that is used to steer the mobile robot by adjusting motor speeds)
K_p = Proportional gain
K_i = Integral gain
K_d = Derivative gain
E(t) = Error at time t, computed as: e(t) = x_center of image - x_centre of line
x_centre of image = Centre of image position (centre field of view)
x_centre of line = Centre line position (average position of gradient peaks)

$\int e(t)dt$ = Accumulated error (integral term)Type equation here.
$de(t)/dt$ = Rate of change of error (derivative term)

The DC motor speed adjustment can be implemented with the following equations, viz:

$$V_l, \text{ Left Speed} = v - u(t) \quad (2)$$

$$V_r, \text{Right Speed} = v + u(t) \quad (3)$$

In which:

v = Base forward speed
u(t) = PID controller output

Finally, Figure 6 shows the experimental setup. The mobile robot is placed on a 315 mm x 315 mm reconfigurable line-following track. It has a thickness of 10mm. The width of the track is 18mm. The track has a square shape with curves at the edges. The mobile robot steers along the track in both clockwise and counterclockwise directions. This procedure was repeated for reduced lighting conditions. For normal lighting conditions, there are two light sources, one on top of the track and another at the upper left side of the track. For reduced lighting conditions, the light on top of the track is switched off. The error magnitudes versus time are stored as data files and retrieved upon completion of each run. During each run, the webcam continuously captures the robot's field of view in real time. The video feed for each run is saved as an MP4 file using OpenCV's 'VideoWriter' module. These experiments aimed to test the system's functionality.

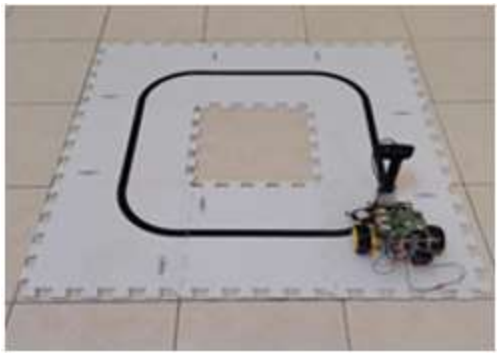


Fig.6. Experimental Setup

3. Results and Discussion

Figure 7 shows the error and motor speeds versus time. The operation time for circling the track was 30 seconds, and it was run in the anti-clockwise direction. The zigzagging pattern implied that whenever a deviation from the centre of the line occurred, both DC motors immediately steered the mobile robot back to the centre of the line, thus reducing the offset. The proportional, integral, and derivative gain values used in the case were 0.1, 0.04, and 0.005, respectively.

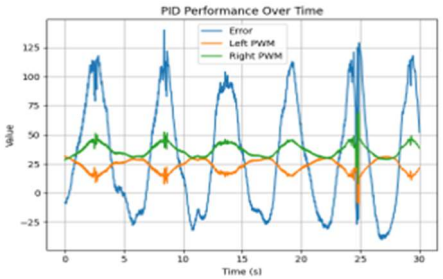


Fig.7. Anticlockwise Direction

The experiment was repeated under reduced external lighting conditions. Figure 8 shows the results obtained. The mobile robot still managed to perform constant corrective actions by steering along the line.

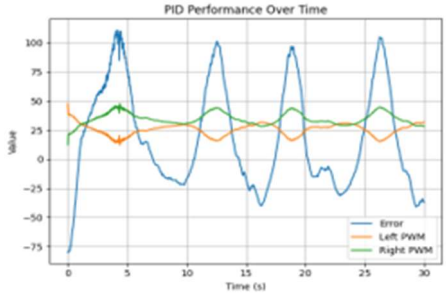


Fig.8. Anticlockwise Direction (Reduced Lighting)

Subsequently, the mobile robot was run in the clockwise direction along the track under normal and reduced lighting conditions. The proportional, integral, and derivative values were changed to 0.35, 0.005, and 0.02, respectively. Figure 9 shows the results under normal lighting conditions. The corrective action was maintained. The DC motor steered the mobile robot towards the centre of the line when deviation occurred. In this case, the corrective actions reduced negative errors.

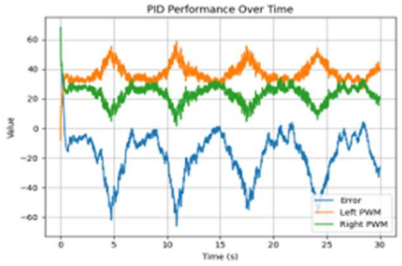


Fig.9. Clockwise Direction

Figure 10 shows the results under reduced lighting conditions. The same corrective action was exhibited. This showed robust performance even when the lighting was reduced. In both cases, adaptive thresholding was implemented into the program. This ensures that the line is detected accurately in both bright and low-light conditions.



Fig.10. Clockwise Direction (Reduced Lighting)

The main advantage (Dewantoro et al., 2021) of the GUI-based and vision-based line-following robot over the infra-red line-following robot is that it enables real-time observation and interactive control. It does not require constant manual tuning of the infrared sensors, which is cumbersome. These features are beneficial in the context of academic settings.

4. Conclusion

A mobile robot learning kit for learning control systems and line-following has been built. It integrated PID control, computer vision, and data logging. This provides students with hands-on experience in tuning PID control parameters and understanding the control actions of line-following mobile robots. The data logging capabilities enable error tracking and visualization of motor speed. This enhances students' engagement and promotes active learning. Test runs, and experimentation have confirmed its viability. It can be conveniently built using easily obtainable hardware, a microcontroller, and open-source libraries. It supports hands-on experimentation to enhance understanding of control theory and computer vision. Overall, it strengthens competencies in embedded systems, robotics, programming, and control, which are key areas in Mechatronics. It offers a low-cost kit that is integrated and targeted towards mechatronics students in Malaysian polytechnics.

In the future, the learning kit will be further improved by incorporating remote web-based PID tuning interfaces. It will also include adaptive tuning capabilities to obtain the optimal gain values for maximum performance in control and line-following operations by mobile robots.

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DEVELOPMENT OF DIGITAL TO ANALOG CONVERTER (DAC) TRAINING KIT FOR ELECTRONIC LABORATORY PURPOSES

Nor Aizam binti Muhamed Yusof

Department of Electrical Engineering,Politeknik Tuanku Sultanah Bahiyah,09000 Kulim Kedah, Malaysia

Corresponding author e-mail address: noraizamyusof74@gmail.com

Abstract

This project presents the design and development of an innovative 4-bit Digital-to-Analog Converter (DAC) training kit aimed at enhancing student engagement and understanding in the Electronic Circuit (DEE30043) course, a core module in the Electrical Engineering curriculum. The training kit addresses key challenges identified during laboratory sessions, including difficulties in circuit assembly, limited hands-on experience, and frequent component failures. Compact and user-friendly, the kit enables students to explore the principles and operation of 4-bit DAC circuits through real-time analog voltage readings and accurate output waveforms. By bridging the gap between theoretical concepts and practical application, the kit promotes active learning, improves conceptual clarity, and offers a portable and reliable tool for efficient education delivery.

Keywords: Digital to analog converter; Electronic laboratory; Real-time voltage

1. Introduction

The growing demand for skilled professionals in electronics and embedded systems has highlighted the need for practical learning tools that bridge the gap between theoretical knowledge and real-world applications. Digital-to-Analog Converters (DACs) are fundamental components in modern electronic systems, enabling the conversion of digital signals into analog output. However, the lack of accessible and interactive tools often makes learning about DACs a difficult task. Existing laboratory setups are often costly, complex, or unsuitable for beginners, creating a significant education gap that reduces practical understanding and application. This gap in educational resources necessitates a dedicated training kit that streamlines learning while maintaining technical accuracy (S. Lyubomirov, et al. 2020).

The 4-bit Digital-to-Analog Converter (DAC) Training Kit is designed to tackle these challenges by offering a simple, hands-on platform for learning. It allows students to convert a 4-bit digital input into an analog voltage and observe the process in real-time. This interactive approach makes it easier to understand concepts like binary-to-analog conversion, voltage levels, and resolution. By combining affordability and ease of use, the training kit provides a solution for both educators and learners, fostering confidence and competence in electronics (Diosanto et al. 2017)

Research in educational tools has shown that interactive platforms significantly enhance student engagement and comprehension. For example, Yuan et al. (2019) emphasized the importance of hands-on learning in electronics education, noting that students who used simulation and hardware-based kits outperformed those relying solely on theoretical instruction. Similarly, Kumar et al. (2018) demonstrated the efficacy of low-cost training modules in promoting skill development in embedded systems. These studies underscore the potential impact of an affordable DAC training kit tailored to modern educational needs.

The study by Sunil S. Parmar and colleagues (2016), the 32-bit DAC is presented with noise voltage analysis and other performance parameters, theoretical and simulation in microwind 3.1 with noise voltage analysis. The study highlights the limitations of R-2R DACs, particularly in terms of resolution and efficiency due to resistor mismatches, which lead to Integral Non-Linearity (INL) and Differential Non-Linearity (DNL). To address these issues, the paper explores calibration techniques aimed at minimizing non-linearities and improving accuracy

The 4-bit DAC training kit also addresses the limitations of traditional teaching methods, which often fail to connect theoretical principles with practical applications. By enabling students to experiment with digital signals and observe the corresponding analog outputs, the kit bridges this gap and ensures a holistic understanding of DACs. Moreover, its compact and portable design allows educators to integrate it seamlessly into classroom and laboratory settings, enhancing the flexibility and accessibility of electronics training (Ruxin Zhan 2024).

The study by Daniela et al. (2020) presented a comprehensive educational approach that integrates both software and hardware solutions for the study of modern Digital-to-Analog Converters (DACs) and their practical applications. Their research responds to the growing need for pedagogical innovations in engineering and electronics education, particularly in the context of rapid technological advancements and increasing demands for industry-ready graduates.

Furthermore, Balestrieri and colleagues (2024) proposed a case study on the development and implementation of experimental modules designed for teaching modern Digital-to-Analog Converters (DACs) in university-level digital circuits courses, specifically targeting engineering students at Paisii Hilendarski University of Plovdiv. Utilizing the Texas Instruments ASLK PRO lab kit and the Arduino Mega 2560 platform equipped with the AT Mega 2560 AVR microcontroller, the authors created hands-on educational tools that integrate precise measuring equipment for effective learning.

The significance of this study lies in its potential to transform electronics education by making complex concepts more accessible and engaging. By providing a cost-effective and interactive platform, the 4-bit DAC Training Kit not only empowers students to build foundational skills but also prepares them for advanced applications in areas such as signal processing, embedded systems, and IoT devices. Additionally, the training kit's emphasis on practical experimentation aligns with industry demands for hands-on experience, enhancing the employability of graduates.

In conclusion, the development of the 4-bit DAC Training Kit represents a significant step forward in electronics education. By addressing current challenges in teaching and learning, incorporating insights from prior research, and emphasizing practical application, this study aims to contribute to the growing field of hands-on educational tools. The training kit serves as a valuable resource for fostering technical proficiency and sparking interest in the principles underlying modern electronic systems.

2. Methodology

The methodology for developing the 4-bit Digital-to-Analog Converter (DAC) training kit involves a structured, multi-phase process aimed at addressing the educational challenges faced by students in understanding DAC concepts. Each phase is designed to ensure that the final product

is pedagogically effective, technically reliable, and user-friendly. The following steps detail the entire development process.

2.1 Develop a schematic of the 4-bit DAC circuit

The conceptual design phase involves developing a detailed schematic of the 4-bit Digital-to-Analog Converter (DAC) circuit. This schematic serves as a foundational blueprint for the system's hardware implementation. Additionally, the functional flow of the DAC training kit is outlined to illustrate its operation from the selection of 4-bit digital input via switches or a microcontroller interface, through the conversion process within the resistor network and op-amp stage, to the final analog voltage output as shown in Figure 1.

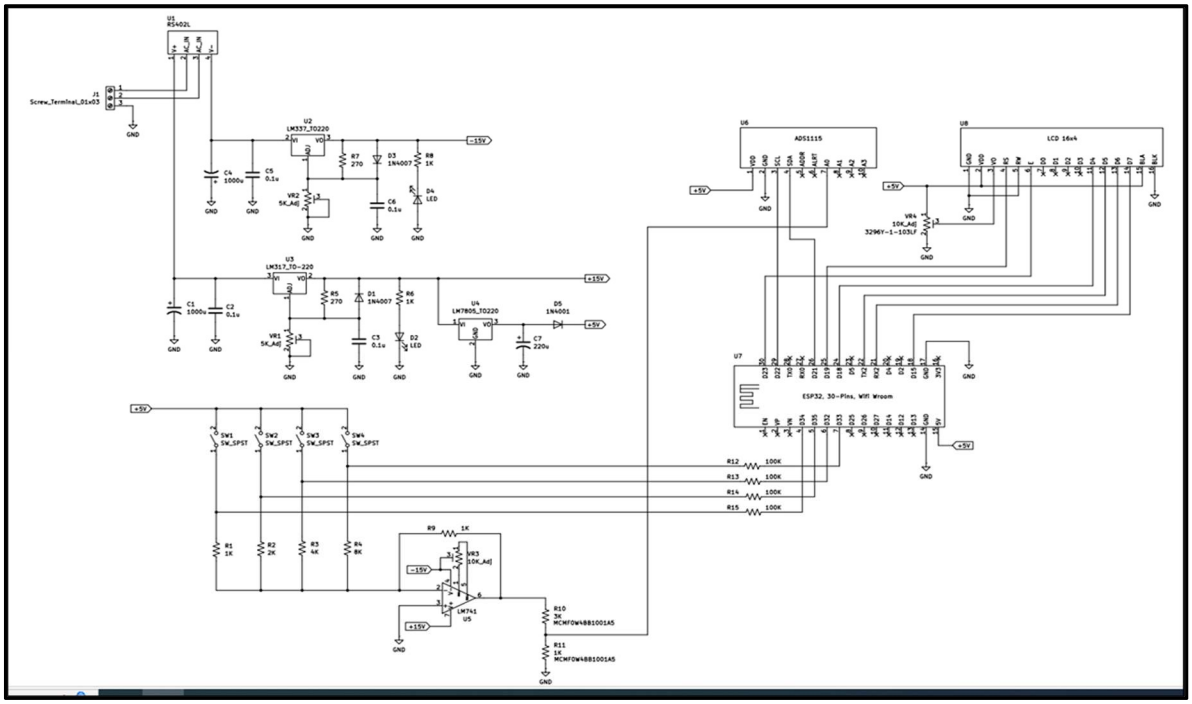


Fig. 1. DAC schematic circuit

2.2 Component selection

The component selection process focuses on cost-effective and reliable parts to ensure the functionality and durability of the 4-bit DAC training kit. Precision resistors with 1% tolerance are used to construct the R-2R ladder network, ensuring accurate digital-to-analog conversion. A microcontroller Arduino are included for bit control and display integration while an LCD can display the analog output value. Additional components like capacitors and operational amplifiers are selected to stabilize and buffer the signal. All components are chosen based on availability, affordability, and ease of integration.

2.3 Prototype Development

The circuit is first assembled on a breadboard to facilitate initial testing and validation. All components, including tactile switches for binary input, precision resistors arranged in an R-2R

ladder for digital-to-analog conversion, and an operational amplifier for signal buffering, are carefully integrated. The setup also includes LCD display to visualize the binary input and corresponding analog output. This stage ensures that all connections are correct, and the DAC functions as intended before finalizing the design. Testing on the breadboard allows easy troubleshooting, adjustment, and verification of the system's performance in a flexible prototyping environment.

2.4 Testing and validation

The prototype undergoes thorough testing to verify accurate digital-to-analog conversion for all possible 4-bit binary input combinations. Each input is applied using switches and the resulting analog output voltage is measured using a multimeter. The output values are compared against theoretical results to assess the resolution and linearity of the DAC.

2.5 Printed Circuit Board Design

Designing a Printed Circuit Board (PCB) involves a systematic process that begins with defining the circuit requirements and creating a schematic diagram using design software like KiCad. The schematic serves as a blueprint, showing how components are connected. Next, the designer lays out the PCB by positioning components on a virtual board and routing conductive traces to connect them, considering factors like signal integrity, component placement, and power distribution as shown in Figure 2.

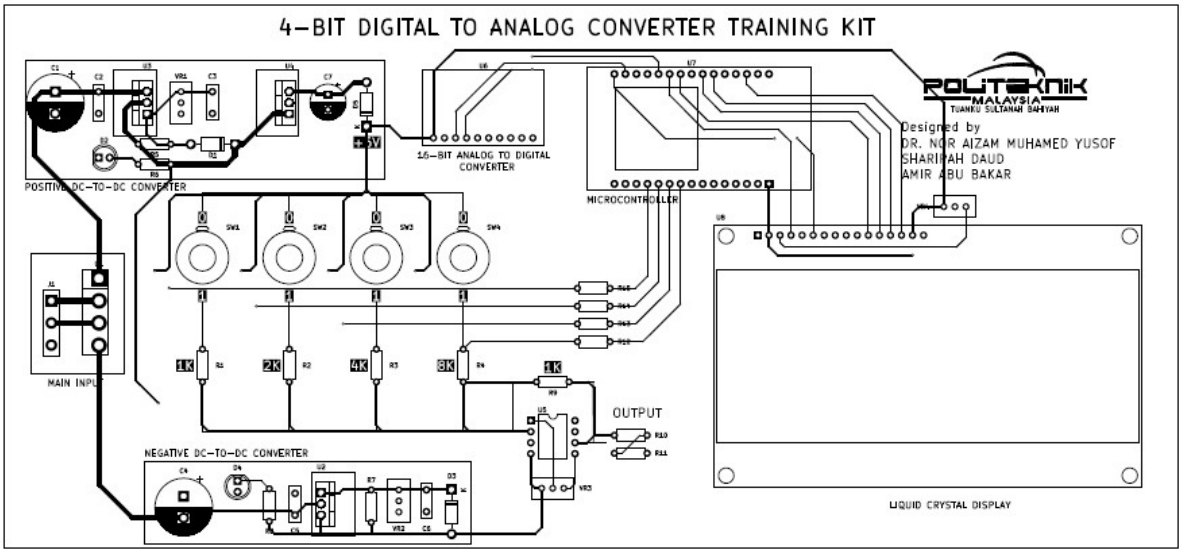


Fig.2. PCB layout of DAC

Figure 2 shows the PCB drawing for a DAC (Digital-to-Analog Converter) training kit include a compact and well-organized layout designed for educational purposes. The board features input terminals for digital signals, often represented as binary inputs, connected to the pins of a DAC chip. Resistors in an R-2R ladder configuration or other passive components are arranged systematically to implement the conversion logic. Additionally, the PCB includes a precision voltage reference, power supply connections, and output terminals to visualize the analog signal. The layout prioritizes clarity, with labeled components and pathways, enabling students to understand the working principles of DACs through hands-on interaction. Key design

considerations such as minimal noise interference and proper grounding ensure accurate signal conversion and smooth learning experiences.

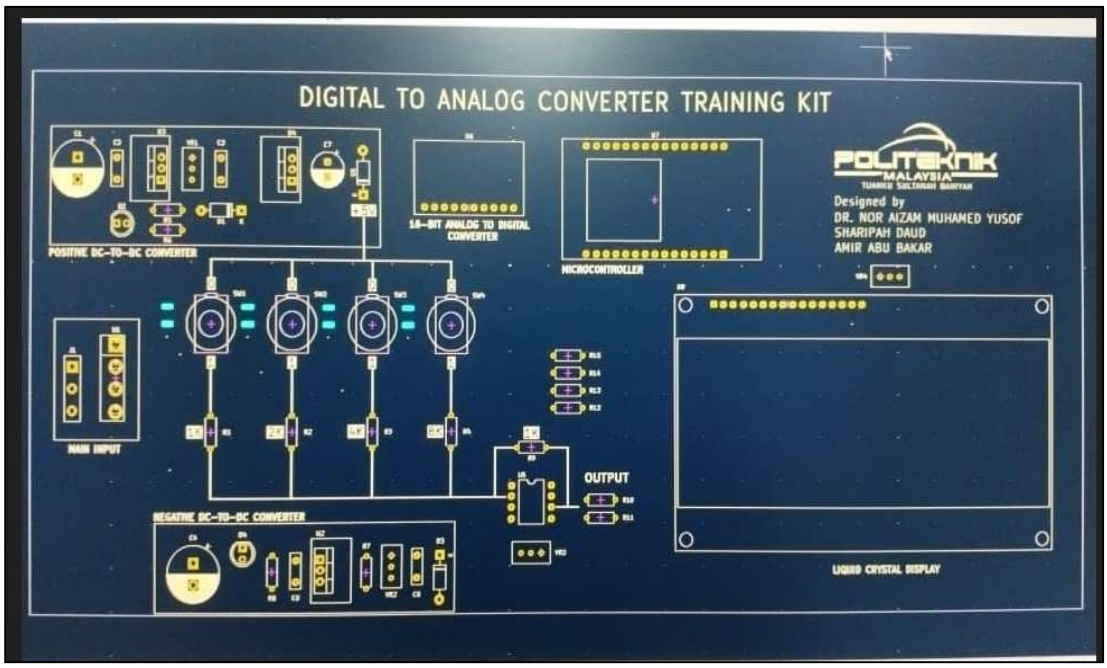


Fig.3. 4 Bit DAC Training Kit

After completing the PCB layout, the design is validated through simulations and Design Rule Checks (DRC) to detect any electrical or layout errors. Once validated, the design is exported as Gerber files the industry-standard format for PCB manufacturing. These files are then submitted to a PCB fabrication service for production. This stage combines precision and attention to detail, transforming the schematic into a physical, reliable printed circuit board. The final PCB, tailored to the specific requirements of the DAC training kit, is illustrated in Figure 3.

3. Results and Discussion

The expected result is a smooth, linear analog output voltage that corresponds precisely to the 4-bit binary input. For instance, with a reference voltage of 5V, the output should vary in steps of 0.3125V (5V/16 levels) as the binary input increments from 0000 to 1111. The output should exhibit minimal distortion, and the simulated waveform should match theoretical calculations for a binary-weighted DAC. This ensures the training kit effectively demonstrates the principles of digital-to-analog conversion, providing accurate and consistent results for educational purposes. Furthermore, the design is expected to show stable performance across a range of operating conditions, validating its reliability for real-world use.
b. Simulation Result:

Table 1 shows the simulation of the 4-bit Digital-to-Analog Converter (DAC) Training Kit is conducted to validate the circuit design and functionality before physical implementation. Using circuit simulation software like Multisim or Proteus, the resistor ladder network is modelled to represent the binary-weighted DAC. Each input bit is represented by a switch or logic input, and the operational amplifier buffers the resulting analog output. The simulation tests various combinations of the 4-bit binary input (0000 to 1111) to ensure accurate voltage levels at the output. Additionally, parameters like reference voltage, resistor tolerances, and op-amp

performance are analyzed to identify potential issues, such as signal distortion or voltage drop, ensuring the design meets the expected resolution and linearity.

Table 1. Simulation and Calculation Result

Binary Input				Simulation	Calculation
R	2R	4R	8R	Voltage	Voltage
0	0	0	0	0	0.0000
0	0	0	1	-0.6237692	-0.6250
0	0	1	0	-1.2486397	-1.2500
0	0	1	1	-1.8735093	-1.8750
0	1	0	0	-2.4983783	-2.5000
0	1	0	1	-3.1232462	-3.1250
0	1	1	0	-3.7481136	-3.7500
0	1	1	1	-4.3729801	-4.3750
1	0	0	0	-4.9978456	-5.0000
1	0	0	1	-5.6227107	-5.6250
1	0	1	0	-6.2475748	-6.2500
1	0	1	1	-6.872438	-6.8750
1	1	0	0	-7.4973006	-7.5000
1	1	0	1	-8.1221619	-8.1250
1	1	1	0	-8.7470226	-8.7500
1	1	1	1	-9.3718834	-9.3750

The performance of the 4-bit R-2R ladder DAC was evaluated through both simulation and theoretical calculations, with binary inputs ranging from 0000 to 1111. The results demonstrate a close agreement between the simulated output voltages and the expected theoretical values. For example, for the minimum input 0000, both simulation and calculation yield a 0 V output. As the binary input increments, the output voltage decreases linearly in steps of approximately -0.625 V, reaching -9.375 V at the maximum input 1111. Minor deviations observed in simulation results, such as -0.6238 V instead of -0.6250 V for input 0001, can be attributed to rounding errors, model imperfections, or resistor mismatch in the simulation environment. Despite these small discrepancies, the simulation closely matches the theoretical values, confirming the accuracy and functionality of the R-2R ladder DAC design. This validates the use of the R-2R structure for effective digital-to-analog conversion in low-to-medium resolution applications.

Based on Table 2, the simulated and calculated DAC voltages you have provided earlier, here is a new table that includes the expected (calculated) values, measured (simulated) values, error deviation (%), and performance (%) for each binary input. The error deviation (%) is calculated as:

$$Error\ Deviation\ (\%) = \frac{simulated - calculated}{calculated}\ x\ 100\%$$

Table 2. Overall performance of the DAC

Binary input	Calculated value (volts	Simulated value (%)	Error deviation (%)	Performance (%)
0000	0.000	0.000	0.195	99.80
0001	-0.625	-0.623	0.112	99.89
0010	-1.250	-1.248	0.080	99.92
0011	-1.875	-1.873	0.064	99.94
0100	-2.500	-2.949	0.057	99.95
0110	-3.125	-3.123	0.050	99.95
0111	-3.750	-3.748	0.047	99.96
1000	-4.375	-4.373	0.044	99.96
1001	-5.625	-5.627	0.040	99.96
1010	-6.250	-6.242	0.038	99.96
1011	-6.875	-6.872	0.037	99.96
1100	-7.500	-7.497	0.035	99.97
1101	-8.125	-8.122	0.034	99.97
1110	-8.750	-8.742	0.034	99.97
1111	-9.375	-9.371	0.033	99.95
Average				99.25

4. Conclusion

The development of the 4-bit Digital-to-Analog Converter (DAC) Training Kit offers a practical and innovative solution to the challenges faced in electronics education. By providing a hands-on platform to explore the principles of digital-to-analog conversion, the kit bridges the gap between theoretical knowledge and practical application. Its design incorporates key features such as a resistor ladder network, operational amplifier, and user-friendly controls, ensuring an intuitive learning experience for students. Through simulations and prototype testing, the kit demonstrates its reliability, accuracy, and ease of use, making it a valuable tool for fostering a deeper understanding of electronic circuits and signal processing.

This study highlights the educational significance of the training kit in preparing students for advanced applications in embedded systems, IoT, and other electronics fields. By addressing the need for cost-effective and accessible learning tools, the 4-bit DAC Training Kit supports the development of essential technical skills and enhances engagement in electronics education. Its potential for commercialization further underscores its impact, offering opportunities to reach a wider audience and contribute to the growth of practical, industry-aligned training in academic and professional settings

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PENERUS SEPARUH GELOMBANG FASA TUNGGAL MENGGUNAKAN SIMULASI PERISIAN *MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE DAN PSIM* DALAM PENGAJARAN DAN PEMBELAJARAN KURSUS ELEKTRONIK KUASA

Hasnita binti Ramli*, Zunainah binti Hamid, Pimpa Soowan

Electrical Engineering Department, Politeknik Tuanku Sultanah Bahiyah, 09000 Kulim-HiTech, Kedah, Malaysia

*Corresponding author e-mail address: hasnita@ptsb.edu.my

Abstrak

Penukar Elektronik Kuasa digunakan secara meluas pada masa kini untuk pelbagai aplikasi daripada penggunaan tenaga kuasa kecil hingga tenaga kuasa besar. Penukar gelombang penuh dan penukar separuh gelombang digunakan terutamanya untuk penukaran input fasa tunggal kepada bentuk gelombang keluaran yang dikehendaki. Kajian ini membandingkan prestasi penukar separuh gelombang satu fasa tidak terkawal dengan menggunakan perisian simulasi komputer yang berbeza. Pada masa kini perisian simulasi komputer telah menjadi medium penting dalam proses pengajaran dan pembelajaran. Dalam kajian ini, perisian MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM telah digunakan untuk membantu pelajar mendalami bidang elektronik kuasa. Litar penerus AU/AT tidak terkawal separuh gelombang dengan beban rintangan telah direka bentuk, disimulasikan dan dianalisa menggunakan lima perisian komputer iaitu MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM. Prestasi penukar separuh gelombang tersebut telah disimulasi dengan memplot bentuk gelombang voltan keluaran. Berdasarkan keputusan voltan keluaran daripada lima perisian simulasi komputer yang dijalankan, menunjukkan bahawa penukar AU ke AT separuh gelombang fasa tunggal boleh menghasilkan voltan keluaran yang sama dengan ketara walaupun menggunakan perisian simulasi komputer yang berbeza dengan parameter yang berbeza kerana perisian yang berbeza memerlukan parameter berbeza bagi memenuhi keperluan setiap perisian tersebut untuk menghasilkan voltan keluaran yang terbaik. Kajian ini membuktikan bahawa simulasi perisian komputer telah menjadi medium yang sangat penting dalam keberkesanan proses pengajaran dan pembelajaran pada masa kini.

Kata Kunci: Elektronik kuasa; Penerus AU/AT; Perisian komputer.

1. Pengenalan

Elektronik kuasa adalah kursus asas yang paling diperlukan untuk pelajar jurusan kejuruteraan elektrik dan automasi. Mengajar dalam kursus elektronik kuasa adalah sangat mencabar, kerana bidangnya agak meluas dan merangkumi asas-asas daripada pelbagai bidang kejuruteraan. Pada masa kini, disebabkan peningkatan bilangan kursus yang diambil oleh pelajar, maka tempoh pengajaran bagi setiap kursus telah dikurangkan. Dalam mengatasi masalah ini, simulasi perisian komputer menjadi medium penting untuk membantu kelancaran proses pengajaran dan pembelajaran. Pelajar dibenarkan mengubah parameter litar dan meneliti kesan perubahannya ke atas pembolehubah elektrik tersebut. Proses ini bersamaan dengan penciptaan makmal maya di mana skrin komputer menggantikan osiloskop dalam persekitaran makmal sebenar (Santosh S. Raghuwanshi.et.al, 2012). Pada masa kini, pelbagai medium perisian komputer, seperti *MATLAB/SIMULINK, MULTISIM, LIVEWIRE, PSPICE,* PSIM dan lain-lain, tersedia untuk mensimulasi litar elektronik kuasa dan digunakan sebagai medium pengajaran bagi menjalankan aplikasi amali secara maya dalam kursus elektronik kuasa (Abdulatif A. M. Shaban, 2009).

Simulasi perisian komputer ialah percubaan untuk memodelkan situasi sebenar atau hipotesis pada komputer supaya ia boleh dikaji untuk melihat bagaimana sistem tersebut berfungsi. Dengan menukar pembolehubah, ramalan analisa boleh dibuat bagi menentukan operasi sistem tersebut. Dalam usaha ke arah ini, tindak balas arus dan voltan yang berbeza dalam litar elektronik kuasa boleh ditunjukkan. Walau bagaimanapun, simulasi sistem elektronik kuasa sangat mencabar kerana faktor berikut (Abuelma'atti .et. al, 2002):

i. Ketaklinearan melampau yang ditunjukkan oleh suis.
ii. Pemalar masa dalam sistem mungkin berbeza mengikut beberapa susunan magnitud dan kekurangan model.

Oleh itu, adalah penting bahawa objektif analisis menggunakan perisian komputer dinilai dengan teliti dan pakej simulasi yang sesuai dipilih. Memandangkan pertimbangan di atas, pakej simulasi berasaskan *MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM* telah digunakan untuk mensimulasikan litar elektronik kuasa seperti penerus, penyongsang, pemenggal dan pengawal voltan AU. Mereka mempunyai model peranti terperinci dan dapat mewakili bahagian pengawal sistem penukar bersama ciri fungsinya dengan cara yang dipermudahkan sebaik mungkin. Dalam kajian ini keluaran dari simulasi litar penerus telah diambil kira. Penerus ialah peranti elektrik yang menukarkan arus ulang alik (AU) kepada arus terus (AT), satu proses yang dikenali sebagai penerusan. Penerus mempunyai banyak kegunaan termasuk sebagai komponen bekalan kuasa. Penerus boleh dibina daripada komponen diod keadaan pepejal, diod tiub vakum, injap arka merkuri dan komponen lain (Abuelma'atti .et. al, 2002).

Perisian *MATLAB* ialah perisian pengiraan berangka untuk pengiraan kejuruteraan dan saintifik. *MATLAB* digunakan untuk teori litar, reka bentuk penapis, proses rawak, sistem kawalan dan teori komunikasi. Fungsi matriks *MATLAB* ditunjukkan sebagai serba boleh dalam melakukan analisis data yang diperoleh daripada eksperimen elektronik. Ciri-ciri grafik *MATLAB* amat berguna untuk paparan tindak balas frekuensi penguat dan menggambarkan prinsip dan konsep fizik semikonduktor. Pengaturcaraan interaktif dan grafik serba boleh *MATLAB* amat berkesan dalam meneroka beberapa ciri peranti dan litar elektronik (Vipul Sharma, 2010).

Perisian *PSPICE* ialah akronim untuk program simulasi dengan penekanan litar bersepadu. Ianya telah diilhamkan untuk keperluan dan memodelkan peranti dengan tepat yang digunakan dalam reka bentuk litar bersepadu. Kini ia telah menjadi program komputer standard untuk simulasi elektrik dan elektronik. Perisian *PSPICE* popular kerana ketersediaan dan keupayaan untuk berkongsi versi penilaiannya secara bebas. Versi penilaian ini sangat berkuasa untuk simulasi elektronik kuasa (Santosh S. Raghuwanshi.et.al, 2012).

Perisian *MULTISIM* dan perisian reka bentuk litar memberikan jurutera analisis lanjutan, keupayaan reka bentuk untuk mengoptimumkan prestasi, mengurangkan ralat reka bentuk dan memendekkan masa untuk membuat prototaip. *Intuitive NI tools* menghasilkan lakaran papan litar bercetak (PCB) yang mudah disimpan dan penjimatan kos yang ketara (Udit Mamodiya, 2017).

Perisian *LIVEWIRE* ialah pakej terkini untuk mereka bentuk, mensimulasi dan menganalisis litar. Ia mewakili satu langkah ke hadapan yang ketara berbanding perisian yang lain. Perisian ini menawarkan lebih banyak komponen untuk digunakan dalam mereka bentuk litar, ketepatan simulasi yang tiada tandingan, wayar yang tidak putus apabila komponen dialihkan, dan pautan automatik sepenuhnya yang sangat pantas ke PCB Wizard 3. *LIVEWIRE* ialah alat simulasi yang

berguna untuk pelajar dari semua peringkat yang ingin maju dalam bidang elektronik (Hasyireen Abd Halim, 2024).

Perisian *PSIM* ialah perisian simulasi yang direka khas untuk elektronik kuasa dan modul pemacu motor. Dengan simulasi pantas dan antara muka mesra pengguna, *PSIM* menyediakan persekitaran simulasi yang mantap untuk elektronik kuasa. Persekitaran simulasi *PSIM* terdiri daripada program skema Litar *PSIM*, Enjin simulator dan program pemprosesan bentuk gelombang Simview (Powersim, 2020).

1.1 Cabaran Dalam Simulasi Komputer

Simulasi litar elektronik kuasa dan sistem kawalan gerakan menimbulkan banyak cabaran kepada pengaturcara simulasi dan akhirnya kepada pengguna. Untuk mengatasi cabaran ini, adalah dinasihatkan untuk menjadikan medium simulasi telus dan meminimumkan data masukan. Keperluan untuk program simulasi boleh diringkaskan seperti berikut (Shuhui Li, 2005):

a) Antara Muka Mesra Pengguna (*User Friendly Interface)*
Program simulasi harus mempunyai antara muka yang mudah digunakan untuk kemasukan data dan untuk data keluaran pemprosesan.

b) Keupayaan Pemodelan Pelbagai Peringkat (*Multi-Level Modelling Capability)*
Sebagai contoh, dalam simulasi pemacu motor, penukar elektronik kuasa diterangkan oleh penyambungan model elemen litar. Sebaliknya, mesin elektrik dan beban diterangkan dengan baik oleh persamaan pembezaan yang dirumus dari segi pembolehubah keadaan.

c) Model Tepat (*Accurate Models)*
Untuk analisis terperinci, program simulasi memerlukan model yang tepat bagi semua elemen litar. Walaupun model yang tepat telah tersedia, tetapi sukar untuk mengetahui nilai parameternya. Nilai kearuhan dan kapasitan selalunya sukar untuk dianggarkan.

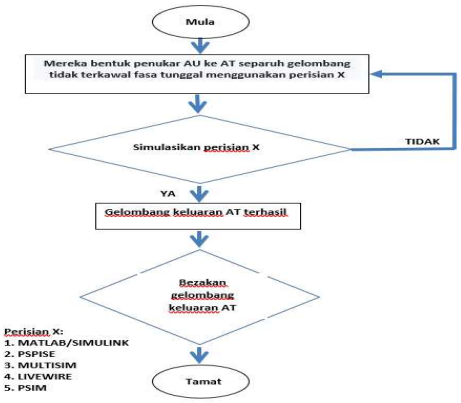
d) Operasi Teguh Penukaran Suis (*Robust Switching Operations)*
Tindakan penukaran suis akibat keadaan *solid state switches* (diod, thyristor dan transistor) mesti dikendalikan dengan sewajarnya. Berdasarkan cara suis dimodelkan, peralihan *on/off* mereka sama ada mewakili *nonlinearity* yang melampau atau membawa kepada struktur rangkaian masa yang berbeza-beza.

Cabaran yang disenaraikan di atas menentukan bahawa perlu ada penilaian yang teliti terhadap objektif simulasi. Secara umum, adalah tidak wajar untuk mensimulasikan semua aspek sistem secara terperinci. Ini menyebabkan, masa simulasi mungkin menjadi sangat lama dan kandungan maklumat keluaran mungkin tidak tepat, sekali gus membawa kepada fenomena yang tidak menarik. Dalam hal ini, simulasi terbaik adalah simulasi yang paling mudah dan boleh memenuhi objektif simulasi dengan pantas.

2. Metodologi

Hasil simulasi penukar gelombang AU ke AT boleh direka bentuk, disimulasikan dan dianalisis litar dengan menggunakan carta alir pada Rajah 1. Litar penukar gelombang AU ke AT separuh gelombang satu fasa dengan beban rintangan telah direka bentuk menggunakan perisian X. Kemudian, perisian X akan disimulasikan. Jika reka bentuk litar tersebut memenuhi spesifikasi perisian tersebut, voltan keluaran AT akan dihasilkan. Jika simulasi tidak berjaya menghasilkan bentuk gelombang voltan AT yang dijangkakan, maka reka bentuk litar akan disemak semula dan

disimulasikan semula. Kemudian hasil dapatan iaitu voltan keluaran separuh gelombang AT satu fasa daripada setiap perisian X yang telah disimulasi, dibandingkan dan dianalisa bagi mendapatkan keputusan yang dikehendaki.



Rajah 1. Carta alir metodologi

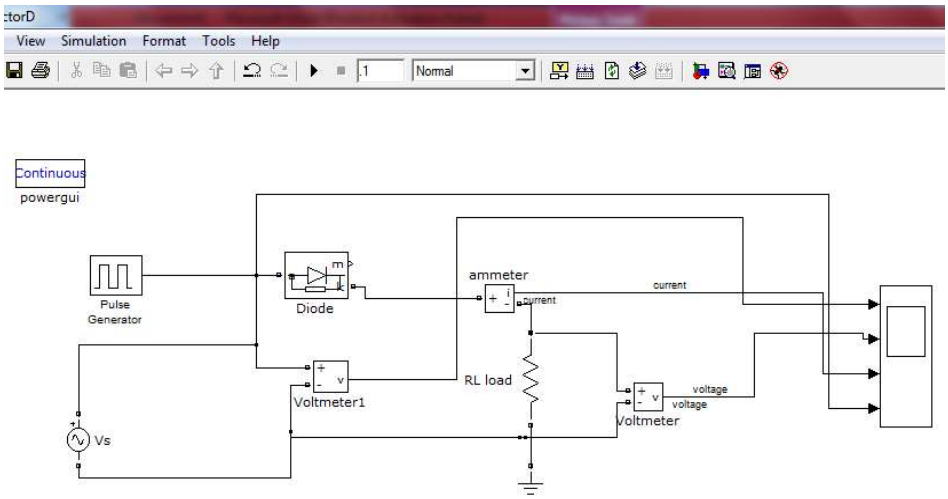
Hasil dapatan daripada simulasi lima perisian *MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM,* didapati semua perisian telah berjaya menukarkan voltan masukan AU separuh gelombang satu fasa kepada voltan keluaran AT separuh gelombang satu fasa. Didapati juga hanya perisian *PSPICE* mempunyai kekurangan dari segi paparan gelombang voltan masukan, dimana ia tidak dapat di paparkan bersekali dengan paparan voltan gelombang keluaran dalam satu paparan skrin.

3. Keputusan dan Perbincangan

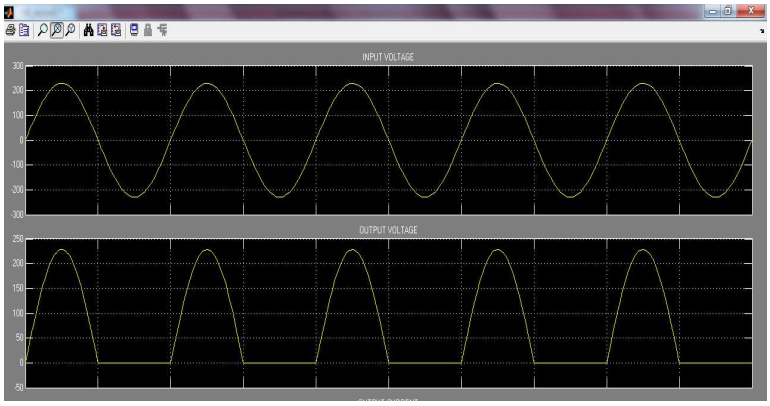
Dalam bahagian ini, simulasi penerus separuh gelombang satu fasa tidak terkawal dengan beban rintangan dijelaskan dengan menggunakan lima pakej perisian simulasi yang berbeza dan bentuk keluaran gelombang yang sepadan telah diplotkan. Analisa simulasi dilakukan dengan membandingkan keluaran dari penggunaan perisian *MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM.*

3.1 Simulasi menggunakan perisian *MATLAB/SIMULINK*.

Kaedah simulasi berasaskan *MATLAB* telah dijalankan untuk penerus dalam set blok Simulink (Agam Kumar Tyagi, 2012). Di sini penerus separuh gelombang digunakan yang mengalir untuk kitaran positif sahaja. Rajah 2. menunjukkan rajah litar penerus separuh gelombang fasa tunggal dan bentuk gelombang input dan output yang sepadan ditunjukkan. Spesifikasi litar adalah: voltan masukan AU ialah 230 V, perintang beban ialah 1Ω, frekuensi 50Hz dan menggunakan diod untuk pembetulan. Dengan menggunakan litar penerus bentuk gelombang AT berdenyut boleh diperolehi. Bentuk gelombang masukkan dan keluaran ditunjukkan dalam Rajah 3., di mana voltan keluaran AT ialah 230V.



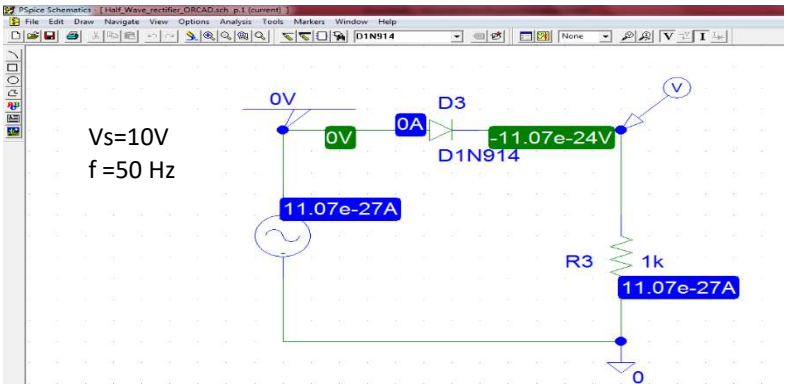
Rajah 2. Gambar rajah litar penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *MATLAB/SIMULINK*.



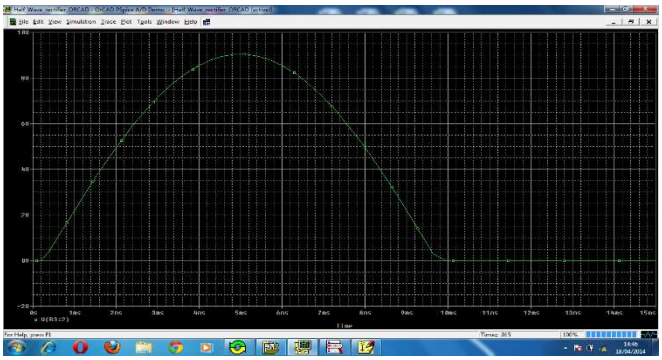
Rajah 3. Voltan masukan dan keluaran penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *MATLAB /SIMULINK*.

3.2 Simulasi menggunakan perisian *PSPICE.*

Kaedah simulasi berasaskan *PSPICE* bagi rajah litar penerus separuh gelombang satu fasa tidak terkawal ditunjukkan dalam Rajah 4. Bentuk voltan keluaran yang sepadan ditunjukkan dalam Rajah 5. Spesifikasi litar adalah, voltan masukan AU = 10V, frekuensi = 50 Hz dan perintang beban =1kΩ. Semasa separuh kitaran positif, diod menjadi pincang hadapan dan voltan keluaran AT dihasilkan. Tiada voltan keluaran dihasilkan pada separuh kitaran negatif kerana diod menjadi pincang songsang. Perisian *PSPICE* mempunyai kekurangan dari segi paparan gelombang voltan masukan, dimana ia tidak dapat di paparkan bersekali dengan paparan voltan gelombang keluaran dalam satu paparan skrin.



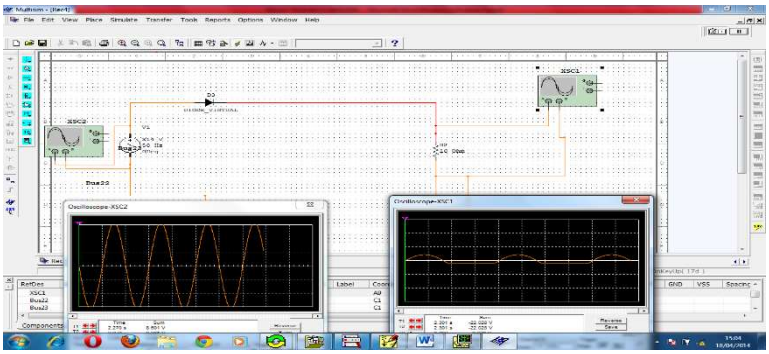
Rajah 4. Gambar rajah litar penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *PSPICE*.



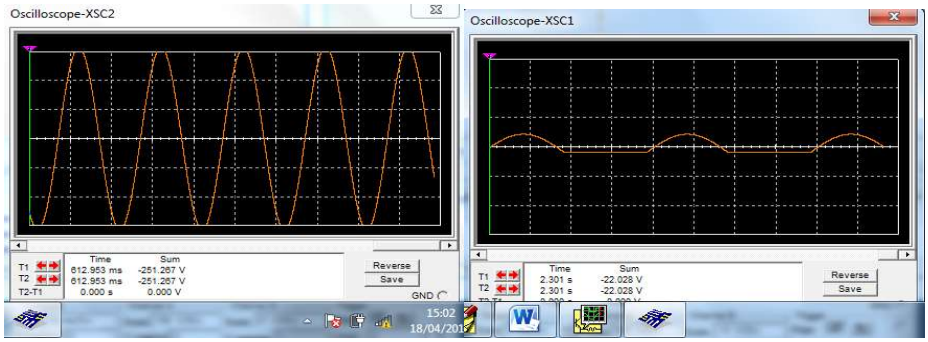
Rajah 5. Voltan keluaran penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *PSPICE*.

a. Simulasi menggunakan perisian *MULTISIM*

Rajah 6. menunjukkan litar kuasa penerus separuh gelombang tidak terkawal satu fasa, menggunakan diod untuk menghasilkan voltan keluaran AT terkawal,Vo. Spesifikasi litar adalah, nilai voltan masukan = 314V, rintangan beban = 10Ω dan frekuensi pensuisan = 50Hz. Selepas simulasi berlaku, bentuk gelombang voltan masukan dan voltan keluaran dengan beban rintangan ditunjukkan dalam Rajah 7.



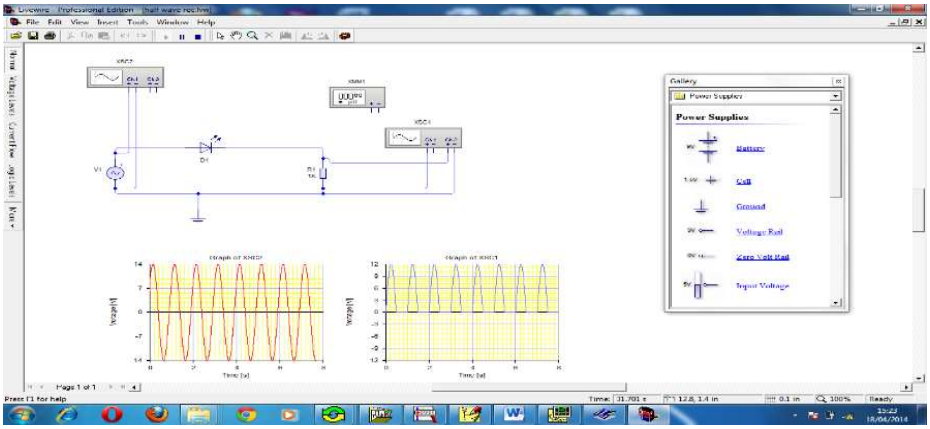
Rajah 6. Gambar rajah litar penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *MULTISIM.*



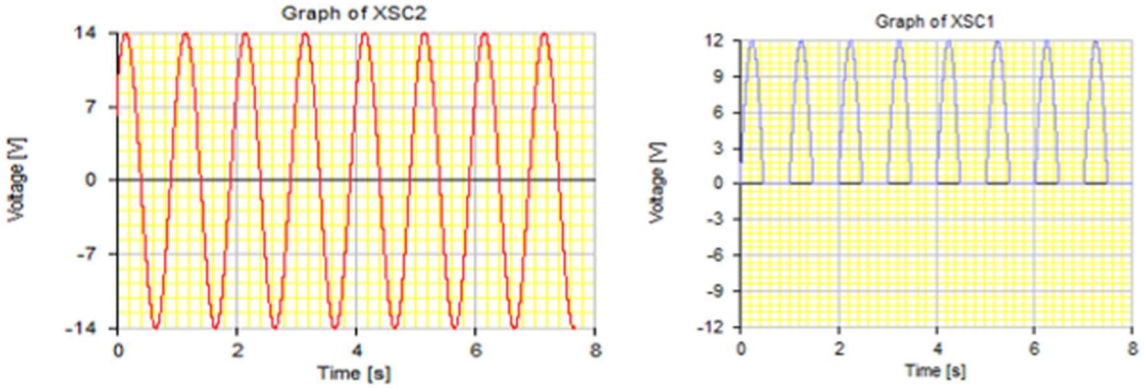
Rajah 7. Voltan masukan dan keluaran penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *MULTISIM*.

3.3. Simulasi menggunakan perisian *LIVEWIRE*

Simulasi berasaskan *LIVEWIRE* untuk rajah litar penerus separuh gelombang fasa Tunggal tidak terkawal dengan beban rintangan ditunjukkan dalam Rajah 8., yang menggunakan diod untuk menghasilkan voltan keluaran DC, Vo. Spesifikasi litar adalah, nilai voltan masukan = 14V, rintangan beban = 1kΩ dan frekuensi pensuisan = 1Hz. Selepas simulasi berlaku, voltan keluaran dan bentuk gelombang arus keluaran dengan beban rintangan ditunjukkan dalam Rajah 9.



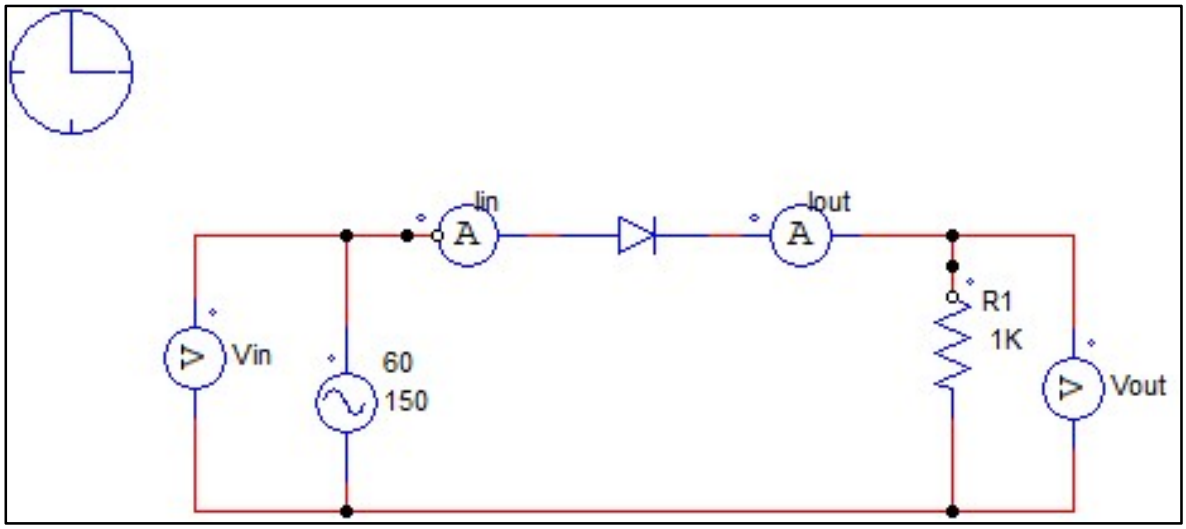
Rajah 8. Gambar rajah litar penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *LIVEWIRE*.



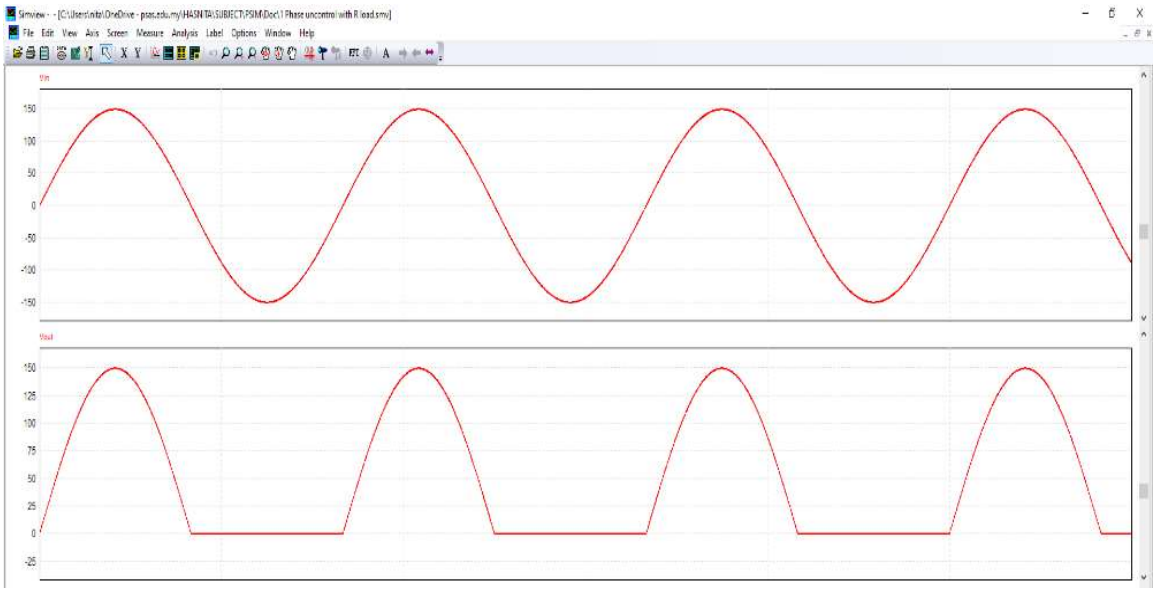
Rajah 9. Voltan masukan dan keluaran penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *LIVEWIRE*.

3.4 Simulasi menggunakan perisian *PSIM*

Simulasi berasaskan *PSIM* untuk rajah litar penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan, bentuk gelombang voltan masukan dan keluaran yang sepadan ditunjukkan dalam Rajah 10.-11., yang menggunakan diod untuk menghasilkan voltan keluaran DC, Vo. Spesifikasi litar adalah, nilai voltan masukan = 150V, rintangan beban = 1kΩ dan frekuensi pensuisan = 60 Hz. Selepas simulasi berlaku, voltan masukan dan voltan keluaran dengan beban rintangan ditunjukkan dalam Rajah 3.5b.

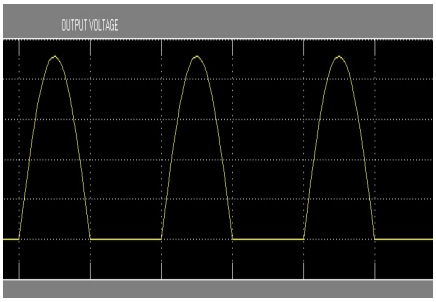
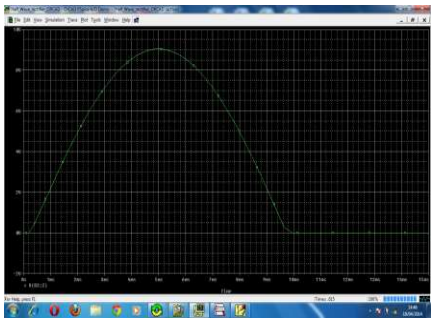
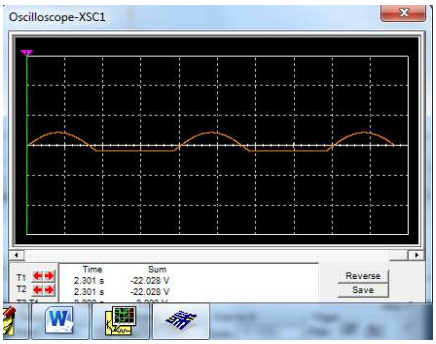
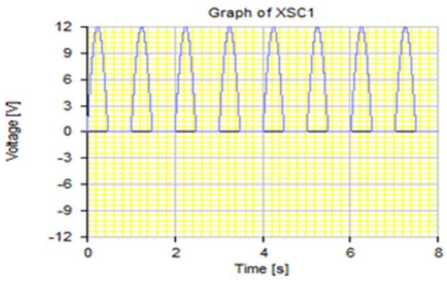


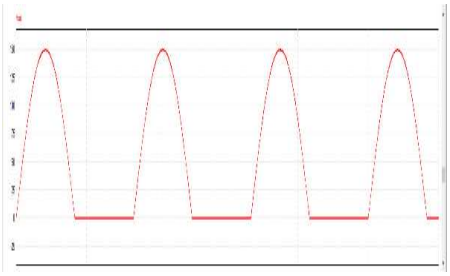
Rajah 10. Gambar rajah litar penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *PSIM*.



Rajah 11. Voltan masukan dan keluaran penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan menggunakan perisian *PSIM*.

Jadual 1. Perbandingan parameter yang digunakan dan voltan keluaran yang terhasil menggunakan perisian *MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM*

No	Perisian	Parameter/ Spesifikasi	Voltan Keluaran	Graf Voltan Keluaran, Vo
1.	MATLAB / SIMULINK	Vin = 230V (AU) Frekuensi = 50Hz Beban/Perintang = 1Ω	Voltan keluaran AT (Vo)	
2.	PSPICE	Vin =10V (AU) Frequency = 50Hz Beban/Perintang = 1kΩ	Voltan keluaran AT (Vo)	
3.	MULTISIM	Vin =314V (AU) Frekuensi = 50Hz Beban/Perintang = 10Ω	Voltan keluaran AT (Vo)	
4.	LIVEWIRE	Vin =14V (AU) Frekuensi = 1Hz Beban/Perintang = 1kΩ	Voltan keluaran AT (Vo)	

5.	PSIM	Vin =150V (AU) Frekuensi = 60Hz Beban/Perintang = 1kΩ	Voltan keluaran AT (Vo)	

Berdasarkan Jadual 1, menunjukkan bahawa operasi penerus separuh gelombang fasa tunggal tidak terkawal dengan beban rintangan ini mempunyai dua keadaan pengaliran (Daniel W. Hart, 2010):

i. Semasa separuh kitar positif, diod berada dalam keadaan pincang ke hadapan. Voltan keluaran AT positif dihasilkan.
ii. ii) Semasa separuh kitar negatif, diod berada dalam keadaan pincang songsang. Tiada arus yang mengalir melalui rintangan dan diod. Tiada voltan keluaran dihasilkan.

Daripada Jadual 1,menunjukkan bahawa kelima-lima perisian MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM dapat digunakan untuk mensimulasi litar dengan baik. Hasil dapatan menunjukkan bahawa walaupun voltan keluaran yang dihasilkan oleh kelima-lima perisian adalah sama tetapi nilai parameter yang digunakan untuk setiap perisian adalah berbeza bergantung kepada ketetapan parameter yang sesuai bagi perisian itu sendiri. Ini kerana perisian yang berbeza memerlukan parameter berbeza bagi memenuhi keperluan setiap perisian tersebut untuk menghasilkan voltan keluaran yang terbaik. Didapati juga hanya perisian *PSPICE* mempunyai kekurangan dari segi paparan gelombang voltan AU masukan, dimana ia tidak dapat di paparkan bersekali dengan paparan voltan gelombang keluaran AT dalam satu paparan skrin.

Masa kini terdapat banyak perisian simulasi komputer di pasaran yang boleh mensimulasikan litar elektrik dan elektronik serta mempunyai fungsi untuk melakukan analisis litar bagi data simulasi. Pertama, simulasi litar boleh menyediakan persekitaran makmal maya yang mantap untuk eksperimen praktikal. Kedua, adalah lebih pantas untuk membina atau mengubah suai litar elektrik atau sistem menggunakan perisian simulasi berbanding melakukan eksperimen praktikal menggunakan perkakasan makmal. Ketiga, dengan fungsi analisis litar yang canggih dalam kebanyakan medium simulasi litar IT, analisis dan reka bentuk litar elektrik/elektronik adalah sangat mudah untuk dilakukan dalam persekitaran simulasi perisian (Prof. Rachana.et, 2021 & Brij Mohan.et al, 2019).

4. Kesimpulan

Proses mereka bentuk dan menganalisis litar penukar AU ke AT elektronik kuasa dengan menggunakan lima jenis medium perisian komputer yang berbeza iaitu *MATLAB/SIMULINK, PSPICE, MULTISIM, LIVEWIRE dan PSIM* diterangkan dalam kertas kajian ini. Kaedah yang dibentangkan dalam mensimulasi litar penerus separuh gelombang satu fasa tidak terkawal dengan beban rintangan bagi kursus elektronik kuasa ini menggunakan lima perisian komputer, dapat membantu pelajar memahami konsep teori, dan membolehkan mereka melaksanakan analisa litar amali dengan simulasi perisian yang berbeza sebagai projek kursus mereka. Oleh itu, teknik yang dibentangkan dalam kertas kajian ini boleh diperluaskan kepada projek reka bentuk dalam kursus elektronik kuasa, sistem pemacu elektrik dan kursus-kursus lain serta boleh menambah penggunaan perisian komputer terkini yang lain sebagai medium simulasi litar.

Disebabkan bilangan pelajar yang semakin bertambah dan kekurangan peralatan makmal, tempoh pengajaran dan pembelajaran akan bertambah. Untuk mengatasi masalah ini, simulasi perisian komputer merupakan medium terpenting untuk membantu proses pengajaran dan pembelajaran.

Simulasi litar ialah kaedah yang sangat berkuasa untuk menyelesaikan pelbagai jenis litar mudah dan rumit bagi sistem elektronik kuasa. Pakej simulasi perisian hari ini menawarkan antara muka pengguna grafik yang mudah digunakan dan menyediakan output grafik yang hebat yang menyaingi peralatan makmal elektronik yang sedia ada. Instrumen maya adalah lebih murah untuk dimiliki dan dikendalikan. Ianya tidak memerlukan penentukuran dan perkhidmatan kos penyelenggaraan yang tinggi. Pelajar boleh menikmati keadaan simulasi litar tanpa perlu menanggung kerumitan penyambungan trainer secara fizikal dengan sejumlah besar penyambungan wayar. Ini menggalakkan pelajar untuk bereksperimen dengan komponen litar elektronik, mengenal pasti fungsi komponen dan menghubungkan setiap fungsi dengan ciri-ciri tindak balas litar secara maya dalam perisian komputer tersebut. Oleh itu, lebih banyak masa dapat dihabiskan untuk mempelajari sesuatu topik dari pelbagai sudut dengan pelbagai teknik, maka lebih baik topik itu akan difahami.

Dalam kajian ini, simulasi bagi litar penukar separuh gelombang satu fasa tidak terkawal dengan beban rintangan telah dilaksanakan menggunakan lima perisian komputer dengan parameter yang berbeza. Dengan antara muka yang mesra pengguna, simulasi dapat dilaksanakan dengan mudah dan pantas kerana tiada pemasangan litar secara fizikal perlu dilakukan. Perbandingan keputusan simulasi menggunakan kelima-lima perisaian komputer dapat dikenalpasti dan dibandingkan. Hasil daripada keputusan yang diperolehi, didapati bahawa tiada perbezaan pada voltan keluaran yang dihasilkan daripada proses simulasi litar bagi kelima-lima perisian tersebut.

Oleh yang demikian, dapat disimpulkan bahawa penggunaan perisian komputer dapat membantu dalam mempelbagaikan kaedah pengajaran dan pembelajaran. Analisa menggunakan simulasi perisian komputer juga mampu meningkatkan pemahaman dan kemahiran pelajar disamping menarik minat pelajar dengan paparan antaramuka yang menarik. Kajian ini membuktikan bahawa simulasi perisian komputer dapat membantu pensyarah dan pelajar dalam proses pengajaran dan pembelajaran supaya menjadi lebih menarik dan menjadi medium yang sangat penting dalam keberkesanan proses pengajaran dan pembelajaran pada masa kini.

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