

# MERGING LANES: WHERE E-LEARNING DIVERSITY MEETS FUTURE TRENDS

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**Universiti Teknologi MARA Cawangan Pulau Pinang**

# **MERGING LANES: WHERE E-LEARNING DIVERSITY MEETS FUTURE TRENDS**

## **MERGING LANES: WHERE E-LEARNING DIVERSITY MEETS FUTURE TRENDS**

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## PREFACE

The continuous advancement of digital technologies has significantly reshaped the educational landscape, particularly in the area of e-learning. In response to these developments, the SIG CS@e-Learning Committee, Department of Computer Science & Mathematics (Jabatan Sains Komputer & Matematik, JSKM), Universiti Teknologi MARA (UiTM), Penang Branch, proudly presents this e-Book as a platform for knowledge sharing, scholarly discourse, and innovation in digital education.

This e-Book is published under the theme “Merging Lanes: Where E-Learning Diversity Meets Future Trends.” The theme symbolises the convergence of diverse pedagogical practices, technological innovations, and learner-centred approaches that collectively shape the future of e-learning. As education moves forward in a rapidly evolving digital era, embracing diversity while aligning with emerging trends is essential to ensure inclusive, flexible, and sustainable learning environments.

This issue comprises approximately **31** articles contributed by dedicated academics and practitioners. The articles reflect a wide spectrum of perspectives and experiences in e-learning, covering innovative teaching strategies, digital tools, online assessment, learner engagement, and emerging technologies. Together, these contributions provide valuable insights into both current practices and future directions in e-learning.

The editorial committee extends its sincere appreciation to all authors for their meaningful contributions to this e-Book. Your commitment to sharing research findings, best practices, and innovative ideas has been vital to the success of this publication. Authors are also encouraged to further enhance and expand their articles for submission to indexed journals such as SCOPUS, Web of Science (WoS), or MyCite, thereby broadening the impact and visibility of their scholarly work.

It is our hope that this e-Book will serve as a useful reference and a source of inspiration for educators and researchers seeking to navigate and contribute to the evolving e-learning landscape.

On behalf of the editorial team, I would like to express my deepest gratitude to all contributors and committee members involved in the publication of this e-Book. The collective effort and shared vision demonstrated in this work highlight our commitment to advancing e-learning practices. May this e-Book continue to inspire innovation, collaboration, and academic excellence in the years ahead.

***Ts. Jamal Othman***

*Chief Editor*

*SIG CS@e-LEARNING*

*The New Frontiers Of E-Learning: Shaping The Future of Education*

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## APPLICATIONS AND ADVANTAGES OF BOOSTED REGRESSION TREES IN STATISTICAL MODELING

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### ABSTRACT

*Boosted Regression Trees (BRT) have become an important technique in statistical modelling due to their strong predictive performance and flexibility in handling complex data structures. This paper presents an overview of the concept, methodology, advantages, and applications of BRT in modern data-driven analysis. The BRT approach combines regression trees with boosting algorithms, where multiple simple models are sequentially developed to improve prediction accuracy by minimizing errors from previous iterations. One of the key strengths of BRT is its ability to capture nonlinear relationships and interactions among variables without requiring strict assumptions about data distribution. In addition, BRT is robust to outliers, capable of handling missing values, and suitable for analysing different types of data, including continuous and categorical variables. The paper also reviews various applications of BRT across multiple domains, such as environmental modelling, epidemiology, and economic analysis. Overall, BRT provides a powerful and efficient framework for both predictive and explanatory modelling, making it a valuable tool for researchers and practitioners in statistical and machine learning fields.*

**Keywords:** *Boosted Regression Tress, Statistical Modeling, Machine Learning Methods, Multiple Linear Regression, Predictive Modeling*

### Introduction

In recent years, machine learning techniques have become essential tools for statistical modelling and data-driven decision making. Among these, ensemble methods have proven to be particularly effective in improving prediction performance by combining multiple models. Boosted Regression Trees (BRT), also known as Gradient Boosting Machines (GBM), represent one such approach that merges the strengths of regression trees and boosting algorithms. The BRT technique builds multiple small regression trees sequentially, with each tree correcting the errors of the previous ones, ultimately resulting in a strong and accurate predictive model.

BRT has several advantages that make it superior to many traditional regression and classification techniques. Firstly, it is highly flexible and capable of capturing nonlinear relationships and complex interactions among predictor variables without requiring prior specification. Secondly, BRT is robust to outliers and missing data, which makes it suitable for real-world datasets that are often

noisy or incomplete. Thirdly, it can handle mixed data types, such as continuous, categorical, and ordinal variables, within the same model framework. Another major advantage is its ability to provide variable importance measures and partial dependence plots, allowing researchers to interpret the influence of each predictor on the response variable. Additionally, by tuning parameters such as the learning rate, number of trees, and tree depth, BRT can balance between accuracy and generalization, minimizing overfitting while maintaining predictive strength.

BRT is also considered a branch of machine learning, which is a subset of artificial intelligence (AI). As an AI-based algorithm, BRT belongs to the family of ensemble learning methods that combine the outputs of multiple weak learners to achieve higher predictive performance. Other well-known machine learning techniques that share similar objectives include Random Forests, Support Vector Machines (SVM), Artificial Neural Networks (ANN), and k-Nearest Neighbors (k-NN). Each of these methods has its own strengths and limitations, but BRT stands out for its balance between accuracy, interpretability, and computational efficiency, making it suitable for both predictive modelling and explanatory analysis.

Because of these advantages, BRT has gained wide adoption in various research domains. It is now considered one of the most reliable ensembles learning methods for predictive analytics, especially when the relationships between variables are complex and not easily captured by linear models. The popularity of BRT continues to grow with the development of efficient computational tools and open-source software such as R and Python, which make implementation easier for researchers and practitioners. This paper aims to introduce the concept, methodology, advantages, and applications of Boosted Regression Trees (BRT) in a simple and structured manner suitable for academic understanding. To achieve this objective, the paper provides a comprehensive review of existing literature, explains the underlying algorithm and mathematical formulation of BRT, and presents a comparative analysis with traditional methods such as Multiple Linear Regression (MLR) to highlight its strengths and practical relevance.

## **Literature Review**

The foundation of BRT lies in the development of decision tree algorithms and the concept of boosting. The Classification and Regression Tree (CART) methodology introduced by Breiman et al. (1984) laid the groundwork for tree-based modeling. Later, the concept of boosting was introduced by Freund and Schapire (1996) through the AdaBoost algorithm, which improved weak learners by iteratively emphasizing misclassified observations. Friedman (2001) then extended the boosting concept to regression problems through the Gradient Boosting Machine (GBM) framework, which uses the gradient of the loss function to guide model improvement. Elith, Leathwick, and Hastie (2008) popularized the application of BRT in ecological and environmental modeling due to its ability to model

complex nonlinear relationships. Since then, BRT has been applied in various disciplines such as finance, epidemiology, and social sciences.

In Malaysia, the application of Boosted Regression Trees (BRT) has gained considerable attention in recent years across diverse research areas. For instance, Cheong et al. (2014) employed BRT to analyze the relationship between land use factors and the incidence of dengue cases in Selangor. Their study demonstrated that BRT effectively identified important predictors such as built-up areas, water bodies, and vegetation cover, showing high accuracy in mapping dengue risk areas. Similarly, McCluskey et al. (2014) applied BRT in the field of real estate to perform mass appraisal of residential property values in Malaysia. Their findings revealed that BRT produced more reliable valuation results compared to conventional regression models, mainly due to its ability to capture nonlinear and complex interactions among property characteristics.

In environmental studies, Shaziayani et al. (2021) utilized an enhanced hybrid model integrating Support Vector Machines (SVM) with BRT and quantile regression (QR) to predict PM<sub>10</sub> concentration levels across several Malaysian cities, including Alor Setar, Klang, and Kuching. Their model, termed SVM\_BRT-QR, outperformed traditional predictive methods in forecasting air quality levels three days ahead. Additionally, Shaziayani et al. (2020) explored the integration of quantile regression into the BRT framework for emission modeling and air pollution forecasting in Malaysia. The study highlighted the robustness of BRT-based models in handling environmental datasets characterized by high variability and uncertainty. These studies collectively demonstrate that BRT is an adaptable and accurate modeling approach widely applied in Malaysia for health, environmental, and economic prediction problems.

## **Methodology**

The Boosted Regression Tree (BRT) method, originally proposed by Friedman (2001), combines two fundamental ideas: regression trees and boosting. Regression trees partition the predictor space into regions based on decision rules, where each terminal node represents a prediction value. However, a single regression tree often suffers from instability and overfitting. Boosting addresses these issues by iteratively adding weak learners (shallow trees) to minimize the residual errors of the ensemble model, resulting in a more accurate and robust prediction model. The general algorithm of BRT can be described as Figure 1. Figure 1 shows the general algorithm of the Boosted Regression Tree (BRT) model, which begins by initializing the model with a constant value, typically the mean of the response variable. The process then iteratively computes the residuals between the observed and predicted values, fits a regression tree to these residuals, and updates the model by adding a fraction of the new tree's predictions, controlled by a learning rate ( $\lambda$ ). This iterative process continues for a fixed number of

iterations or until the model converges, meaning further improvements in prediction accuracy become minimal. Mathematically, the model can be expressed as:

$$F_m(x) = F_{m-1}(x) + \lambda h_m(x) \quad (1)$$

where

$F_m(x)$  is the updated model at iteration  $m$

$h_m(x)$  is the fitted tree to the residuals

$\lambda$  ( $0 < \lambda \leq 1$ ) is the learning rate controlling the contribution of each tree.

This stepwise procedure (1) enables BRT to build a strong predictive model by sequentially improving upon the weaknesses of previous iterations.

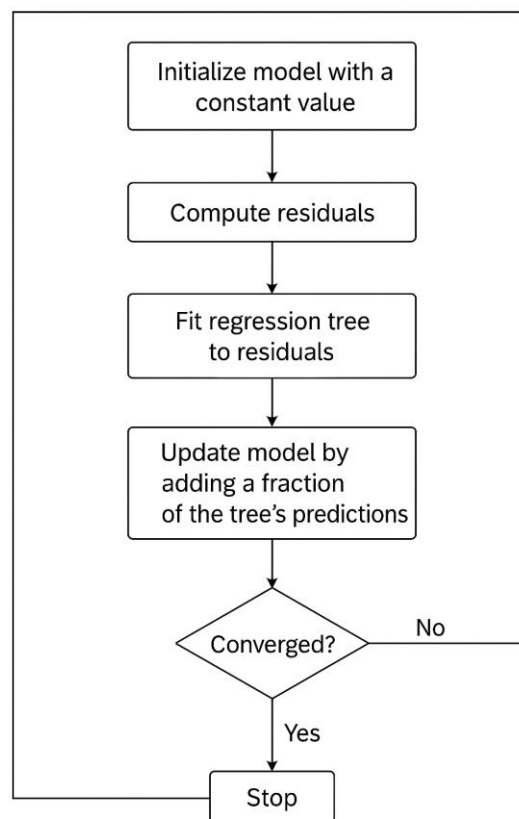


Figure 1. Iterative Framework of the Boosted Regression Tree (BRT) Algorithm

### Comparison of Multiple Linear Regression and Boosted Regression Trees

Multiple Linear Regression (MLR) has been widely applied in statistical modelling, particularly for predicting environmental variables such as air pollutants. It is a well-established technique that models the relationship between a dependent variable and multiple independent variables under the assumption

of linearity. MLR is often preferred due to its simplicity, ease of interpretation, and straightforward implementation. However, despite its popularity, the method is built on several strict assumptions, including linearity, normality of residuals, homoscedasticity, and independence of errors. In real-world applications, especially in environmental and atmospheric studies, these assumptions are frequently violated, which can lead to biased parameter estimates and reduced predictive performance.

In addition, previous studies have highlighted that MLR may perform poorly when dealing with complex systems. Shahraiyni et al. (2016) reported that although MLR is commonly used in air quality modelling, its effectiveness is limited in the presence of multicollinearity and nonlinear relationships among variables. Similarly, Dormann et al. (2013) emphasized that violations of model assumptions can significantly reduce the reliability of linear regression models, particularly when predictors are highly correlated or exhibit nonlinear interactions. As environmental datasets are often dynamic and complex, traditional linear approaches may not be sufficient to capture underlying patterns accurately.

In contrast, Boosted Regression Trees (BRT) offer a more flexible and powerful alternative for modelling complex relationships. BRT combines regression trees with boosting techniques, where multiple decision trees are built sequentially and each new tree is trained to correct the errors of the previous ones. This iterative learning process enables BRT to capture nonlinear relationships and interactions among variables without requiring strict statistical assumptions about the data distribution. As a result, BRT is particularly suitable for high-dimensional and complex datasets commonly found in environmental studies.

One of the main distinctions between MLR and BRT lies in their predictive capability and robustness. While MLR performs adequately when the relationship between variables is linear and assumptions are satisfied, its performance declines in the presence of nonlinearity, interactions, and noisy data. On the other hand, BRT generally demonstrates higher predictive accuracy and greater robustness to outliers and missing data, making it more reliable in practical applications.

However, despite its advantages, BRT is often considered less interpretable than MLR. MLR provides explicit coefficient estimates that are easy to interpret and explain, whereas BRT requires additional tools such as variable importance measures and partial dependence plots to understand the influence of predictors. Therefore, the choice between MLR and BRT depends on the objective of the study: MLR is preferred when interpretability is essential, while BRT is more appropriate when the focus is on prediction accuracy and modelling complex nonlinear relationships.

## **Conclusion**

In conclusion, this paper has presented a comprehensive overview of Boosted Regression Trees (BRT), including its conceptual foundation, methodological framework, and key advantages in statistical modelling. BRT is a powerful ensemble learning technique that integrates regression trees with boosting

algorithms to iteratively improve predictive performance. Unlike traditional methods, it does not rely on strict statistical assumptions, making it highly adaptable to complex and real-world datasets.

The comparative discussion between BRT and Multiple Linear Regression (MLR) highlights the limitations of conventional linear approaches when dealing with nonlinear relationships, multicollinearity, and high-dimensional data. While MLR remains useful due to its simplicity and interpretability, its performance is often constrained in complex systems. In contrast, BRT demonstrates superior predictive accuracy, flexibility, and robustness, particularly in handling interactions among variables and irregular data structures commonly found in applied research.

Overall, the findings suggest that BRT is a highly effective alternative for modern statistical modelling, especially in fields involving complex and nonlinear data patterns. Although it is less interpretable compared to MLR, its strong predictive capability makes it a valuable tool for researchers and practitioners. Future studies may further explore hybrid approaches or model interpretation techniques to enhance the usability and interpretability of BRT in various applied domains.

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## AGGREGATION IN OBJECT-ORIENTED PROGRAMMING: A SPECIALIZED FORM OF ASSOCIATION

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### ABSTRACT

*Object-Oriented Programming (OOP) is one of the fundamental paradigms in modern software development. It offers a range of powerful features that make it highly suitable for addressing real-world problems. Among these features are code reusability, modularity, data encapsulation, enhanced security, and improved code organization, all of which contribute to the development of efficient, maintainable, and scalable software systems. OOP is structured around several core principles, including the use of classes and objects, inheritance, polymorphism, abstraction, and encapsulation (also referred to as information hiding). These principles collectively enable developers to model complex systems in a way that mirrors real-life entities and their interactions. A significant aspect of object-oriented design is the concept of association, which describes relationships between classes. Within this context, aggregation is recognized as a specialized form of association, often contrasted with composition. Both aggregation and composition are referred to as "has-a" relationships, indicating that one class contains references to another. However, aggregation represents a weaker relationship compared to composition. In aggregation, the contained (or referenced) object can exist independently of the containing object. That is, if the container object is destroyed, the contained object is not necessarily affected and may continue to exist on its own. This article aims to provide a brief yet informative explanation of aggregation within the scope of object-oriented programming. It will explore the concept in greater detail and illustrate its implementation through practical examples. In particular, sample code written in the Java programming language will be presented to demonstrate how aggregation can be applied.*

**Keywords:** *Object-oriented programming (OOP), association, aggregation, Unified Modeling Language (UML), Java*

### Introduction

Computer programming often presents significant challenges, particularly as the code grows in size and complexity due to the inclusion of multiple functions or subprograms. The selection of appropriate tools and techniques is essential to guide software developers in completing projects within the specified timeframe and allocated budget (Otu et al., 2023). Object-Oriented Programming (OOP), which is structured around objects defined by standard classes, allows for dynamic modification and interaction among objects through message passing. OOP facilitates faster application development, simplifies code modification, promotes code reusability, and enhances the overall comprehensibility of the program structure (Asagba & Ogheneovo, 2010). In addition to its development advantages, OOP also

provides built-in mechanisms to strengthen software security. Through encapsulation, OOP conceals the internal implementation details of objects by restricting direct access to their attributes and methods. Only designated interfaces are exposed to the outside world, reducing the risk of unintended interference or misuse by other parts of the program (Vincent & Afoloruso, 2020).

Modularity is a fundamental principle in software engineering that involves decomposing a large and complex program into smaller, manageable, and self-contained units or modules. These smaller units are designed to function independently but can be seamlessly integrated to achieve the objectives of the overall system. This approach not only enhances the structural organization of the software but also improves the readability, maintainability, and scalability of the code. Modular programming contributes significantly to the accuracy and clarity of program logic and plays a vital role in simplifying future modifications, debugging, and updates (Hutabarat et al., 2009).

Within the paradigm of Object-Oriented Programming (OOP), one common design technique that reflects modular principles is aggregation, a form of association that establishes a "has-a" relationship between two classes. Both aggregation and composition fall under the broader category of association relationships, which describe how one class incorporates or is composed of instances of another class. However, these two associations differ in terms of the strength of their coupling and the lifecycle dependencies between the related objects. Aggregation is characterized by a loose coupling, where the associated "part" objects can exist independently of the "whole" object. In practical terms, this means that the destruction of the whole object does not necessarily lead to the destruction of its constituent parts. For example, if a "Library" object is deleted, the "Book" objects associated with it can still exist independently. This contrasts with composition, which signifies a strong coupling between classes, where the lifecycle of the part objects is strictly bound to the lifecycle of the whole. In composition, if the whole is destroyed, the parts are destroyed as well (Larman, 2004). This nuanced understanding of class relationships enables developers to model real-world scenarios more accurately and design systems that are both flexible and robust.

This paper is organized to provide a comprehensive examination of the implementation of the aggregation association, specifically focusing on its characteristic of loose coupling, using the Java programming language. Aggregation, as a form of association in object-oriented programming, enables one class to reference another through a "has-a" relationship without establishing strict dependency between their lifecycles. To contextualize this concept, a real-world problem scenario involving two distinct classes will be introduced. This scenario will demonstrate how aggregation is used to model relationships between objects that are logically connected but maintain their independence. For clearer visual representation between classes, the structure of aggregation association will be illustrated through a Unified Modeling Language (UML) class diagram. Following this, the paper will present detailed code implementations for each class, alongside a sample application program. These code examples

will serve to clarify the practical aspects of aggregation and highlight its advantages in promoting modularity, reusability, and maintainability within object-oriented software development.

## Methodology

To illustrate the class relationship represented by an aggregation association, a Unified Modeling Language (UML) class diagram will be utilized. Figure 1 presents the UML class diagram that depicts the relationship between the Customer and Item classes. In this context, the Customer class represents the "whole," while the Item class functions as the "part" within the aggregation relationship. The diagram reflects a scenario where an Item—identified by a specific item code—can be associated with multiple Customers, or it may not be associated with any customer at all. This demonstrates that the Item objects can exist independently of the Customer objects, reinforcing the concept of loose coupling that characterizes aggregation in object-oriented programming.

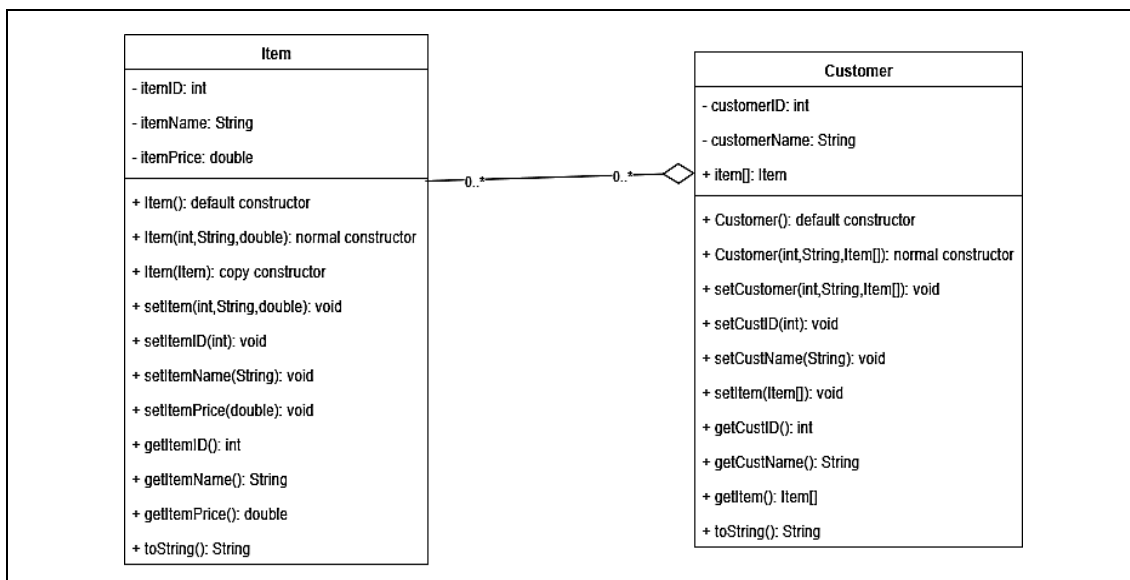


Figure 1: UML Class Diagram – Aggregation Association between Item and Customer classes

## Implementation

The Java programming language was utilized to develop the Item and Customer classes. Each class includes standard methods, such as default and parameterized constructors, mutator methods, accessor methods, and printing functions. The following code presents the complete definition of the Item class.

```

public class Item {
    //attributes
    private int itemID;
    private String itemName;
    private double itemPrice;

    //default constructor
  
```

```

public Item()
{
    itemID = 0;
    itemName = "";
    itemPrice = 0;
}

//normal constructor
public Item(int iID, String iName, double iPrice)
{
    itemID = iID;
    itemName = iName;
    itemPrice = iPrice;
}

//copy constructor
public Item(Item i)
{
    itemID = i.itemID;
    itemName = i.itemName;
    itemPrice = i.itemPrice;
}

//group setter
public void setItem(int iID, String iName, double iPrice)
{
    itemID = iID;
    itemName = iName;
    itemPrice = iPrice;
}

//individual setter
public void setItemID(int itemID){this.itemID = itemID;}
public void setItemName(String itemName){this.itemName = itemName; }
public void setItemPrice(double price){itemPrice = price; }

//getter
public int getItemID()      { return itemID; }
public String getItemName() { return itemName; }
public double getItemPrice() { return itemPrice; }

//printer
public String toString(){
    return "\n Item ID      : "+itemID+
           "\n Item Name   : "+itemName+
           "\n Item Price : RM "+itemPrice;
}

public void display()
{ System.out.printf("%-10d %-15s %-6.2f\n",
                    itemID, itemName, itemPrice);
}
} //close class

```

Figure 2: Complete definition for Item class

Next, Figure 3 presents the detailed definition of the Customer class. This class incorporates the Item class as one of its attributes through association. Specifically, the attribute is defined as an array of Item objects, indicating that each customer can purchase multiple items.

```

public class Customer {
    //attributes
    private int custID;
    private String custName;
    public Item[] item; //array of object and type is Item(is a class
                       // as created in figure 1): aggregation
}

```

```

//default constructor
public Customer(){
    custID = 0;
    custName = "";
    item = new Item[10]; } //maximum item can be stored is 10 objects
//normal constructor
public Customer(int cID, String cName, Item[] itm)
{
    custID = cID;
    custName = cName;
    item = itm;
}

//group setter
public void setCustomer(int cID, String cName, Item[] itm)
{
    custID = cID;
    custName = cName;
    item = itm;
}

//individual setter
public void setCustID(int custID)
{
    this.custID = custID;
}

public void setCustName(String custName)
{
    this.custName = custName;
}

public void setItem(Item[] itm) //receives list of items purchased
{
    item = itm;
}

//getter
public int getCustID()      { return custID;      }
public String getCustName() { return custName;  }
public Item[] getItem()     { return item;     }

//printer
public void display(int totItemPurchased)
{
    System.out.print("\n Customer id   : "+custID);
    System.out.print("\n Customer name : "+custName);
    System.out.print("\n -----");
    System.out.print("\nItem ID      Item Name   Item Price (RM)");
    System.out.print("\n");

    double totPurchase = 0;
    for (int x=0;x<totItemPurchased;x++){ //to display all items
                                           //purchased
        item[x].display();
        totPurchase = totPurchase + item[x].getItemPrice();
    }

    System.out.print("\n Total purchase RM "+totPurchase);
    System.out.print("\n");
}
}
} //close class

```

Figure 3: Complete definition for **Customer** class

The third code segment as shown figure 4, represents the application program that integrates both the Item and Customer classes. This program demonstrates that each customer can purchase a variable number of items by inputting the corresponding item IDs. The array of Customer objects implements aggregation, whereby Item objects are passed as parameters to the Customer constructor during the instantiation process.

```
import java.util.Scanner;

public class custItemApp {
    public static void main(String [] args)
    {
        Scanner scan = new Scanner(System.in);
        String lineSeparator = System.getProperty("line.separator");
        scan.useDelimiter(lineSeparator);

        final int aSIZE = 5; //fixed size to store list of items

        Item[] item = new Item[aSIZE];
        item[0] = new Item (101, "Laptop", 4500);
        item[1] = new Item (102, "Printer", 1200);
        item[2] = new Item (103, "Scanner", 750);
        item[3] = new Item (104, "Pen Drive", 30);
        item[4] = new Item (105, "Head Phone", 120);

        Customer[] cust = new Customer[100]; //maximum size is 100
        int cntCust = 0;
        int cont = 1;

        while (cont == 1) {
            System.out.println("\n ***** ");
            System.out.print("\n Enter the customer ID : ");
            int custID = scan.nextInt();
            System.out.print("\n Enter customer name : ");
            String custName = scan.next();

            Item[] custBuy = new Item[10];
            System.out.print("\n Enter the item ID to purchase : ");
            int totItemPurchased = scan.nextInt();
            //each customer may purchase any of the item as listed
            System.out.println(" 1. Laptop - RM 4500 ");
            System.out.println(" 2. Printer - RM 1200 ");
            System.out.println(" 3. Scanner - RM 750 ");
            System.out.println(" 4. Laptop - RM 30 ");
            System.out.println(" 5. Head Phone - RM 120 ");

            for (int y = 0; y < totItemPurchased; y++) {
                System.out.print("\n Enter item number (" + (y+1) + ") : ");
                int itemNumber = scan.nextInt();
                custBuy[y] = item[itemNumber-1];
                //Assume the customer purchase 3 items
                //eg: custBuy[3] = {item[0], item[4], item[2]};
            }

            cust[cntCust] = new Customer(custID, custName, custBuy);
```

```

        cntCust++;
        System.out.print("\n To continue press [1-Yes,0-No]: ");
        cont = scan.nextInt();

    }

    System.out.println("\n List of customer and item purchased  ");

    for (int x = 0;x<cntCust;x++){
        Item[] totItem = cust[x].getItem();
        int cntNotNull = 0;
        for (int a=0;a<totItem.length;a++)
            {//to determine how many items purchased that stored
            //in the array totItem
                if (totItem[a] != null){
                    cntNotNull++;
                }
            }

        cust[x].display(cntNotNull);
        System.out.println("\n ***** ");
    }
} //close main
} //close class

```

Figure 4: Program segment implementing customer purchases of items

The code segment initializes an array named `item` to store the profiles of five items. An array of `Customer` objects, referred to as `cust`, is used to store customer information, including customer ID, customer name, and an aggregated `Item` object. Each customer may select multiple items for purchase, and the selected items are stored within the `item` array. During instantiation, the customer's ID, name, and associated `Item` objects are assigned to the `cust` array. The application prompts the user to choose whether to continue or terminate the program. Before the program concludes, it displays a list of customers along with detailed information about the items purchased. Additionally, the total purchase amount for each customer is presented.

The concept of aggregation is effectively implemented in the application program through the relationship established between the `Customer` and `Item` classes. In object-oriented programming, aggregation represents a "has-a" relationship where one object contains or references another object without taking ownership of it. In this case, each `Customer` object is associated with one or more `Item` objects, indicating that a customer can purchase multiple items. This relationship is implemented by passing an array of `Item` objects as a parameter to the `Customer` class constructor during the object instantiation process. As a result, the `Customer` class holds a reference to the `Item` objects, allowing the program to manage customer purchases effectively while keeping the `Item` class independent. This design promotes modularity and separation of concerns, as the `Item` class can function independently and be reused elsewhere if needed. During program execution, the user is allowed to input the

customer's ID, name, and select the desired items for purchase by entering item IDs. The selected items are stored in the item array, and together with the customer information, they are used to create a new Customer object stored in the cust array. This structure clearly demonstrates aggregation, where the Customer object maintains a reference to multiple Item objects. Before the application ends—either when the user chooses to stop or all entries are completed—the program displays a summary of each customer's details, the list of purchased items, and the total amount spent. This implementation of aggregation not only ensures a clear and logical organization of data but also enhances the overall readability and maintainability of the code.

## Conclusion

In conclusion, this article has demonstrated the application of aggregation as a fundamental concept of association in object-oriented programming through the use of the Java programming language. By designing and implementing the Item and Customer classes, we established a clear one-to-many relationship, where each customer can be associated with multiple items without implying ownership. This form of association was effectively realized by passing arrays of Item objects as parameters to the Customer class constructor, illustrating how objects can collaborate and interact within a program. The aggregation approach not only promotes modularity and reusability of code but also reflects real-world relationships in software design, making it easier to manage complex data structures (GeeksforGeeks, 2025). Through the development of a simple yet functional application, we showed how aggregation facilitates structured data handling, allowing the system to track customer purchases, display itemized details, and compute total expenditures (Gupta, 2023). This practical implementation reinforces the importance of understanding and applying object-oriented principles such as aggregation to build efficient, scalable, and maintainable software systems.

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## THE ROLE OF VISUAL NOTE-TAKING IN ENHANCING LEARNING AND UNDERSTANDING IN MATHEMATICS

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### ABSTRACT

*In the age of digital education, note-taking has taken on a new role. Where classes are held online over Zoom calls and lessons are explained with the help of an online whiteboard, note-taking is also increasingly becoming more digital in form. Students and teachers are using online document editing apps and visual collaboration tools to record and share information instead of writing everything down in a book. The use of visuals to map out ideas and to showcase interrelationships between them has become extremely popular over the last few decades, especially because visuals help the brain process information much faster and enhance memory and understanding better. Unlike traditional linear note-taking, visual note-taking involves the use of graphic organisers such as diagrams, charts, concept maps, images, and colour to represent ideas and relationships between concepts. This paper aims to review the role of visual note-taking in enhancing students' comprehension, memory retention, and higher-order thinking skills. Based on existing literature, visual note-taking supports meaningful learning by helping learners make connections between new information and prior knowledge. The findings from previous studies suggest that visual representations improve cognitive processing and facilitate deeper understanding, making visual note-taking a valuable strategy for both learning and examination preparation.*

**Keywords:** *Visual note, note taking, memory, students' perceptions, mathematics*

### Introduction

Note-taking is an important skill that helps students understand and remember information during lessons, reading, and self-study. Many students still use traditional text-based notes, which mainly involve writing down information word for word. However, this method may not be effective for understanding complex ideas or seeing connections between concepts. Visual note-taking combines words with visuals to record information in a more meaningful way. It uses images, diagrams, symbols, and structured layouts to help learners organise ideas and understand content more easily. In mathematics, visual aids are especially helpful because they support the understanding and recall of abstract and complex concepts. Therefore, students should include visual elements, not just words and numbers, when taking notes in math classes or preparing for tests.

Visual aids help display information in a way that the brain can understand and remember. For example, drawing diagrams of shapes and angles in geometry helps students see and understand the concepts more clearly (Wienecke et.al.2023). Symbols and graphs in algebra help us grasp equations and functions. Visual aids also make studying more effective by allowing students to quickly review diagrams and symbols rather than reading lengthy notes. However, visual aids should be utilized cautiously. Notes should not be very visual, and students should focus on grasping the concepts rather than depending solely on illustrations.

Visual note-taking is an alternate technique to organizing information using visual features such as diagrams, charts, photographs, and symbols. The method students choose often depends on the learning purpose, such as understanding new content, revising, or preparing for exams. By turning written or spoken information into visual form, students become more actively involved in learning. Visual note-taking may also help exam preparation by assisting students in reorganizing knowledge into clearer study notes or improving existing notes using colour and visuals. Overall, this approach helps promote deeper understanding and meaningful learning by using simple drawings, symbols, and tables with diagrams to make information easier to compare and understand.

### **Literature Review**

Studies on the use of strategic note-taking in mathematics reinforce the importance of visual and organizational factors. Note-taking behaviours such as structuring and highlighting key information have been linked to increased task comprehension and fewer errors when solving complex, reality-based mathematical problems. This implies that students who engage more deeply with information's visual structure are better equipped to process and apply mathematical concepts (Wienecke et. al., 2025). Visual note-taking, which includes the use of mind maps and other visual organisers, has been studied as a method of improving learning and comprehension in educational settings, including mathematics. Roehling (2017) found that visual note-taking helps students organise their thinking and stay more focused during lessons. Wammes et al. (2016) demonstrated that drawing or visual-based notes can improve memory recall up to four times compared to traditional note-taking.

According to research, visual aids assist students in organising complex information, identifying linkages between ideas, and improving retention and comprehension when compared to standard linear notes. Due to the research by Wang Simei (2024), mind maps are an innovative tool that enhances high school mathematics problem-solving by helping students organize and visualize knowledge. They address common challenges such as fragmented understanding, unclear solution steps, and low engagement in traditional instruction. By enabling students to build structured knowledge networks, mind maps improve problem-solving efficiency and strengthen logical reasoning skills. Johanna et. al. (2024), indicates that visualisation interventions in mathematics (such as diagrams,

graphs, and other visual aids) frequently result in positive learning outcomes, particularly in topics with strong visual or spatial components like geometry and calculus, even though most of the visual note-taking research has concentrated on visual tools generally rather than just mathematics. The dual coding of information through verbal and visual channels improves cognitive processing and deepens comprehension, according to multimedia learning theories, which are consistent with these findings.

The application of visual note-taking techniques, especially mind mapping, is highly supported by these theoretical ideas. Additionally, students react favourably to mind mapping as a visual learning and note-taking tool, according to a study by Sentyawati (2022) on students' opinions. Students stated that mind mapping helps them summarize material, fosters creativity, and makes it easier to organize thoughts effectively—skills that are critical for succeeding in mathematics.

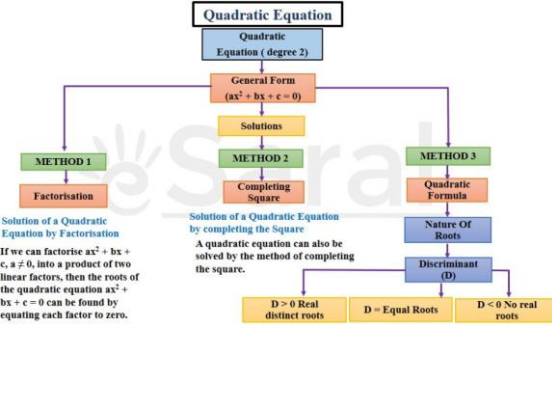
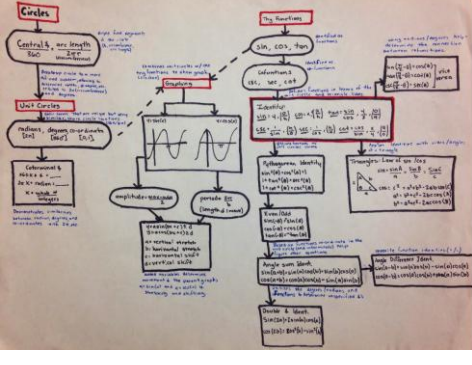
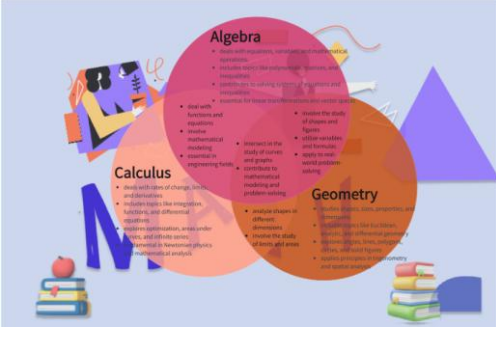
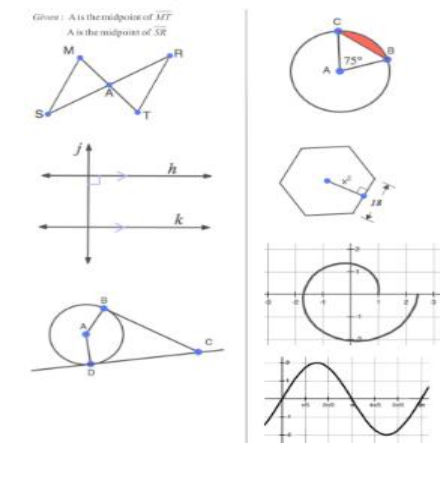
### **Visual Note-Taking in Mathematics Learning**

Mathematics is frequently regarded as an abstract subject since it relies on symbols and formulas, which can make learning difficult when material is solely delivered in text form. Visual note-taking helps address this issue by converting abstract ideas into clear visual representations. In mathematics, tools such as diagrams, graphs, concept maps, and flowcharts can be used to show relationships between concepts and steps in problem-solving. For example, concept maps help students connect algebraic ideas, while flowcharts illustrate the steps involved in solving equations.

Graphs are a strong kind of visual notation in mathematics, helping students grasp topics like functions, limits, and calculus by displaying relationships between variables. Drawing graphs next to equations helps connect symbols to visual meaning, and labelled geometric models make things like angles, symmetry, and transformations clearer. Visual note-taking also improves memory and problem-solving by using colours, arrows, symbols, and spatial layouts to create cues that aid recall (Santiago, 2011). This systematic method enables students to access knowledge rapidly and utilise mathematical concepts more efficiently.

Visual note-taking promotes higher-order thinking in mathematics by encouraging students to analyse, identify patterns, and synthesise concepts. Learning becomes more meaningful and deeper when information is organised and restructured through the use of visual aids. Integrating these strategies can enhance conceptual understanding, engagement, and performance. However, research on the effectiveness of visual note-taking in mathematics, particularly at the university level in Malaysia, is limited. This study therefore aims to examine its impact on students' understanding and their perceptions of it as a learning tool.

**Table 1: Types of visual note taking in mathematics**

<p><b>Mind maps</b></p> <p>Organise mathematical ideas around a central concept using branches.</p> <ul style="list-style-type: none"> <li>Useful for summarising topics (e.g. algebra, calculus)</li> <li>Show connections between formulas, rules, and examples</li> <li>Effective for revision and exam preparation</li> </ul>	 <p><b>Quadratic Equation</b>      Quadratic Equation (degree 2)      General Form <math>(ax^2 + bx + c = 0)</math>      Solutions      METHOD 1: Factorisation      METHOD 2: Completing Square      METHOD 3: Quadratic Formula      Nature Of Roots      Discriminant (D)      D &gt; 0 Real distinct roots      D = Equal Roots      D &lt; 0 No real roots</p>
<p><b>Concept Maps</b></p> <p>Use boxes or circles connected with labelled arrows.</p> <ul style="list-style-type: none"> <li>Emphasise relationships between mathematical concepts</li> <li>Helpful understanding of definitions and theories</li> <li>Commonly used for abstract topics</li> </ul>	
<p><b>Venn Diagrams</b></p> <p>Compare sets or concepts.</p> <ul style="list-style-type: none"> <li>Used in set theory, probability, and number concepts</li> <li>Show similarities and differences clearly</li> <li>Support reasoning and classification</li> </ul>	
<p><b>Diagrams and Drawings</b></p> <p>Diagrams visually represent mathematical objects.</p> <ul style="list-style-type: none"> <li>Common in geometry, trigonometry, and graphs</li> <li>Help students visualise shapes, angles, and relationships</li> <li>Improve understanding of abstract ideas</li> </ul>	

<p><b>Flowcharts</b></p> <p>Show step-by-step problem-solving processes.</p> <ul style="list-style-type: none"> <li>• Used in algebra, calculus, and word problems</li> <li>• Help students follow logical procedures</li> <li>• Reduce errors in multi-step solutions</li> </ul>	
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**Conclusion**

Visual note-taking improves memory and recall because visual information is processed faster and remembered for longer than text alone. Colours, arrows, icons, and organised layouts are useful memory cues, while mind maps assist link similar concepts, such as differentiation rules, in a clear and systematic manner. These visual aids assist students in recalling information during examinations and in swiftly retrieving mathematical techniques and formulas, hence enhancing mathematical ability. The research concludes that visual note-taking is an effective technique for enhancing students' conceptual understanding of mathematics. Compared to standard linear note-taking, visual notes promote stronger cognitive processing, allowing students to organise and integrate ideas more effectively. They provide a clearer depiction of difficult topics, making abstract mathematical linkages more understandable. Visual notes can help with memory recall by giving memorable visual cues and associations, as well as increasing student engagement by making learning more interactive and visually appealing. Visual note-taking in mathematics classes is an effective tool for creating deeper and more meaningful learning experiences.

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## FORECASTING GOLD MARKET TRENDS USING BACKWARD NEWTON'S DIVIDED DIFFERENCE INTERPOLATION

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### ABSTRACT

*Accurate short-term forecasting plays a crucial role in decision-making across various domains, particularly in financial markets. This study applies Newton's Backwards Divided Difference (NBDD) interpolation method to predict gold price trends using recent historical data. NBDD is especially suitable for extrapolation near the end of a dataset, making it an effective tool for short-term forecasting. Polynomial models of degree 3 and degree 7 are constructed to study the prediction accuracy. The findings indicate that lower-degree polynomials provide a closer fit to historical data, while higher-degree polynomials effectively capture the general trend.*

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

### Introduction

Forecasting commodity prices, particularly gold prices, is a significant task in financial analysis due to gold's role as a safe-haven asset and an investment instrument. Reliable short-term predictions help investors, policymakers and analysts make decisions under uncertainty. Mathematical interpolation techniques have long been used to estimate unknown values based on known data points, especially when recent data carry greater predictive importance.

Newton's Backwards Divided Difference (NBDD) method is an interpolation technique designed to generate polynomial approximations using data points located near the end of a dataset. NBDD focuses on the most recent values, making it suited for short-term forecasting. This study employs NBDD to construct polynomial models of degree 3 and degree 7 for predicting gold price movements, with particular emphasis on comparing low-degree and high-degree polynomial approximations.

## **Literature Review**

Newton's Divided Difference (NDD) interpolation has long been recognised in numerical analysis for its flexibility and efficiency in constructing interpolating polynomials. Its recursive formulation makes it particularly well-suited for datasets where predictions are required near the most recent observations. Kassahun et al. (2022) highlight the effectiveness of NBDD in extrapolating values at or near the end of equally spaced datasets, underscoring its relevance in time series forecasting contexts.

Recent applications of NBDD in financial forecasting have demonstrated promising results. Warpe and Pippal (2023) applied the method to short-term commodity price forecasting, reporting improved predictive performance when recent data points were emphasised. Similarly, Huang (2023) found that NBDD yielded superior short-term forecasts compared to forward-based interpolation methods in economic and financial datasets, reinforcing the method's utility in volatile markets.

Other studies have expanded the scope of NDD interpolation in financial and economic forecasting. Rahman and Chowdhury (2024) compared NDD with Lagrange interpolation in financial time series, concluding that NDD's recursive structure provides better adaptability for short-term predictions. Singh and Patel (2023) demonstrated its effectiveness in capturing rapid fluctuations in equity markets, while Zhou (2021) showed that NDD outperformed spline and forward interpolation methods for extrapolating near-end data in economic time series.

Beyond financial applications, Mohd Zin et al. (2025) applied Newton's Forward Divided Difference (NFDD) to gold price forecasting, showing improved accuracy with higher-order polynomials. Lee (2025) provided a modern overview of NDD interpolation, emphasising its versatility in economics and engineering datasets, particularly with non-uniform spacing. Collectively, these studies illustrate a growing consensus that NDD methods, especially backward formulations, are highly effective for short-term forecasting tasks where recent data points carry greater predictive weight.

## **Methodology**

This study employs the NBDD method to analyse historical gold price data, which were collected monthly and quarterly from March 2022 to April 2025, sourced from MSN Finance, as shown in Figure 1. The dataset consists of equally spaced observations, making it suitable for divided difference interpolation.



Figure 1: Gold Price from March 2022 to April 2025

In the NBDD framework, the independent variable values are indexed from the most recent observation backwards, with  $x_i$  ordered from bottom to top. Table 1 shows the construction of the NBDD table using the MSN Finance data.

Table 1: NBDD construction

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

Two interpolating polynomial models are derived:

A degree 3 polynomial,  $P_3(x) = 2658.50 + 45.1667x - 1.0111x^2 + 0.6278x^3$

A degree 7 polynomial,  $P_7(x) = 2658.50 + 45.1667x - 1.0111x^2 + 0.6278x^3 + 0.2516x^4 + 0.4326x^5 + 0.0051x^6 + 0.0005x^7$

These models were implemented using Maple software to compute interpolated values and forecast future gold prices. Finally, prediction performance was assessed using Percentage Absolute Relative

Error (PARE), allowing a comparative analysis of the models' effectiveness in capturing gold price trends.

## Results

The application of NBDD yields two approximate polynomial functions of degree 3 and degree 7, as summarised in Table 2.

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

Date	$x_i$	Gold Price $f(x_i)$	Approx. Degree 3	Approx. Degree 7	PARE Degree 3 (%)	PARE Degree 7 (%)
01/08/2022	5	1787.70	-8981.7222	-117058.7087	602.4178	6648.0063
03/01/2023	10	1846.10	-3754.6667	-2162.212	303.3837	217.1232
01/11/2023	14	1992.20	-988.0222	2092.75	149.5945	5.0472
01/04/2024	19	1847.20	1097.0333	2028.47	40.6110	9.8132
02/01/2025	25	2257.10	2206.5000	2150.51	2.2418	4.7224

For the earlier data points, both degree 3 and degree 7 approximations exhibit extremely large deviations from the actual gold prices, as reflected by very high PARE values. In particular, degree 7 exhibits substantially larger errors, reaching up to 6648.01%, which suggests severe overfitting and numerical instability when higher-degree polynomials are applied far from the interpolation nodes.

As the data points move closer to the interpolation range, the approximation accuracy improves notably for both degrees. The degree 7 approximation demonstrates a significant reduction in error, with a PARE of only 5.05%, compared to 149.59% for the degree 3 approximation. This trend continues for the end data points, where degree 7 again outperforms degree 3, recording a lower PARE of 9.81% versus 40.61%.

At the end of the data point, both methods achieve relatively accurate approximations. However, degree 3 yields the lowest error at 2.24%, compared to 4.72% for Degree 7, indicating that lower-degree interpolation may offer more stable and reliable predictions near the endpoint of the data range.

## Discussion

The comparison between degree 3 and degree 7 polynomials reveals a clear trade-off between approximation accuracy and numerical stability across different time periods. At earlier data points,

particularly in August 2022 and January 2023, both interpolation degrees produced large errors, with degree 7 showing extremely high PARE values. This behaviour suggests that higher-degree polynomials are highly sensitive to data distribution and prone to oscillations when estimating values far from the interpolation nodes.

As the evaluated points move closer to the central interpolation region, the performance of the degree 7 polynomial improves significantly. Degree 7 achieves substantially lower PARE values compared to degree 3, indicating its ability to capture more complex fluctuations in gold price movements. This demonstrates that higher-degree interpolation can provide better local accuracy when sufficient nearby data points are available.

However, the results from January 2025 indicate that degree 3 interpolation yields a lower error than degree 7. This suggests that lower-degree polynomials may offer more reliable and stable approximations near the endpoints of the dataset. The smoother nature of the degree 3 polynomial helps prevent excessive oscillations, making it more suitable for estimating long-term trends.

## Conclusion

As a conclusion, the increasing polynomial degree does not necessarily guarantee improved prediction accuracy. While degree 7 interpolation can outperform degree 3 within certain regions, it is also more susceptible to numerical instability and overfitting. Therefore, selecting an appropriate polynomial degree is crucial and should consider the intended prediction range and the balance between accuracy and stability.

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## THE DEVELOPMENT OF LEARNWISE, AN ENGLISH LEARNING COURSEWARE FOR PKSK PREPARATION: A PROTOTYPE

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### ABSTRACT

*This project focuses on developing an interactive web-based English learning courseware tailored for Year 5 and Year 6 students to enhance their English proficiency and support their preparation for the Pentaksiran Kemasukan Sekolah Khusus (PKSK). Many pupils experience difficulties in understanding basic English instructions, perceive the subject as challenging, and lack motivation due to traditional teaching approaches that rely heavily on textbooks and worksheets, with minimal integration of technology in the classroom. To address these issues, the project applies Constructivist Learning Theory and adopts the ADDIE instructional design model, encompassing the phases of Analysis, Design, Development, Implementation, and Evaluation. Developed using Adobe Animate, the courseware integrates multimedia elements such as text, audio, graphics, and animations to create interactive activities focusing on spelling, grammar, synonyms, antonyms, idioms, quizzes, and games. These features promote self-paced learning, provide immediate feedback, and enhance engagement through gamified and visually enriched learning experiences. Preliminary evaluations and feedback from teachers and students indicate improvements in comprehension, confidence, and motivation compared to conventional instructional methods. Overall, this initiative demonstrates how a theory-driven multimedia courseware can effectively support primary school students' English language development while aligning with Malaysia's digital education goals.*

**Keywords:** *courseware, English, PKSK, ADDIE, Constructive Learning Theory*

### Introduction

With the advancement of information technology, e-learning has significantly transformed both teaching and learning processes. It refers to the use of digital technologies and the internet to deliver lessons, allowing students to learn anytime and anywhere at their own pace. Interactive features such as videos, animations, and quizzes enhance engagement and sustain students' interest (Hollister et al., 2022). In English language learning, e-learning courseware has been shown to improve vocabulary, grammar, pronunciation, and learners' confidence (Wati et al., 2025). This project aims to integrate educational technology into English learning for Malaysian primary school students, particularly Year 5 and Year 6 pupils preparing for the PKSK examination, which remains a key pathway to prestigious schools such as Sekolah Berasrama Penuh (SBP), Maktab Rendah Sains MARA (MRSM), and Sekolah Menengah Kebangsaan Agama (SMKA). Insights from an interview with an English teacher revealed

that conventional teaching methods relying on textbooks and whiteboards are less interactive, resulting in low engagement, short attention spans, and limited opportunities to develop essential 21st-century skills such as critical thinking and problem-solving.

Many English classrooms still rely on traditional, teacher-centered methods such as lectures, textbooks, and memorization, which limit active participation, creativity, and meaningful learning (Yue, 2024). Students also tend to have shorter attention spans, making long, non-interactive lessons less effective. Research shows that technology-supported learning increases engagement, motivation, and autonomy compared to conventional approaches (Yuliani et al., 2023; Yao-Ping Peng et al., 2023). However, limited use of digital tools restricts opportunities for self-paced learning and immediate feedback. Therefore, there is a strong need for an interactive e-learning courseware with multimedia elements and student-centered strategies to better prepare Year 5 and Year 6 students for the PKSK examination.

Grounded in Constructivist Learning Theory, which emphasizes active learning through exploration and guided support within the Zone of Proximal Development (Vygotsky, 1978) the LearnWise courseware promotes meaningful and self-directed learning experiences. Designed for PKSK candidates, the courseware includes modules on grammar, spelling, synonyms, antonyms, and idioms, delivered through interactive quizzes, games, and multimedia elements with instant feedback. By combining educational theory with digital innovation, the project enhances students' motivation, confidence, and English proficiency while supporting Malaysia's digital education agenda and strengthening English language learning at the primary school level (Dawi & Hashim, 2022).

Thus, the development of this project is to identify the e-learning needs of Standard 5 and 6 students preparing for PKSK, to design and develop a Constructivist-based English e-learning courseware, and to evaluate its usability and functionality in supporting student engagement and learning outcomes.

## **Methodology**

The development of LearnWise is grounded in Constructivist Learning Theory and guided by the ADDIE instructional design model, ensuring that the courseware promotes active, student-centered knowledge construction while systematically progressing through the phases of Analysis, Design, Development, Implementation, and Evaluation to produce an effective and structured e-learning solution.

Constructivist Learning Theory explains that learning happens when learners actively build their own understanding through experience, interaction, and reflection, rather than simply receiving information from teachers. In this theory, learners are seen as active participants who develop knowledge by connecting new information with what they already know. Vygotsky (1978) introduced

the concept of the Zone of Proximal Development, which suggests that learners learn best when they are given appropriate guidance and support that helps them achieve tasks they cannot complete on their own.

The ADDIE model provides a standard framework for instructional design. It lays out a systematic method for creating effective learning content and educational programs. The process has five phases Analysis, Design, Development, Implementation and Evaluation. These stages offer guidance for designers throughout the planning creation and refinement of learning materials. The ADDIE model facilitates straightforward decisions at every step. This helps ensure learning plans directly address learner needs utilize suitable materials and establish outcomes that can be measured. In educational and e-learning contexts, the ADDIE model is commonly used because it offers a flexible yet organized approach that can be adapted to different environments, including online courseware, multimedia learning systems, and language-learning applications.




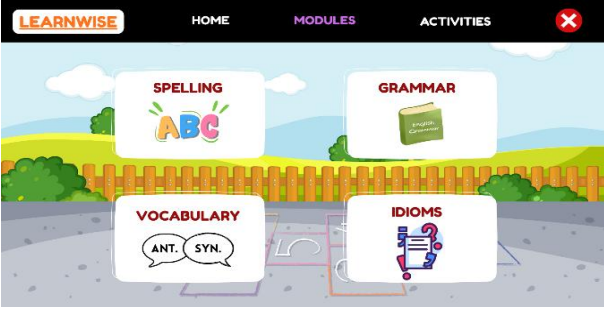
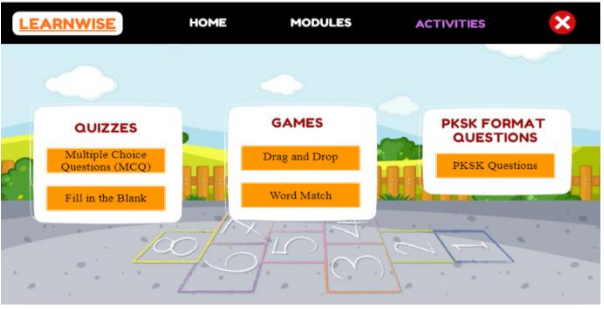

Figure 1: Phases in ADDIE Model

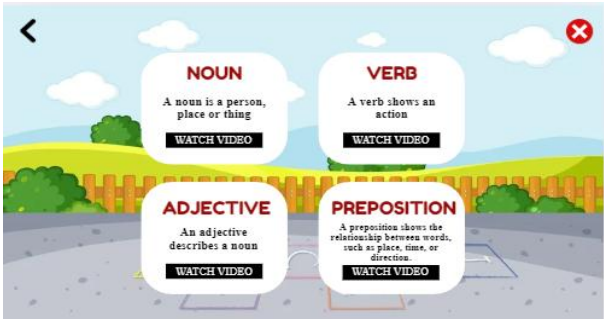

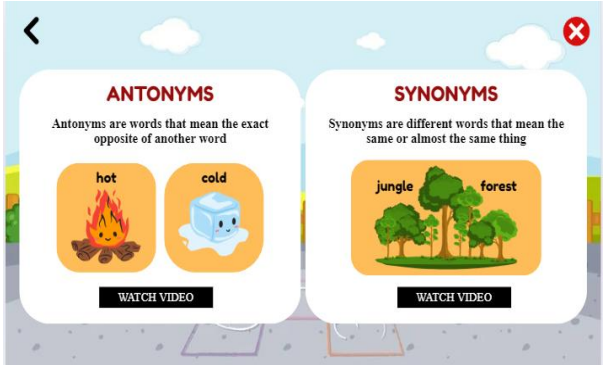
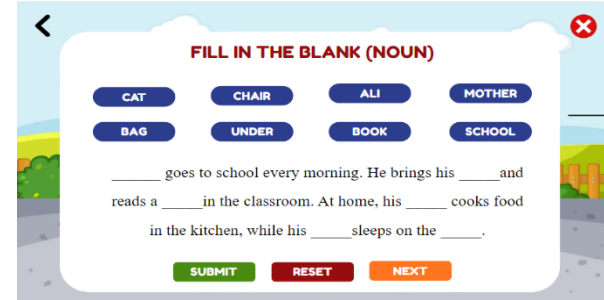
## Design


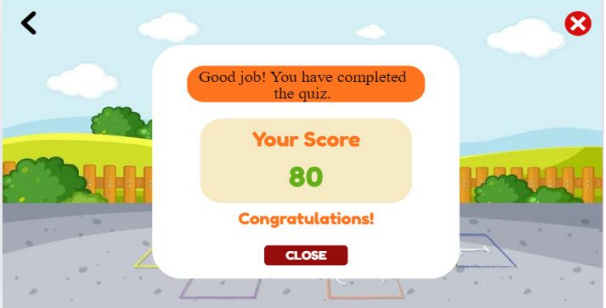
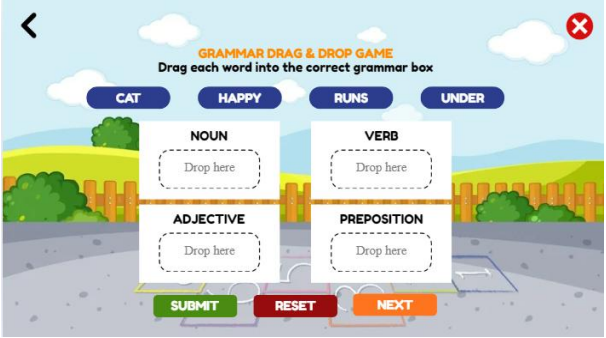

A prototype is an early working model of the LearnWise courseware developed during the design and development phases to visualize and test the structure, interface, and interactive features before full implementation. It represents the actual look and functionality of the system, including the Homepage, learning modules, activities, and PKSK-format questions. Guided by Constructivist Learning Theory, the prototype is designed to promote active learning by enabling students to explore content, interact with materials, and construct knowledge through meaningful tasks.

Based on the interface design, the prototype demonstrates how students engage with English content through quizzes, drag-and-drop games, word-matching activities, and PKSK-style questions. These interactive components encourage learners to apply grammar and vocabulary knowledge actively rather than passively receive information. The inclusion of immediate feedback and score displays allow students to reflect on their performance, identify mistakes, and improve their understanding. Table 1 below presents the prototype of the LearnWise courseware.

Table 1: Prototype of the LearnWise courseware

Prototype	Description
<p>1. Homepage</p> 	<p>The Homepage displays a colorful design and a clear “START” button. The simple layout, bright colors help create a positive learning environment and encourage students to start learning.</p>
<p>2. Modules page</p> 	<p>The Modules page shows the main English learning modules in LearnWise, which include Spelling, Grammar, Vocabulary, and Idioms. Each module is displayed using clear labels and icons to help students easily recognize and choose the topic they want to learn. The simple layout allows students to move freely between modules based on their learning needs.</p>
<p>3. Activities page</p> 	<p>This Activities page presents three main activity types: Quizzes (MCQ and Fill in the Blank), Games (Drag and Drop and Word Match), and PKSK Format Questions. Students can select activities based on their learning goals and readiness.</p>
<p>4. Spelling Module page</p> 	<p>This Spelling Module page presents spelling lessons through an instructional video that explains the spelling of key words along with the simple definitions and visual illustrations. Students can watch, pause, and replay the video to support understanding the at their own pace.</p>

<p>5. Grammar Module page</p> 	<p>This Grammar Module page presents grammar lessons through instructional video that explain nouns, verbs, adjectives, and prepositions using simple definitions, visuals and example sentences. Students can watch, pause, and replay the videos to support understanding at their own pace.</p>
<p>6. Idioms Module page</p> 	<p>The Idioms Module page video explains each idiom using simple narration, animation, and visual examples. Students watch how the idioms are used in a short situation, helping them understand the meaning in a real context.</p>
<p>7. Vocabulary Module page</p> 	<p>This Vocabulary Module page introduces antonyms and synonyms using clear definitions, visuals, and example words. Students can click the “Watch Video” button to view short videos that explain the concepts through simple examples and illustrations.</p>
<p>8. Quizzes page (MCQ and Fill in the Blank)</p> 	<p>The Quizzes page shows the Quizzes section that has MCQ and Fill in the Blank that has progress bar, score display, and time limit. St select answers based on their understanding and receive immediate updates on their progress during the quiz.</p>

<p>9. Quiz Feedback page</p> 	<p>Immediate feedback after students answers a question. Correct answers are highlighted in green with positive reinforcement, while incorrect answers are shown in red with a brief explanation to help students understand their mistake before moving to the next question.</p>
<p>10. Score page</p> 	<p>The score page displays a congratulatory message and students final score after completing the quiz. It provides closure to the activity and allows students to exit the quiz by clicking the “Close” button.</p>
<p>11. Games page (Drag and Drop and World Match)</p> 	<p>The Games page includes interactive activities such as drag-and-drop and word match. Students drag words into words into correct grammar categories and match words with antonyms or synonyms. These games allow students to practice language concepts through hands-on interaction.</p>
<p>12.PKSK Format Questions page</p> 	<p>This page presents PKSK-style English multiple choice questions with a timer and question progress indicator. Students select the correct answer based on their understanding and submit their response before proceeding to the next question.</p>

## Conclusion

In conclusion, this chapter has described the overall methodology used in developing LearnWise: An English Learning Courseware for PKSK preparation, highlighting how the ADDIE model systematically guided the project through the Analysis, Design, Development, Implementation, and Evaluation phases. Particular emphasis was placed on the Design phase, where detailed storyboards and interface planning were carried out to structure the content, layout, and interactive elements. These designs were then translated into a functional prototype that visualized the actual flow, features, and user interaction of the courseware before full implementation. Grounded in Constructivist Learning Theory, both the design and prototype were developed to promote active, learner-centered engagement through interactive activities, immediate feedback, and meaningful tasks. Overall, the integration of a structured design process and a well-developed prototype provided a strong foundation for enhancing students' understanding, confidence, and readiness for the PKSK examination.

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## THE DEVELOPMENT OF MATH E-LEARNING PORTAL FOR PKSK CANDIDATES

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### ABSTRACT

*This project presents the development of an interactive mathematics e-learning portal designed for Standard 6 students preparing for the Pentaksiran Kemasukan Sekolah Khusus (PKSK). Aligned with the KSSR syllabus and supported by structured assessment components, the portal aims to strengthen students' mathematical understanding and problem-solving skills. It incorporates interactive exercises, automated quizzes, real-time feedback, and gamified learning features to enhance motivation and encourage self-paced learning. Developed using modern web technologies, Bijak Pecahan portal offers a user-friendly interface suitable for primary school learners. Findings from initial usability testing, along with feedback from teachers and students, indicate that the portal significantly improves exam readiness and promotes independent learning. Overall, this project addresses the growing demand for effective digital learning solutions within the Malaysian primary education context.*

**Keywords:** portal, mathematics, e-learning, PKSK, Bijak Pecahan

### Introduction

In today's digital era, technology has transformed the way people communicate, access information, and acquire knowledge. The rapid growth of e-learning has enabled students at all levels to learn more flexibly and efficiently through internet-based platforms. E-learning integrates various multimedia elements such as videos, quizzes, and interactive assessments, allowing learners to study at their own pace and according to their individual needs. Its widespread adoption during the COVID-19 pandemic highlighted its importance not only as an alternative mode of instruction but also as an essential component of modern education systems that enhances teaching effectiveness and student engagement (Cataudella et al., 2021).

This project focuses on the topic of fractions in Mathematics for Standard 6 students preparing for the (Pentaksiran Kemasukan Sekolah Khusus (PKSK) examination at Sekolah Kebangsaan Kampung Pasir Puteh (SKKPP). Although the UPSR has been abolished, PKSK remains a key assessment for students seeking admission into institutions under the Ministry of Education (KPM) and MRSM. To ensure the platform meets classroom needs, an interview was conducted with Encik Suhaimi bin Zainol Abidin, a Standard 6 Mathematics teacher at SKKPP. His insights and experience contributed

to shaping the content and design of the e-learning platform, ensuring its relevance, practicality, and effectiveness in supporting both teachers and students in mathematics learning and exam preparation.

Standard 6 students face significant challenges in mastering fractions, particularly in operations such as addition, subtraction, multiplication, and division. The abstract nature of fractions often prevents students from fully understanding fractions as parts of a whole or as numerical relationships. Without concrete representations or engaging learning experiences, many students memorize procedures without grasping underlying concepts, leading to misconceptions and frequent errors. The lack of interactive learning resources further worsens the situation, as traditional materials are often static and less engaging, making it difficult for young learners to maintain interest and develop strong conceptual understanding. Additionally, the structured “Ansur Maju” technique requires continuous practice and guidance and need deeper exploration of concepts and higher-order thinking skills, ultimately affecting students’ readiness for demanding assessments such as the PKSK.

To address these issues, this project outlines three key objectives which is to identify the needs of Standard 6 students and teachers in learning fractions for PKSK preparation, to design and develop an interactive e-learning portal on fractions based on Bloom’s Digital Taxonomy and to evaluate the functionality and usability of the proposed portal to ensure its effectiveness in supporting learning and exam preparation.

## **Methodology**

Bijak Pecahan e-learning portal adopts Bloom’s Digital Taxonomy (BDT) and the ADDIE Model as its core methodology to guide the design and development of the interactive e-learning portal. Bloom’s Digital Taxonomy, adapted from Bloom’s original cognitive framework, integrates digital tools into six hierarchical levels of thinking: remembering, understanding, applying, analyzing, evaluating, and creating (Husain, 2021; Nava et al., 2022). In this project, BDT ensures that learning activities are structured progressively, from recalling basic fraction concepts through quizzes and flashcards, to understanding through videos and simulations, and applying knowledge via interactive problem-solving tasks.

However, ADDIE Model provides a systematic and structured instructional design framework consisting of five phases: Analysis, Design, Development, Implementation, and Evaluation. In the Analysis phase, learners’ needs, learning challenges in fractions, and PKSK requirements are identified. During the Design phase, learning objectives, content structure, user interface, and assessment strategies are carefully planned in alignment with Bloom’s Digital Taxonomy. The Development phase involves creating the actual e-learning portal, integrating multimedia elements, interactive exercises, and feedback mechanisms. Implementation focuses on deploying the portal for student use, while the Evaluation phase assesses usability, functionality, and learning effectiveness through feedback and

testing.

The integration of Bloom’s Digital Taxonomy and the ADDIE Model ensures that the Bijak Pecahan e-learning portal is both pedagogically sound and systematically developed. While BDT guides the cognitive depth and digital engagement of learning activities, ADDIE ensures that each stage of development is organized, learner-centered, and outcome-driven. Together, these methodologies provide a comprehensive framework that enhances conceptual understanding, promotes higher-order thinking skills, and supports effective preparation for the PKSK examination.



Figure 1: Phases in ADDIE Model

### Design

The design of the user interface (UI) for the Bijak Pecahan e-learning portal plays a crucial role in ensuring effective learning and meaningful student engagement. In the design stage, clear learning objectives were first established to ensure that the interface layout, instructional strategies, and assessment methods were properly aligned with the intended learning outcomes. A well-structured interface not only presents content clearly but also guides students through interactive activities in a logical and intuitive manner. As highlighted by Raisal et al. (2024), the design phase is essential in transforming analyzed data into purposeful instructional activities, while Lyonni et al. (2023) emphasize the importance of creating innovative and engaging learning environments. Therefore, the user interface of this portal was carefully designed to be visually appealing, age-appropriate, and easy to navigate, enabling Standard 6 students to interact confidently with mathematical content.

Figure 2 illustrates the Home Page of the Bijak Pecahan e-learning portal, which serves as the main user interface and entry point to the system.

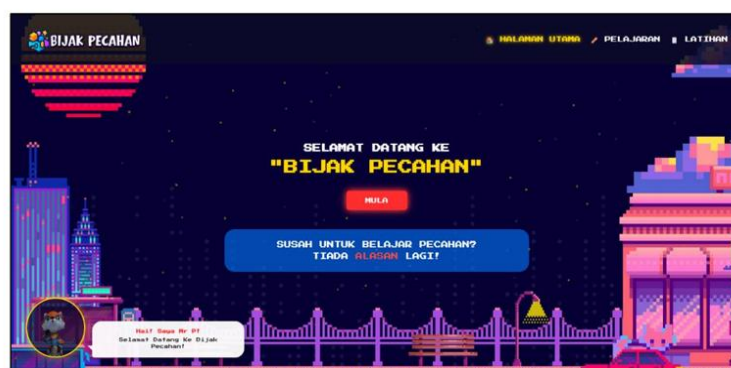


Figure 2: Bijak Pecahan Homepage

Figure 3 shows the Pelajaran Page of the Bijak Pecahan e-learning portal, providing organized access to lesson modules while retaining the same navigation bar for easy site navigation. A heading, “Mari Belajar Bersama!”, motivates learners, and topic-specific buttons allow students to choose lessons based on their preferences.

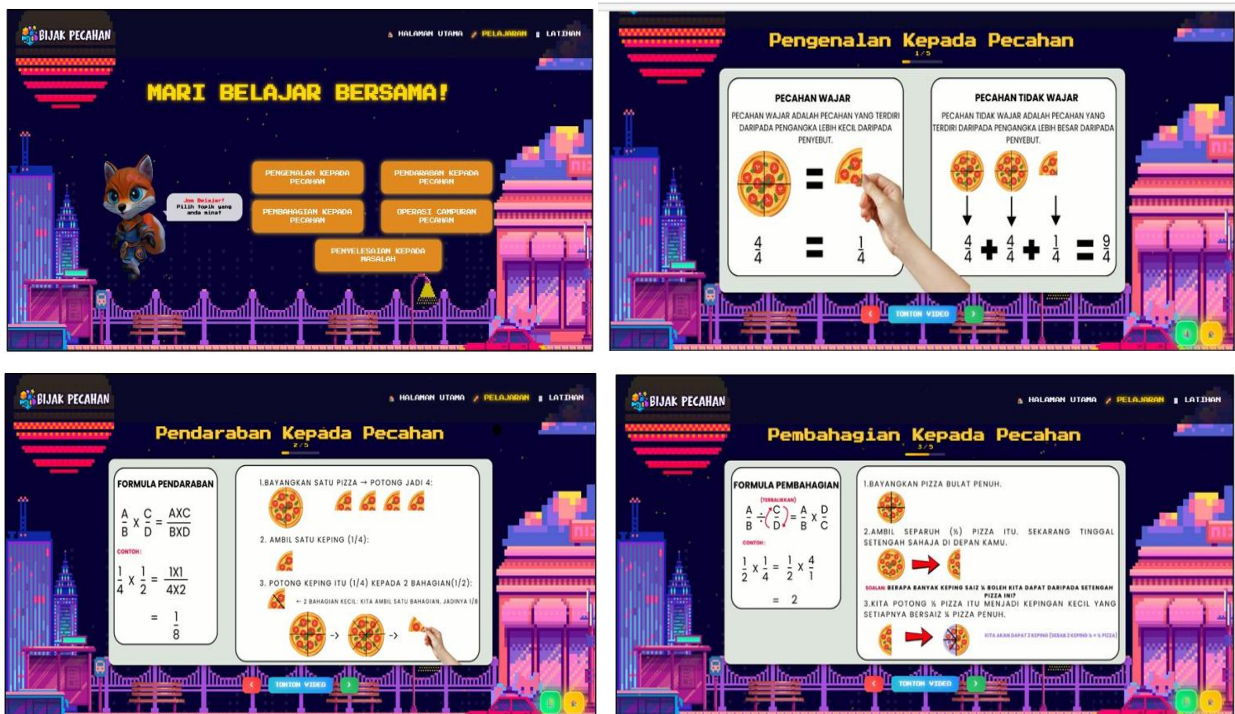


Figure 3: Bijak Pecahan Pelajaran Page

Additionally, functional icons located at the bottom-right corner include a book icon that opens the digital textbook via the AnyFlip platform as shows at Figure 4. These features collectively support an interactive, well-organized, and learner-centered learning environment for effective reinforcement of fraction concepts.



Figure 4: e-Book using AnyFlip

Figure 5 shows the Latihan Page which consists of Latihan, Ujian Sumatif and Main and Cabar. This page was designed to reinforce students’ understanding of fractions through interactive practice. Exercises are divided into formative activities such as drag-and-drop, memory, and daily tasks with immediate feedback and summative assessments (ujian PKSK) to evaluate overall performance.

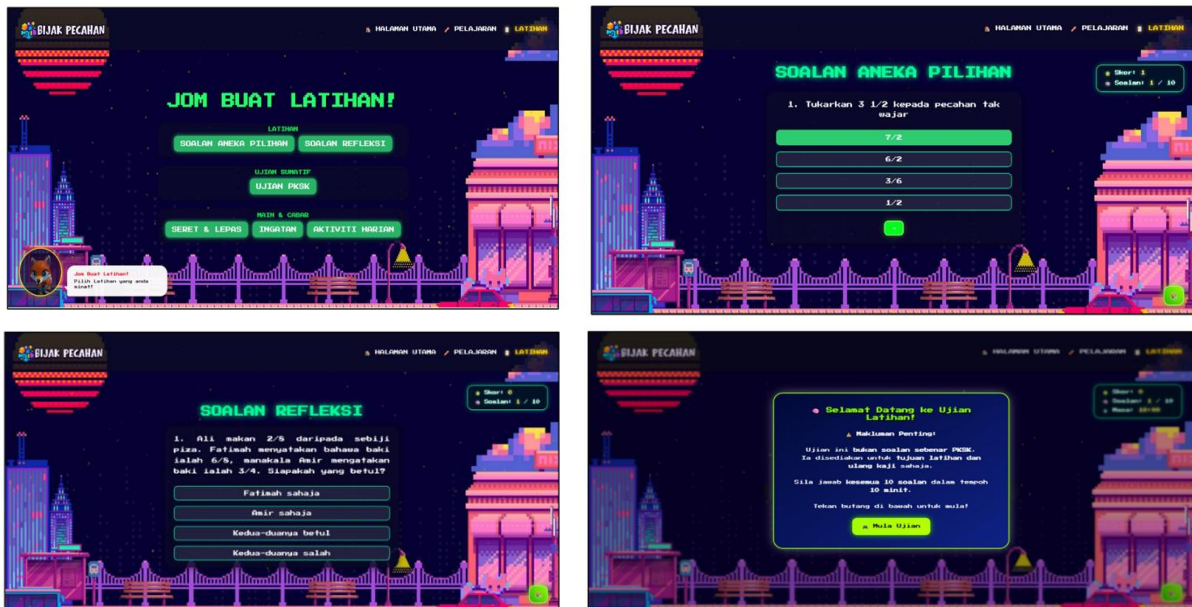


Figure 5: Latihan Page

Figure 6 illustrates the Permainan Page which consists of Seret & Lepas Page, Permainan Ingatan Page and Reka Menu Tengah Hari Page.

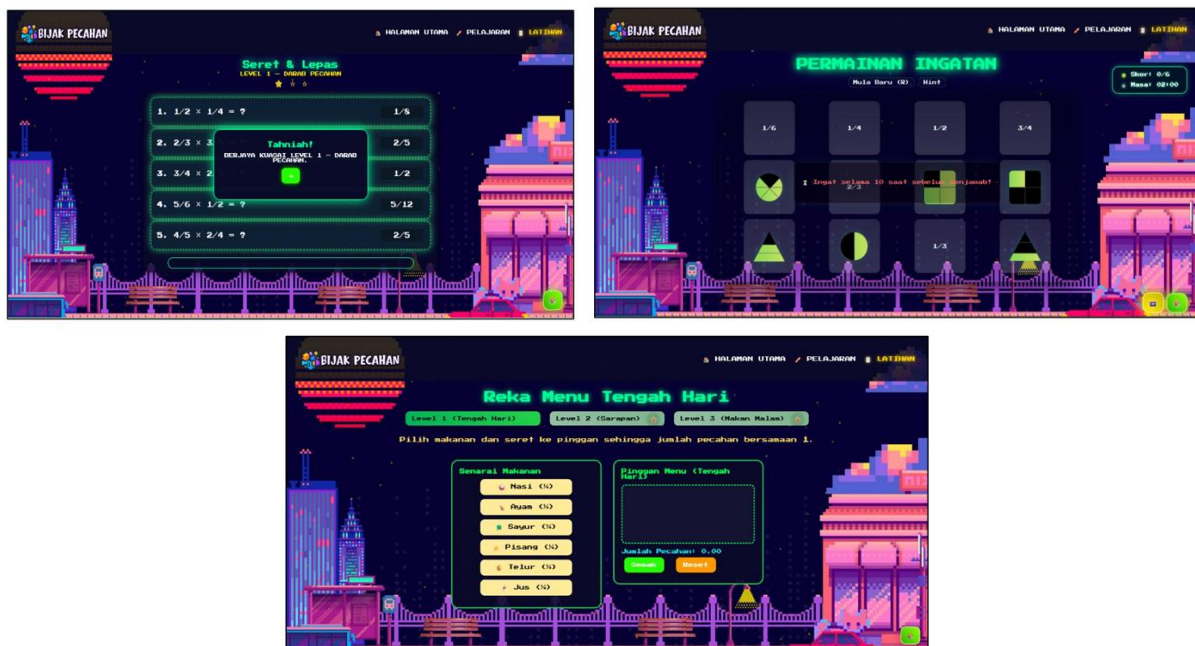


Figure 6: Permainan Page

## Conclusion

The Bijak Pecahan e-learning portal successfully demonstrates the effectiveness of combining interactive multimedia with Bloom's Digital Taxonomy and ADDIE Model to support Standard 6 students in learning fractions and preparing for the PKSK examination. The portal's design incorporates animations, visual tools, interactive activities, and step-by-step explanations that make abstract fraction concepts more accessible and engaging. Expert reviews and usability assessments confirmed that the portal effectively enhances conceptual understanding and supports independent learning, achieving all project objectives.

The Bijak Pecahan e-learning portal contributes significantly to the field of educational technology by providing a structured, interactive, and student-centered learning environment. Features such as immediate, detailed feedback allow students to reflect on errors, strengthen problem-solving skills, and progress at their own pace, reducing reliance on continuous teacher support. The portal serves not only as a practical tool for PKSK preparation but also as a model for future interactive mathematics e-learning applications. Overall, this project lays a strong foundation for the development of effective digital learning resources in primary education and highlights the potential of technology-enhanced instruction to improve engagement, motivation, and understanding in mathematics.

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# ANALYSIS OF MAPLE-BASED SOLUTIONS AMONG FIRST YEAR CIVIL ENGINEERING STUDENTS IN CALCULUS 1 ASSESSMENT

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## ABSTRACT

*This study investigates the use of Maple, a Computer Algebra System (CAS), by first year Civil Engineering students in Calculus I course at UiTM Cawangan Pulau Pinang, focusing on conceptual understanding and mathematical communication. Using qualitative document analysis, fifteen student Maple assessment scripts were examined to identify patterns of tool usage, procedural accuracy, and conceptual alignment. Findings indicate that while students were generally proficient in executing commands such as diff () and solve (), there was a significant disconnect between symbolic outputs and underlying calculus concepts. Key issues included over reliance on Maple outputs, confusion between the first order and second order derivatives, and incomplete mathematical communication. These results suggest that CAS tools alone do not guarantee conceptual development while guided interpretation and justification are essential for meaningful learning. The study highlights the need for instructional designs that integrate Maple with problem based or inquiry-oriented approaches to foster deeper understanding and higher order thinking skills in introductory engineering mathematics courses.*

**Keywords:** *Maple, Calculus I, Civil Engineering students, computer algebra system (CAS)*

## Introduction

Calculus 1 is a foundational subject in engineering education, particularly for engineering students, as it provides essential mathematical tools for modelling and problem solving. However, first year university students often struggle with abstract calculus concepts such as derivatives and concavity. Research has shown that these difficulties are frequently rooted in weak conceptual understanding rather than procedural errors alone (Ghazali and Zakaria, 2011).

To address these challenges, Computer Algebra Systems (CAS) such as Maple software have been increasingly integrated into calculus instruction. Maple offers symbolic computation and dynamic visualization capabilities that allow students to explore calculus concepts through multiple representations. Maple software is used to solve mathematical problems in the form of numeric or symbolic (Parma & Saparwadi, 2015). According to Kossivi (2025), using dynamic visualization could improve the way calculus is taught in college so that students can become more confident and gain a deeper understanding of arithmetic.

Despite these benefits, previous research has cautioned that students may use CAS tools in a procedural manner, focusing on executing commands without adequately interpreting results. This concern is particularly relevant in introductory calculus courses, where students are still developing foundational reasoning and mathematical communication skills. However, most existing studies have examined learning outcomes or instructional interventions, with limited attention given to students' actual CAS-based solution scripts.

Therefore, this study analyses Maple based solutions submitted by first year Civil Engineering students enrolled in a Calculus 1 course. Using qualitative document analysis, the study focuses on conceptual alignment and the quality of mathematical communication demonstrated in students' Maple assessment scripts.

## **Methodology**

### **Participants and Context**

The participants in this study were 30 first year Civil Engineering students enrolled in a Calculus 1 course. As part of a course assignment, students were required to use Maple to solve calculus problems involving differentiation and analysis of functions including sketching a graph of function.

### **Research Design**

A qualitative document analysis approach was adopted. Student scripts were treated as documents that reflect students' mathematical reasoning and use of CAS tools. From 30 submissions, fifteen Maple scripts were selected for analysis. These scripts were chosen as representative samples that exhibited common solution strategies and errors observed across the class.

### **Data Analysis Procedure**

Each selected Maple script was analyzed based on the several criteria such as types of Maple commands used (e.g. diff, solve), correctness of mathematical procedures, conceptual understanding of calculus principles, and completeness and clarity of solution presentation. Errors identified in the scripts were coded into categories to facilitate systematic analysis.

## **Result**

Analysis of the Maple scripts revealed that most students were able to use basic symbolic commands correctly, particularly for differentiation and inequality solving. Commands such as diff () and solve () were frequently used to determine intervals of increase, decrease, and concavity.

However, many students applied these commands procedurally, without explicitly linking the outputs to calculus concepts or verifying the mathematical context of the problem.

Table 1 below shows four main types of errors that was identified in the analysed scripts. The most frequent issue was over reliance on Maple outputs (Error 3), followed by conceptual errors related to derivative tests (Error 1).

Table 1: Main Types of Errors Identified in the Analysed Scripts

Code	Error Type	Description	Frequency
Error 1	Conceptual Error	Incorrect application of calculus concepts (e.g. using first derivative for concavity)	9
Error 2	Procedural Error	Correct command applied to an incorrect or unverified function	4
Error 3	CAS Over-reliance	Direct use of Maple outputs without interpretation or justification	11
Error 4	Incomplete solution	Missing conclusions or explanatory statements	5

Besides that, analysis of the selected Maple scripts revealed several instances of conceptual misalignment between calculus theory and the use of computer algebra system commands. Although most students were able to generate correct symbolic outputs using Maple, misunderstandings of fundamental calculus concepts were evident.

One prominent issue involved confusion between the use of first and second derivatives. In several scripts, students applied first derivative tests when analyzing concavity, indicating incomplete understanding of higher-order derivatives. While Maple correctly computed derivatives and solved inequalities, students frequently misapplied these results to draw incorrect or unsupported conclusions.

Another form of conceptual misalignment was observed in the interpretation of inequality solutions. Some students obtained correct solution intervals from Maple but failed to relate these intervals to the original calculus problem, such as identifying regions of increase, decrease, or concavity. This suggests that Maple outputs were often treated as final answers rather than as intermediate results requiring mathematical interpretation.

## Discussion

This study examined how first year Civil Engineering students used Maple to solve Calculus 1 problems, focusing on conceptual alignment and mathematical communication. The findings show that although students were generally able to execute Maple commands correctly, accurate computational outputs did not consistently reflect strong conceptual understanding. This supports previous research

demonstrating that students' difficulties in calculus are often rooted in weak conceptual understanding rather than procedural errors alone (Sofroniou et al., 2015).

A key issue identified was students over reliance on Maple outputs, with limited interpretation or justification provided in their solutions. While Maple successfully generated derivatives and solution intervals, several students struggled to apply these results meaningfully, particularly when analyzing function behavior. Similar findings have been reported in recent studies, which suggest that technologies such as dynamic mathematics software, intelligent tutoring systems, and online assessment platforms have been widely adopted to improve both cognitive and affective outcomes in mathematics classrooms. (Omer et al., 2025).

Despite these challenges, Maple remains a valuable tool for supporting calculus learning through symbolic computation and visualization. Recent literature emphasizes that using maple software in learning mathematics affects students' ability to solve a problem (Ni'mah et al, 2024) Therefore, the findings of this study highlight the importance of designing Maple based tasks and assessments that explicitly require students to explain and justify their reasoning in order to support deeper conceptual understanding in introductory engineering mathematics courses.

### **Teaching Implications**

The results of this study have several implications for teaching Calculus 1 to first-year engineering students. First, Maple based assignments should explicitly require students to interpret and explain Maple outputs. Instructors should emphasize the conceptual meaning of derivatives before introducing CAS tools. Beside that, Scaffolded tasks that separate computation from reasoning may help students develop deeper understanding. Finally, the assessment rubrics should include marks for interpretation and mathematical explanation, not just focused on the correct outputs.

### **Conclusion**

This study investigated the conceptual alignment and mathematical communication of first year Civil Engineering students within a Maple based Calculus 1 course. The qualitative document analysis of student scripts revealed that while students possess a high level of proficiency in executing procedural commands such as  $\text{diff}()$  and  $\text{solve}()$ , there remains a significant disconnect between these symbolic outputs and the underlying calculus theory.

The results identified three primary areas of concern such as CAS over reliance, conceptual misalignment and incomplete mathematical communication. For CAS over reliance, students frequently treated Maple as a "black box," accepting symbolic results as final answers without interpretive justification. For conceptual misalignment, a critical confusion between first and second-order derivatives was observed, leading to incorrect conclusions about function behavior like concavity.

Other than that, the incomplete mathematical communication indicates that many students failed to relate their computational findings back to the original problem context.

These findings align with recent literature, such as Ni'mah et al. (2024), which suggests that the effectiveness of software like Maple is highly dependent on the pedagogical framework in which it is placed. While their research demonstrated that a Problem-Based Learning (PBL) model can achieve 100% group effectiveness by making mathematics more contextual and enjoyable, our data suggests that without such a structured inquiry-based model, students may default to a passive relationship with technology.

Technology offers powerful tools that can enhance both teaching and learning in mathematics. When used appropriately, it can help students visualize abstract concepts, receive immediate feedback, and personalize their learning experience (Radha, 2015). The significant interaction between dynamic visualization and conceptual gain noted by Kossivi (2025) suggests that for students to overcome the abstract nature of derivatives and integrals, instructors must go beyond teaching software syntax and focus on synchronized animated representations.

In summary, the integration of Maple into engineering education provides a powerful platform for computation, but it is not a substitute for conceptual development. In order to provide future Civil Engineers with the requisite Higher Order Thinking Skills (HOTS), instructional designs must change from a product orientation to a process orientation. This study recommends the adoption of hybrid models, such as PBL-Maple integration, to ensure that students use technology not just to solve problems faster, but to understand them more deeply

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## ANALYSIS OF PERFORMANCE AMONG PRE-DIPLOMA BUSINESS STUDENTS BASED ON ASSESSMENT COMPONENTS

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### ABSTRACT

*This study examined the continuous assessment performance of Pre-Diploma Commerce students through a quantitative case study approach. The continuous assessment comprised three components: a test on Arithmetic and Algebra, an individual assignment on the Application of Mathematics in Business and a group assignment on Basic Statistics contributing a total of 60% to the course assessment. 28 Pre-Diploma Commerce students participated in the study. Descriptive statistics, including mean and standard deviation, were used to analyse students' performance across the different assessment components, which covered distinct mathematical topics and skills. The findings revealed variations in students' performance across assessment types and content focus, reflecting differences in conceptual understanding and application skills. This study provides preliminary insights into students' achievement patterns in continuous assessment and highlights the importance of diversified assessment components in monitoring learning progress at the pre-diploma level.*

**Keywords:** *continuous assessment, pre-diploma students, mathematics performance, descriptive statistics, academic achievement*

### Introduction

Mathematics is a fundamental subject in pre-diploma programmes, particularly for commerce students who must apply mathematical concepts in business contexts. However, students at the pre-diploma level often struggle to master basic mathematical concepts due to weak foundational knowledge and limited prior exposure to abstract reasoning. These challenges may affect their performance, especially when different assessment components evaluate different types of skills and content areas. Continuous assessment plays an important role in monitoring students' learning progress throughout the semester. Unlike final examinations, continuous assessment allows educators to evaluate students' understanding through various forms of assessment, such as tests and assignments, which may focus on different topics and cognitive skills. In mathematics courses, assessment components often cover a range of topics, including arithmetic, algebra, applications in business, and basic statistics, each requiring distinct levels of conceptual understanding and application.

For Pre-Diploma Commerce programmes, understanding students' performance in continuous assessment is essential, as it provides early indicators of learning difficulties before the final

examination. Analysing coursework performance can help educators identify strengths and weaknesses in students' learning and evaluate the effectiveness of assessment strategies used in the course. Despite its importance, limited studies have focused specifically on continuous assessment performance among pre-diploma students, particularly within the context of mathematics education. Therefore, this study aims to analyse the continuous assessment performance of Pre-Diploma Commerce students through a case study approach. By examining students' achievement across different coursework components, this study seeks to provide preliminary insights into performance patterns that may inform teaching and assessment practices at the pre-diploma level. Continuous assessment has been widely adopted in higher education as an effective approach to monitor students' learning progress throughout a course. Unlike a single high-stakes final examination, continuous assessment allows educators to evaluate students' understanding through multiple assessment tasks conducted over time. Previous studies have suggested that continuous assessment supports learning by encouraging regular engagement with course content and providing opportunities for formative feedback (Hernández, 2012; Gibbs & Simpson, 2004). This approach is particularly important in mathematics education, where students often require continuous practice and reinforcement to develop conceptual understanding and procedural fluency.

In mathematics courses, different assessment components are often designed to evaluate different types of knowledge and skills. Test-based assessments typically focus on procedural knowledge and accuracy, while assignment-based assessments emphasise application, reasoning, and problem-solving skills (Brookhart, 2011). Studies have shown that students may demonstrate varying levels of performance depending on the nature of the assessment and the mathematical content being assessed (Smith & Walker, 2021). As a result, analysing students' performance across different coursework components can provide meaningful insights into their strengths and learning challenges. Group-based assessments have also gained attention in educational research, particularly for their potential to enhance learning through peer interaction and collaborative problem-solving.

Research indicates that group assignments may lead to higher achievement due to shared understanding and peer support, although they may not always reflect individual mastery equally (Johnson & Johnson, 2009). In contrast, individual assessments are more likely to capture students' independent understanding of mathematical concepts. These differences highlight the importance of examining multiple assessment components rather than relying on a single measure of achievement. For pre-diploma students, especially those enrolled in Commerce programmes, mathematics learning often presents additional challenges due to weak foundational knowledge and limited prior exposure to abstract concepts.

Studies have reported that pre-university students frequently struggle with algebraic manipulation and basic mathematical reasoning, which may affect their performance in test-based assessments (Tambychik & Meerah, 2010). However, application-based tasks and contextualised

assignments may help students better engage with mathematical content by relating it to real-world business situations. Despite extensive research on continuous assessment and mathematics learning, limited studies have focused specifically on analysing continuous assessment performance among pre-diploma students within a single cohort. In particular, there is a lack of descriptive case studies that examine students' achievement across different coursework components covering distinct mathematical topics. Therefore, this study addresses this gap by providing a focused analysis of continuous assessment performance among Pre-Diploma Commerce students, offering preliminary insights into assessment-based achievement patterns at the pre-diploma level.

### **Methodology**

This study employed a quantitative descriptive case study design to analyse the continuous assessment performance of Pre-Diploma Commerce students in a mathematics course. A case study approach was adopted to allow an in-depth examination of assessment outcomes within a specific cohort, without the intention of making broad generalisations. The participants in this study were 28 Pre-Diploma Commerce students from a higher education institution. A census sampling approach was used, whereby all students enrolled in the course were included in the study. The cohort represented students with diverse academic backgrounds typically found at the pre-diploma level.

The course assessment structure comprised continuous assessment and a final examination. However, this study focused solely on the continuous assessment components, which contributed 60% of the total course assessment. The continuous assessment included a test on Arithmetic and Algebra, an individual assignment on Mathematics in Business and a group assignment on Basic Statistics. Each component assessed different mathematical topics and skills, including procedural knowledge, application of concepts, and basic statistical understanding. The final examination, which covered the topics of Equations and Functions, Business Mathematics, Basic Statistics and Sequences was excluded from the analysis as the results were not available at the time of data collection. Data were collected from students' coursework records obtained during the semester. The scores for the test, individual assignment, and group assignment were compiled and anonymised prior to analysis to ensure confidentiality. Only numerical scores related to continuous assessment were included in the dataset.

Data analysis was conducted using descriptive statistical methods. Measures such as mean, standard deviation, minimum, and maximum scores were used to summarise students' performance for each assessment component. The analysis aimed to provide an overview of performance patterns across different types of continuous assessment rather than to conduct inferential comparisons.

### **Results and Discussion**

The analysis of continuous assessment performance among the 28 Pre-Diploma Commerce students revealed differences across the three coursework components. Table 1 presents the descriptive statistics for students' performance in the continuous assessment components: the test, individual assignment, and group assignment. The statistics include the mean, standard deviation, minimum, and maximum scores, providing an overview of students' achievement and the distribution of scores in each component.

Table 1: Descriptive Statistics of Test, Individual Assignment, and Group Assignment Scores

	Test	Individual Assignment	Group Assignment
<b>Mean</b>	78.5	97.5	89.8
<b>Minimum</b>	26.3	85.0	80.0
<b>Maximum</b>	96.3	100.0	100.0
<b>Standard Deviation</b>	18.4	3.7	7.5

The mean score for the test, which covered Chapter 1 (Arithmetic and Algebra), was 78.5, with a minimum of 26.3 and a maximum of 96.3. The test's standard deviation was 18.4, indicating relatively wide variation in students' performance on this component. For the individual assignment on Chapter 3 (Introduction to the Application of Mathematics in Business), the mean score was notably higher at 97.5, with a minimum of 85.0 and a maximum of 100.0. The standard deviation was only 3.7, suggesting that students performed consistently well in this assessment, with relatively little variation in scores. The group assignment on Chapter 4 (Introduction to Basic Statistics) showed a mean score of 89.8, a minimum of 80.0, and a maximum of 100.0, with a standard deviation of 7.5. This indicates that, while students generally performed well on the group assignment, there was slightly greater variability in scores than on the individual assignment. Overall, the results suggest that students performed best in the individual assignment, followed by the group assignment, with the test showing the greatest variation in performance. These findings highlight differences in achievement patterns across assessment types and the skills required for each coursework component.

The findings of this study reveal notable differences in students' performance across the three continuous assessment components. The individual assignment on the application of mathematics in business had the highest mean score (97.5) and the lowest variability, suggesting that students performed consistently well when applying mathematical concepts in a contextualised, practical setting. This result aligns with previous research indicating that application-based tasks and contextualised assignments can enhance students' engagement and achievement, particularly for learners with weaker foundational skills (Tambychik & Meerah, 2010; Smith & Walker, 2021). The high performance in the individual assignment also highlights the potential benefit of allowing students to work independently with clear instructions and real-world scenarios.

The group assignment on basic statistics produced a slightly lower mean score (89.8) and greater variability ( $SD = 7.5$ ) than the individual assignment. This suggests that while collaborative tasks may support learning through peer interaction and shared problem-solving, differences in group dynamics and individual contribution may influence overall scores. These findings are consistent with prior studies emphasizing that group assessments can enhance learning but may not always reflect each student's independent understanding of the subject matter (Mohamad, 2023; Johnson & Johnson, 2009). In contrast, the test on arithmetic and algebra showed the lowest mean score (78.5) and the highest variability ( $SD = 18.4$ ), indicating that students struggled more with this assessment component. This aligns with the existing literature, which highlights that procedural and test-based assessments often challenge pre-diploma students, particularly in topics requiring foundational mathematical skills and timely problem-solving under exam conditions (Brookhart, 2011; Hernández, 2012). The wide variation in test scores suggests differences in individual preparedness and mastery of basic concepts, underscoring the importance of continuous practice and reinforcement in mathematics learning.

Overall, the results demonstrate that students' performance is influenced by both the type of assessment and the cognitive skills required. Application-based and collaborative assessments appear to support higher achievement and more consistent performance, while traditional tests may reveal learning gaps and variability in students' understanding. These findings reinforce the importance of implementing diverse assessment strategies in pre-diploma mathematics courses to capture a more comprehensive picture of students' learning outcomes and to provide formative feedback for improvement (Gibbs & Simpson, 2004; Brookhart, 2011).

## **Conclusion**

This study examined the continuous assessment performance of Pre-Diploma Commerce students using a quantitative, descriptive case study approach, focusing on coursework components that accounted for 60% of the total course assessment: the test, individual assignment, and group assignment. The findings revealed clear variations in students' performance across assessment components, indicating that the type of assessment and the nature of the mathematical skills being evaluated play important roles in shaping achievement patterns. The individual assignment, which emphasised the application of mathematics in business contexts, recorded the highest mean score with minimal variability, suggesting that contextualised and application-based tasks are particularly effective in supporting consistent performance among pre-diploma students. This outcome highlights the importance of designing assessments that connect mathematical concepts to real-world situations, especially for students who may struggle with abstract reasoning. The group assignment on basic statistics also demonstrated relatively strong performance, reflecting the potential benefits of collaborative learning through peer interaction and shared problem-solving; however, the observed variability in scores suggests that group

dynamics and individual contribution may influence outcomes. In contrast, the test component, which focused on arithmetic and algebra, exhibited the lowest mean score and the widest variation in performance, underscoring persistent challenges in foundational mathematical skills and differences in students' preparedness and test-taking abilities. These findings emphasise the value of continuous assessment as a diagnostic tool, enabling educators to identify learning gaps early and provide timely support before the final examination. Although this study offers useful preliminary insights into assessment-based performance patterns, it is limited by its focus on a single cohort and the exclusion of final examination results, which restricts broader generalisation of the findings. Future research may extend this work by incorporating final examination performance, examining relationships between coursework and summative assessment, and involving larger or multiple cohorts to strengthen the robustness of the conclusions. Nevertheless, the present study contributes meaningful evidence to the understanding of continuous assessment practices in pre-diploma mathematics education and supports the use of diverse assessment strategies to enhance student learning and academic development.

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## COMPARISON BETWEEN ISLAMIC AND CONVENTIONAL FINANCE IN MALAYSIA: A BRIEF VIEW

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### ABSTRACT

*This paper provides a comparative study of Islamic and conventional financial systems, focusing on their distinct philosophies, instruments, and demographic impact. While conventional finance relies on the time value of money and interest-based lending, Islamic finance is governed by Shariah principles, which prohibit Riba (interest) and Gharar (uncertainty). It emphasizes risk-sharing and asset-backed transactions through instruments like Sukuk, Murabahah, and Ijarah. The analysis highlights the sector's growth, now exceeding \$4 trillion in assets, driven by a global Muslim population of two billion and a rising demand for ethical, ESG-aligned investments. Furthermore, it examines the evolution of the industry in Malaysia, explaining the transition from "Islamic Windows" to independent subsidiaries and full-fledged Islamic banks. By contrasting the risk-transfer model of conventional banking with the risk-sharing framework of Islamic finance, the study concludes that the latter offers a stable, transparent, and ethically grounded alternative. This paradigm not only meets religious obligations but also contributes to global financial resilience and social justice through mechanisms like Zakat and Waqaf.*

**Keywords:** *Islamic and Conventional Finance, Riba, Murabahah, Ijarah, Waqaf*

### Introduction

In the modern global economy, two distinct financial systems operate side by side: Islamic Finance and Conventional Finance. While both aim to facilitate economic growth and provide liquidity, they are built on fundamentally different philosophies, legal frameworks, and ethical considerations. Understanding these differences is crucial for investors, policymakers, and consumers alike. Malaysia has one of the most advanced Islamic banking systems in the world. The industry evolved from a single pioneer (Bank Islam) to a "window" system in which conventional banks offered Islamic products, and finally to the current structure of full-fledged Islamic subsidiaries.

### On Principles and Risk

The core of Islamic finance is built upon the prohibition of Riba (interest), Gharar (uncertainty), and Maysir (gambling), as standardized by the Accounting and Auditing Organization for Islamic Financial Institutions (AAOIFI, 2024). Unlike conventional systems that focus on risk transfer, Shariah-compliant models utilize Shariah maxims to apply moral ethics to modern financial transactions (Mansoori, 2022).

### On Demographics and Global Growth

The global demand for Shariah-compliant services is increasingly driven by a demographic transition within the Muslim world, which now represents a significant portion of the global emerging middle class (World Bank, 2024). This growth is not limited to religious practitioners; institutional interest is

rising as Islamic finance increasingly integrates with global Environmental, Social, and Governance (ESG) frameworks (International Monetary Fund [IMF], 2024). Projections suggest that this sector will continue to spur sustainable growth through 2025 and beyond (Standard & Poor's Global, 2025).

### On the Malaysian Framework

Malaysia's leadership in the industry is a result of robust Shariah governance and clear operational guidelines established by the central bank (Bank Negara Malaysia, 2023). This regulated environment has allowed for the successful evolution of various banking models, ensuring that Islamic financial institutions remain resilient during periods of global market volatility (Hassan & Lewis, 2023). The key historical milestones:

- 1983: The Islamic Banking Act was passed, leading to the creation of Bank Islam.
- 1993: Bank Negara Malaysia introduced the Islamic Banking Scheme (IBS), allowing conventional banks to open "Islamic Windows."
- 2005 onwards: Following a liberalisation drive, many banks converted their windows into independent Islamic Subsidiaries to ensure a clearer separation of funds.

The following table lists the major licensed Islamic banks in Malaysia and the year they began offering Islamic financing (either as a window, a pioneer, or a full subsidiary):

**Table 1.** List of Banks Offering Islamic Financing in Malaysia

Ref.	Bank Name	Year Offer Islamic Financing	Note
1	Bank Islam Malaysia Berhad	1983	First full-fledged Islamic bank in Malaysia.
2	Maybank Islamic Berhad	1993	Started as an Islamic window; subsidiary in 2008.
3	Public Islamic Bank Berhad	1993	Started as an Islamic window; subsidiary in 2008.
4	CIMB Islamic Bank Berhad	1993	Started via BCB/Bumiputra window; subsidiary in 2005.
5	Bank Rakyat	1993	Converted into a full Islamic cooperative bank.
6	Bank Muamalat Malaysia Berhad	1999	Established following the merger of BBMB and BOCB.
7	RHB Islamic Bank Berhad	2005	First to convert the window to a subsidiary (March 2005).
8	Affin Islamic Bank Berhad	2006	Incorporated in 2005; officially launched in April 2006.

9	Hong Leong Islamic Bank Berhad	2006	Converted from an Islamic window.
10	AmBank Islamic Berhad	2006	Formed as a subsidiary to manage Islamic operations.
11	Alliance Islamic Bank Berhad	2007	Subsidiary of Alliance Bank Malaysia Berhad.
12	HSBC Amanah Malaysia Berhad	2008	First foreign bank to receive an Islamic subsidiary license.
13	Standard Chartered Saadiq Berhad	2008	Foreign Islamic subsidiary.
14	OCBC Al-Amin Bank Berhad	2008	Foreign Islamic subsidiary.
15	MBSB Bank Berhad	2018	Received a full Islamic banking license in 2018.
16	Al Rajhi Banking & Investment (M)	2006	Foreign-owned full-fledged Islamic bank.
17	Kuwait Finance House (Malaysia)	2005	First foreign-owned Islamic bank in Malaysia.

### ***Core Philosophies and Demographic Reach***

The foundational difference between the two systems lies in the treatment of interest, known as *Riba*. In Islamic jurisprudence, money is viewed strictly as a medium of exchange rather than a commodity that can generate wealth on its own. The most significant divergence lies in the "why" behind the money.

### **Islamic Finance (Shariah-Compliant)**

This system is rooted in the principles of Shariah (Islamic law), which are derived from the Quran and the Sunnah (teachings of the Prophet Muhammad). Its core pillars include:

- i. *Prohibition of Riba* (Interest/Usury): This is perhaps the most defining feature. In Islam, money is viewed as a medium of exchange, not a commodity to be sold at a profit (interest). Instead, profit must come from legitimate trade, investment, or services.
- ii. *Prohibition of Gharar* (Excessive Uncertainty/Speculation): Transactions must be clear and transparent, avoiding undue risk or ambiguity that could lead to dispute or unfair gain.
- iii. *Prohibition of Maysir* (Gambling): Speculative activities without a real economic purpose are forbidden.

- iv. *Emphasis on Profit and Loss Sharing (PLS)*: This principle ensures that the financier and the client share the risks and rewards of a venture, promoting a more equitable distribution of wealth. This means that if a business fails, both parties bear the loss, aligning incentives. This ensures that the financier and the entrepreneur are partners in an enterprise, aligning their incentives toward the success of the real economy.

## **Conventional Finance Principles**

Conventional finance operates on a secular, market-driven basis. It utilizes interest as the primary incentive for lending and allows for complex speculative instruments. The "time value of money" is the central tenet, where a dollar today is worth more than a dollar tomorrow due to its potential earning capacity via interest.

## **Demographic Context**

The demographic footprint of these systems is shifting. Conventional finance remains the global standard, serving a vast majority of the world's 8.2 billion people. However, Islamic finance is the fastest-growing sector in the financial world. Originally centered in the Middle East and Southeast Asia (specifically Malaysia and Indonesia), it now serves a global Muslim population of approximately 2 billion. Furthermore, the total assets of Islamic finance now exceed USD4 trillion globally. Ethical investors in Western markets are also increasingly drawn to this model due to its inherent alignment with Environmental, Social, and Governance (ESG) criteria.

## ***Financial Instruments and Risk Management***

The operational structures of these systems reflect their underlying values. Islamic finance requires all transactions to be backed by tangible assets, whereas conventional finance often deals in debt-based obligations.

## **Comparison of Instruments**

Islamic institutions utilize contracts such as *Murabahah* (cost-plus financing) and *Ijarah* (leasing). In a *Murabahah* transaction, the bank purchases an asset and resells it to the client at a transparent profit margin, avoiding the concept of interest. Conversely, a conventional mortgage involves a loan where the borrower repays the principal plus interest over time. A critical distinction is found in the capital markets. Conventional bonds represent a debt obligation where the issuer must pay interest. In contrast, *Sukuk* (Islamic certificates) represent partial ownership in an underlying asset or project. The "interest" paid to *Sukuk* holders is actually a share of the profit generated by the asset.

## **Risk Allocation**

Risk management in Islamic finance is rooted in risk-sharing. In a *Musharakah* (partnership) agreement, both the financier and the entrepreneur share the risks of the venture. This differs fundamentally from the conventional model of risk transfer, where interest is charged regardless of the borrower's business

success, effectively shifting the burden of failure onto the borrower while the lender remains protected by collateral.

### Governance and Ethical Frameworks

The governance of these systems determines their social impact and long-term stability. Islamic financial institutions are subject to a dual-regulatory layer. In addition to national central bank regulations, they must adhere to the oversight of a Shariah Supervisory Board. This board, comprised of scholars, ensures that all products from savings accounts to complex investment funds remain compliant with religious ethics.

### Social Impact and ESG

Islamic finance integrates social welfare through *Zakat* (mandatory almsgiving) and *Waqaf* (charitable endowments). It strictly prohibits investment in "Haram" (forbidden) industries, such as tobacco, gambling, and weapons. While conventional finance has recently adopted ESG frameworks as a voluntary measure to satisfy modern investors, these ethical constraints are mandatory and foundational in the Islamic model. This "built-in" ethics layer often makes Islamic banks more resilient during global financial crises, as they avoid the high-leverage and speculative derivatives that often trigger market collapses.

Next, Figure 1 represents the summary of the two concepts, the Islamic Finance versus the Conventional Finance, while Table 2 lists the comparison of Islamic and Conventional Finance in terms of the Principles, Structures, and Demographics of major licensed Islamic banks in Malaysia:

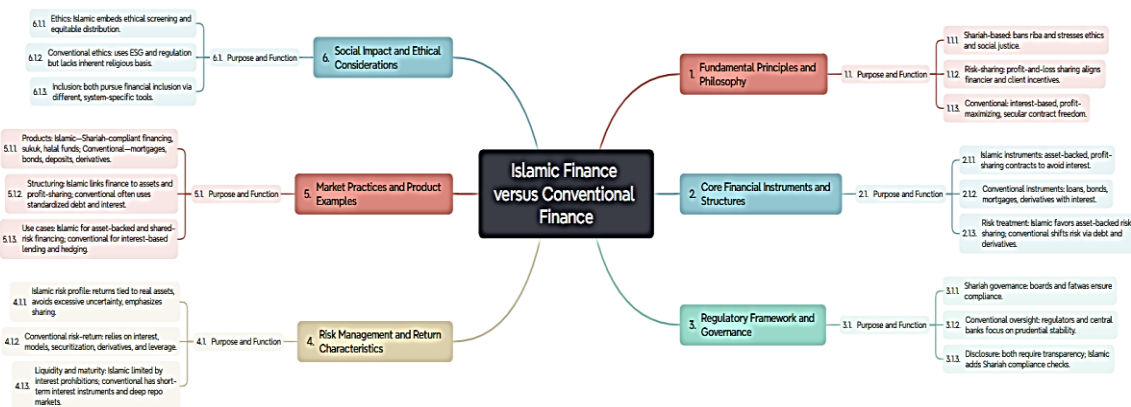


Figure 1. Summary using mind-map: Islamic Finance versus Conventional Finance

Table 2. Comparison of Islamic and Conventional Finance (Principles, Structures, and Demographics)

Feature	Islamic Finance	Conventional Finance
Core Principle	Shariah-compliant, ethical, social justice, risk-sharing	Profit maximisation, time value of money, risk transfer
Interest (Riba)	Prohibited	Core component, charged on loans and deposits
Speculation (Gharar/Maysir)	Prohibited/Restricted (focus on real assets)	Allowed, derivatives are widely used for speculation
Asset Backing	Mandatory, transactions linked to tangible assets/services	Not always mandatory, can be purely debt-based
Key Instruments	<i>Murabahah, Ijarah, Musharakah, Mudarabah, Sukuk</i>	Loans, mortgages, bonds, shares, derivatives
Risk Bearing	Shared between the financier and the client	Primarily borne by the borrower (interest paid regardless of profit)
Governance	Shariah Supervisory Board (additional layer)	Regulatory bodies (Central Banks, Financial Authorities)
Ethical/Social Focus	Inherent ESG, <i>Zakat, Waqf</i> , and the prohibition of 'Haram' investments	Often an 'add-on' through ESG funds, profit-driven
Target Demographics	Global Muslim population, ethical investors	Global population
Market Share (Approx.)	~\$4 trillion assets (growing)	~\$300 trillion assets (dominant)

### **Conclusion**

While conventional finance provides the liquidity and scale necessary for global trade, Islamic finance offers a better alternative that focuses on stability, equity, and ethical responsibility. As the global Muslim population continues to grow and the demand for socially responsible investing rises among all

demographics, the integration of Islamic financial principles into the mainstream global market is likely to accelerate.

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## CHALLENGES IN EARLY SCHOOL MATHEMATICS LEARNING: A FOCUS ON STUDENTS' UNDERSTANDING

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### ABSTRACT

*Mathematics learning in the early school years plays an important role in developing students' thinking skills and attitudes toward the subject. However, concerns remain about whether the current mathematics content is too difficult or not fully understood by students. This paper examines students' level of understanding in early mathematics and explores whether the difficulty of the subject aligns with their developmental level. A qualitative approach was employed through classroom observations and teacher reflections to identify the challenges students face in learning basic mathematical concepts. The findings indicate that students' difficulties are influenced not only by the complexity of the content, but also by teaching methods, prior knowledge, and the learning environment. This study highlights the importance of developmentally appropriate teaching strategies to support meaningful learning in early mathematics.*

**Keywords:** *Early mathematics, students' understanding, learning challenges, teaching strategies*

### Introduction

Mathematics learning in the early school years plays a key role in developing students' thinking skills and attitudes toward the subject. Understanding basic mathematical concepts helps children build confidence and prepares them for later learning in more advanced topics. However, many students struggle to grasp early mathematics, raising questions about whether the curriculum is too demanding or whether students simply do not understand the content well enough (Clements & Sarama, 2020).

Previous research shows that teaching methods and instructional design significantly influence students' success in early mathematics. For example, game-based methods were found to improve preschool children's understanding and performance in early mathematics more than traditional worksheets and number books, suggesting that interactive, age-appropriate teaching strategies are effective in enhancing mathematical understanding (Abdullah et al., 2021). Studies of parental involvement also show that play-based approaches at home can support learning when parents actively engage in mathematical activities with children (Lim et al., 2022).

In addition to teaching methods, technology-enhanced learning tools are increasingly discussed in the literature as ways to support mathematics understanding. Research on augmented reality (AR) mathematical picture books showed that such tools can increase students' geometric thinking and reduce cognitive load compared to traditional materials, indicating that appropriate media and teaching resources can make abstract mathematical ideas more concrete and easier to grasp (Wang et al., 2024). Teacher preparedness is another factor that influences early mathematics learning. Studies of early childhood teachers show that teachers' understanding of mathematical concepts and their readiness to implement technology and effective instructional approaches affect students' learning outcomes (Rahman et al., 2020).

Despite these advances, gaps remain in understanding how curriculum demands, developmental readiness, and instructional strategies together influence students' early mathematics learning. This paper explores these issues by focusing on students' understanding and perceived difficulty of mathematics content at the early school level. Teacher preparedness also affects students' learning outcomes. Studies in early mathematics show that when teachers have good content knowledge and are confident in teaching mathematical concepts, students tend to achieve better understanding (Abd. Halim, Mamat, & Mohd Radzi, 2023). This finding is consistent with research showing that teacher knowledge and instructional quality are important predictors of how well students grasp early mathematics (Meylani, 2024).

In addition, studies show that using interactive tools, like digital manipulatives, and having different types of classroom activities can help students understand mathematics better. These tools make abstract ideas easier to see and more interesting to learn (Meylani, 2024; MJSSH, 2023). This means that learning early mathematics is not just about how difficult the content is, but also about how teachers teach, how ready teachers are, and the learning environment in the classroom. Even with these improvements, there are still gaps in understanding how the curriculum, students' readiness to learn, their motivation, and teaching methods all work together to affect learning. This paper focuses on these issues by examining how students understand early mathematics and how difficult they find the content.

## **Students' Level of Understanding in Early Mathematics**

Students' level of understanding in early mathematics can vary widely. It is not just about knowing the right answer, but also about how well they grasp concepts, apply ideas, and solve problems. The following points are commonly used to assess or describe students' understanding:

### **1. Recognizing and Understanding Numbers**

What it means: Students can identify numbers, understand their value, and know how numbers relate to each other.

Example: Knowing that 7 is more than 5, or understanding that 10 is made of  $5 + 5$ .

Why it matters: Students who understand numbers well can perform addition, subtraction, and other operations more easily. Those who only memorize numbers may struggle to apply them in different situations.

## **2. Understanding Basic Operations**

What it means: Students can add, subtract, and eventually multiply or divide, depending on their level.

Example: Solving “ $3 + 4 = ?$ ” using fingers, objects, or mental strategies.

Why it matters: Understanding how and why operations work is more important than memorizing answers. It helps students solve problems in real life.

## **3. Recognizing Patterns and Relationships**

What it means: Students can see patterns in numbers, shapes, or sequences and understand the rules.

Example: Continuing a shape pattern like “● ○ ● ○ ...” or recognizing even and odd numbers.

Why it matters: Pattern recognition shows logical thinking and helps students understand sequences, number relationships, and problem-solving strategies.

## **4. Problem-Solving Skills**

What it means: Students can apply math concepts to solve simple problems.

Example: “Ali has 2 candies, his friend gives him 3 more. How many does Ali have now?”

Why it matters: Students with strong problem-solving skills can apply math in real-life situations. Those who struggle may know the steps but not understand what the question is asking.

## **5. Conceptual Understanding vs. Memorization**

What it means: Students know why an answer is correct, not just how to get it.

Example: Understanding that “ $5 - 2 = 3$ ” because they remove 2 objects from 5, not just recalling the answer from memory.

Why it matters: Conceptual understanding leads to deeper learning and helps students tackle new or complex problems later.

## **6. Confidence and Attitude**

What it means: Students’ willingness to try math problems and their attitude toward learning.

Example: A student tries a new problem even if it seems hard, versus a student who avoids it.

Why it matters: Confidence affects learning. Positive attitudes encourage participation and deeper understanding, while low confidence can limit progress even for capable students.

## **Determining Whether the Difficulty of Early Mathematics Matches Students' Developmental Level**

It is important to check if math lessons are not too hard or too easy for young students. Here are some key points:

### **1. Cognitive Readiness**

Students need to think logically and understand numbers.

Example: A 6 year old can do addition and subtraction up to 10, but multiplication might be too hard.

Why it matters: Too difficult tasks can make students frustrated and confused.

### **2. Attention Span**

Students can only focus for a certain time.

Example: Young children may pay attention for 10–15 minutes; long or complicated tasks may be too hard.

Why it matters: Lessons must match how long students can concentrate.

### **3. Prior Knowledge**

Students need to know the basics before learning new topics.

Example: Students who know numbers 1–20 are ready to learn addition up to 20.

Why it matters: Without prior knowledge, new topics can be confusing.

### **4. Learning Pace and Task Difficulty**

New topics should be introduced slowly and step by step.

Example: Fractions or multi-step problems may be too much if introduced too soon.

Why it matters: Gradual difficulty helps students learn better and avoid stress.

### **5. Use of Hands-On Materials**

Using objects, pictures, or tools makes math easier to understand.

Example: Using blocks to teach addition or subtraction helps students see the problem.

Why it matters: Young children understand concepts better when they can touch or see them.

### **6. Confidence and Emotional Readiness**

Students need to feel confident to try new problems.

Example: Some students try hard questions, others give up easily.

Why it matters: If lessons are too difficult, students may feel frustrated and lose interest in math.

## Comparison of Students' Understanding and Developmental Appropriateness in Early Mathematics

Table 1 shows a clear relationship between students' level of understanding in early mathematics and the suitability of the difficulty level based on their developmental stage.

**Table 1: Comparison of Students' Understanding and Developmental Appropriateness in Early Mathematics**

Aspect	Students' Understanding	Developmental Appropriateness	Implication
Number Concepts	Recognize numbers and understand values.	Content matches cognitive readiness.	Supports accurate and meaningful learning.
Basic Operations	Perform simple addition and subtraction.	Taught according to age and ability.	Prevents confusion and overloading.
Patterns & Relationships	Identify simple patterns and sequences.	Uses simple and concrete examples.	Develops logical thinking skills.
Problem-Solving	Apply math to simple real-life problems.	Tasks match attention span.	Improves application of concepts.
Conceptual Understanding	Understands <i>why</i> answers are correct.	Builds on prior knowledge step by step.	Encourages deep learning.
Learning Support	Uses hands-on materials and visuals.	Learning pace is gradual.	Helps students grasp abstract ideas.
Confidence & Attitude	Shows willingness to engage in math.	Emotional readiness is considered.	Builds positive attitude toward math.

The findings indicate that students' understanding is influenced not only by their ability to recognize numbers and perform basic operations, but also by how the content is presented and paced. When mathematical concepts such as number relationships, basic operations, and patterns are introduced gradually and supported with hands-on materials, students are more likely to develop conceptual understanding rather than rely on memorization.

The table also highlights the importance of considering students' prior knowledge, attention span, and emotional readiness when designing mathematics lessons. Tasks that are too difficult or introduced too quickly may cause confusion, frustration, and low confidence among young learners. In contrast, developmentally appropriate tasks encourage students to engage actively in problem-solving and build positive attitudes toward mathematics. Overall, aligning the difficulty of early mathematics

content with students' cognitive and emotional development is essential to support meaningful learning and long-term understanding.

## Conclusion

In conclusion, this study shows that challenges in early mathematics learning are influenced by several factors, not only by the difficulty of the subject content. While some mathematical concepts may be hard for young students to understand, teaching methods, students' prior knowledge, and the classroom environment also play important roles in shaping their understanding. When lessons are not taught in ways that match students' developmental levels, students may find it difficult to grasp basic mathematical ideas. Therefore, it is important for teachers to use teaching strategies that are appropriate to students' age and cognitive development. By using clear explanations, suitable learning activities, and a supportive learning environment, teachers can help students build a stronger understanding of mathematics. This will also help students develop confidence and a positive attitude toward mathematics from an early age.

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# EVALUATING STUDENTS' SATISFACTION WITH VIRTUAL LEARNING ENVIRONMENTS AT UiTM CAWANGAN PULAU PINANG

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## ABSTRACT

*Virtual learning environments have been institutionalized as a core instructional modality within Malaysian higher education. Systematic evaluation of student perceptions is imperative to ensure pedagogical efficacy and the sustainability of digital delivery systems. This study investigates undergraduate satisfaction with virtual learning at UiTM Cawangan Pulau Pinang using a quantitative survey methodology (n = 44). The research instrument, adapted from validated e-learning success frameworks, evaluated dimensions including system usability, instructional interaction, technical support, and overall satisfaction via a 5-point Likert scale. Data analysis involved descriptive statistics, 95% confidence interval estimation, and independent samples t-tests. Findings reveal a high overall satisfaction level (M = 4.29, SD = 0.53), with a 95% CI of [4.13, 4.45], indicating consistently positive institutional experiences. Furthermore, no statistically significant gender-based disparities were observed (t = 0.16, p = 0.87), suggesting an equitable digital learning environment. These localized empirical insights contribute to institutional quality assurance and provide a data-driven foundation for optimizing digital pedagogical practices at the branch campus level.*

**Keywords:** virtual learning, student satisfaction, confidence interval, higher education, digital learning

## Introduction

The rapid proliferation of digital technologies has fundamentally restructured the landscape of global higher education. Virtual learning environments have evolved from supplementary instructional aids into indispensable infrastructures for pedagogical delivery. Within the Malaysian context, public higher education institutions have successfully institutionalized blended and online learning modalities, catalysed by national digitalization strategies and policy directives from the Ministry of Higher Education.

Student satisfaction serves as a pivotal metric for evaluating the efficacy of these digital systems, as empirical evidence suggests it significantly influences learner motivation and long-term academic retention (Al-Fraihat et al., 2019; Dhawan, 2020). While prevailing literature identifies

infrastructure and communication as primary determinants of the online learning experience (Adnan, 2020; Nasir et al., 2020), there remains a critical research gap regarding campus-specific experiences, particularly within the unique demographic and operational context of UiTM branch campuses.

Although national-level studies provide general insights, there remains limited campus-specific empirical evidence focusing on UiTM branch campuses. Institutional differences in student demographics, academic programs, and technological infrastructure may influence satisfaction levels. Moreover, quantitative estimation using confidence intervals and inferential comparisons across demographic groups are not consistently reported in campus-based studies.

Therefore, this study evaluates students' satisfaction with virtual learning environments at UiTM Cawangan Pulau Pinang. The objectives of this study are threefold: first, to describe the demographic characteristics of respondents; second, to estimate the population mean satisfaction score using a 95% confidence interval; and third, to examine whether satisfaction differs significantly between male and female students.

## **Literature Review**

The theoretical evaluation of VLE efficacy often employs multidimensional frameworks that synthesize system quality, information accuracy, and service reliability to determine user satisfaction (Al-Fraihat et al., 2019). Central to this evaluation is the Technology Acceptance Model, which posits that perceived usefulness and ease of use are the primary antecedents of user attitudes. When students perceive digital platforms as intuitive and closely aligned with their academic objectives, their overall satisfaction and continued engagement are significantly enhanced (Chung et al., 2020).

Furthermore, the quality of pedagogical interaction remains a cornerstone of the digital learning experience. Effective instructional design, characterized by structured communication and timely feedback, is essential to mitigate the inherent transactional distance of virtual settings (Martin et al., 2020). In Malaysia, the success of these systems is further moderated by external factors such as internet stability and student socioeconomic diversity (Adnan, 2020). Although Nasir et al. (2020) reported moderate to high satisfaction levels among Malaysian undergraduates, the extent to which these findings generalize to localized branch campus environments requires further empirical validation.

From a methodological perspective, many prior studies primarily rely on descriptive statistics to summarize satisfaction levels. Although mean comparisons provide useful insight, the absence of interval estimation reduces inferential robustness. Confidence intervals offer an enhanced statistical approach by estimating the likely range of the population parameter with specified precision. This approach strengthens interpretative validity and supports institutional quality monitoring. Furthermore, subgroup comparisons using independent samples t-tests enable examination of potential demographic disparities, such as gender differences in digital learning experiences.

Gender-based differences in e-learning satisfaction have yielded mixed findings in the literature. Some studies suggest that technological confidence and digital self-efficacy may vary across gender groups, potentially influencing satisfaction levels. However, other research reports negligible differences when institutional support structures are adequately provided. These inconsistencies underscore the importance of context-specific empirical testing rather than assuming demographic disparities.

Despite the growing body of research on online learning satisfaction, there remains a scarcity of empirical evidence focusing specifically on UiTM branch campuses, including UiTM Cawangan Pulau Pinang. Institutional characteristics, disciplinary composition, and student demographics may shape unique satisfaction patterns. Therefore, conducting campus-based statistical evaluations contributes not only to local quality assurance but also to the broader discourse on digital learning effectiveness in Malaysian higher education.

In summary, the literature suggests that virtual learning satisfaction is influenced by a combination of technological usability, instructional interaction, and institutional support. However, methodological enhancements through inferential estimation and campus-level analysis are needed to provide more precise and contextually grounded conclusions. This study responds to that gap by employing confidence interval estimation and inferential comparison to evaluate student satisfaction within a specific institutional setting.

## **Methodology**

### *Research Design*

This study adopts a quantitative cross-sectional survey design to systematically evaluate student satisfaction within a virtual learning context. This methodological approach facilitates the simultaneous analysis of multiple variables at a specific point in time, providing a robust empirical snapshot of the students' digital learning experiences (Al-Fraihat et al., 2019).

### *Participants*

The study sample consisted of 44 undergraduate students ( $n = 44$ ) from UiTM Cawangan Pulau Pinang. The respondents represented a diverse array of academic disciplines, including Hotel and Tourism Management, Civil Engineering, Electrical Engineering, and Mechanical Engineering. Demographically, most of the cohort was aged between 22 and 25 years. In terms of gender distribution, male students constituted 65.9% of the sample, while female students accounted for 34.1%.

### *Instrumentation*

The primary research instrument was an online questionnaire, synthesized and adapted from the validated e-learning evaluation framework developed by Al-Fraihat et al. (Al-Fraihat et al., 2019). The instrument was refined to ensure contextual relevance to the institutional environment of UiTM branch campuses. The questionnaire was structured into two sections: Section A captured demographic metadata (age, gender, faculty, and GPA), while Section B employed a 5-point Likert scale (ranging from 1 = Strongly Disagree to 5 = Strongly Agree) to measure ten critical dimensions of the virtual learning experience. These dimensions include system usability, instructional clarity, technical support efficiency, and overall user satisfaction. The aggregate Satisfaction Score was derived by calculating the mean responses of items 6 through 15.

### *Data Analysis*

Data were subjected to both descriptive and inferential statistical analysis to ensure rigorous interpretation of the findings. Descriptive statistics, including frequency distributions, means, and standard deviations, were utilized to summarize the fundamental characteristics of the dataset. For inferential analysis, a 95% confidence interval was constructed to estimate the population mean satisfaction level with high precision. Additionally, an independent samples t-test was performed to examine potential satisfaction disparities between genders. To ensure the validity of the inferential results, the Shapiro–Wilk test was employed to verify the assumption of normality, with all statistical significance evaluated at a threshold of  $\alpha = 0.05$ .

## **Results**

### *Demographic Characteristics*

The demographic profile of the 44 respondents ( $n = 44$ ) reflects a diverse academic representation within UiTM Cawangan Pulau Pinang. As illustrated in the composite visualization in Figure 1, the sample is characterized by specific trends in age, faculty affiliation, and academic performance. Establishing a clear demographic baseline is essential in virtual learning research, as student background variables often influence the perceived usability and success of digital platforms (Al-Fraihat et al., 2019; Nasir et al., 2020).

Figure 1(a) demonstrates that the cohort is predominantly composed of students within the 22 to 25-year age range, with most participants aged 23. In terms of academic discipline, Figure 1(b) shows that the Faculty of Hotel and Tourism Management constitute the largest segment of the sample (59.1%), followed by a combined representation from Civil, Electrical, and Mechanical Engineering faculties. This multi-disciplinary composition ensures that the evaluation of the Virtual Learning Environment accounts for varying instructional needs across different fields of study (Chung et al.,

2020). Furthermore, the academic performance of the respondents, as shown in Figure 1(c), indicates a high-achieving cohort, with 65.9% of students maintaining a Cumulative Grade Point Average between 3.20 and 3.60. Regarding gender distribution, the sample consists of 29 male students (65.9%) and 15 female students (34.1%). A comprehensive breakdown of these frequencies and percentages is provided in Table 1. This balanced yet diverse demographic profile provides a robust foundation for the subsequent inferential analysis of student satisfaction levels.

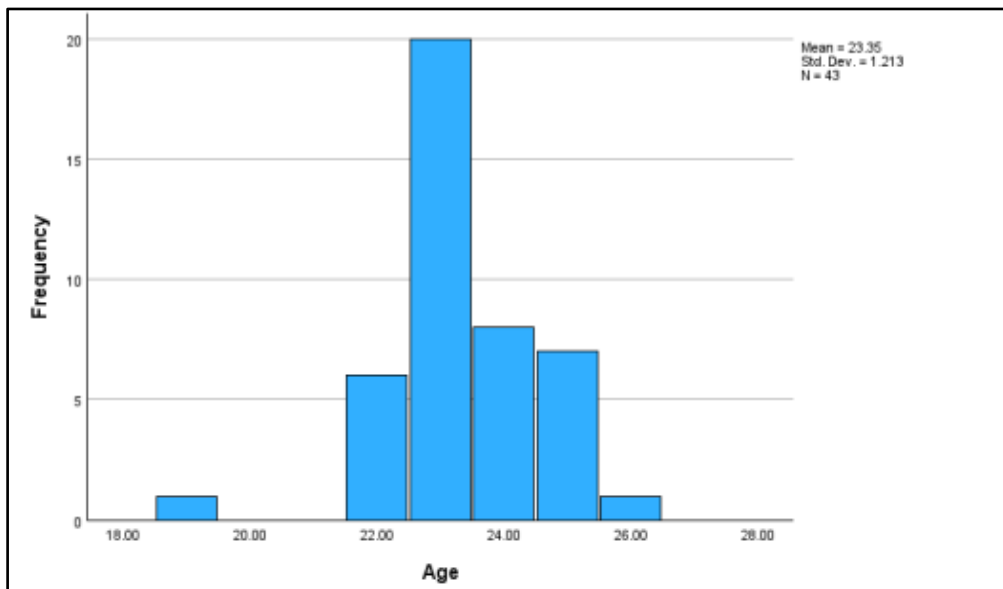


Figure 1(a): Composite visualization of respondents' demographic characteristics for age distribution

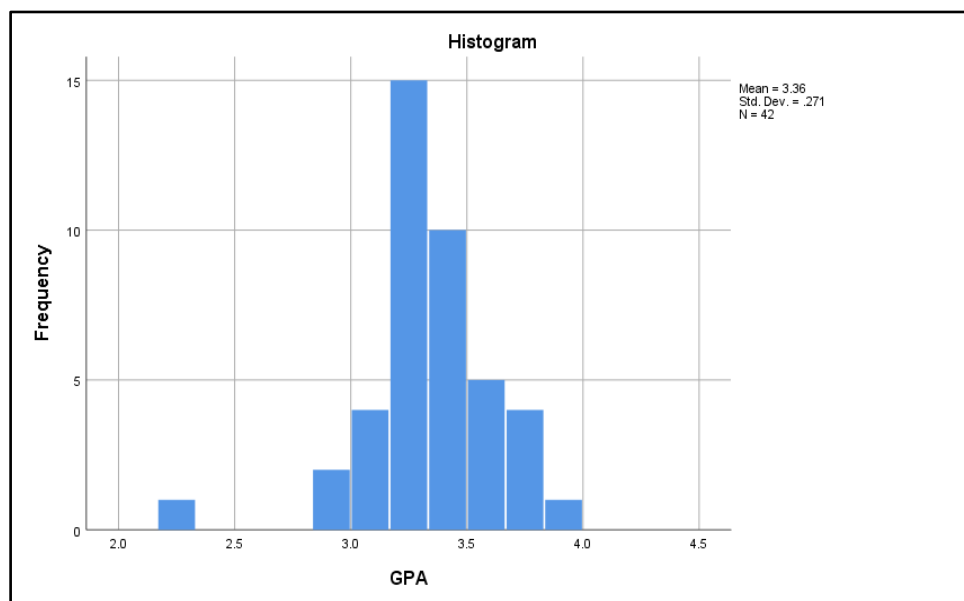


Figure 1(b): Composite visualization of respondents' demographic characteristics for academic faculty representation

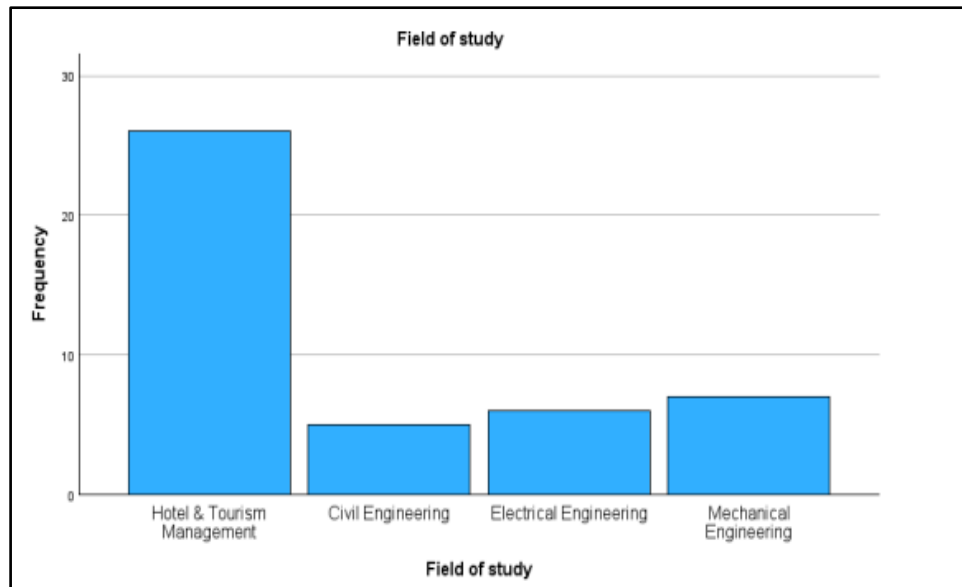


Figure 1(c): Composite visualization of respondents' demographic characteristics for cumulative grade point average categories.

The detailed breakdown of the sample distribution is presented in Table 1.

Table 1: Demographic Profile of Respondents (n = 44)

Variable	Category	Frequency (n)	Percentage (%)
<b>Gender</b>	Male	29	65.9%
	Female	15	34.1%
<b>Age</b>	22 – 25 Years	44	100.0%
<b>Faculty</b>	Hotel and Tourism Management	26	59.1%
	Civil Engineering	5	11.4%
	Electrical Engineering	6	13.6%
	Mechanical Engineering	7	15.9%
<b>GPA</b>	3.20 – 3.60	29	65.9%
	Others	15	34.1%

*Overall Satisfaction Level*

The primary objective was to estimate the population mean satisfaction score using a 95% confidence interval. The aggregate satisfaction metric, derived from ten critical items (usability, instructional clarity, technical support, and learning confidence), yielded a high mean score of 4.29 (SD = 0.53). The relatively low standard deviation suggests a high degree of consensus among respondents. The 95%

confidence interval for the mean was calculated as [4.13, 4.45]. Given that the entire interval remains substantially above the neutral midpoint (3.00), it can be inferred with high confidence that the student population at UiTM Cawangan Pulau Pinang holds a robustly positive perception of the virtual learning environment (Al-Fraihat et al., 2019).

#### *Gender Comparison*

To examine potential disparities in the virtual learning experience, an independent samples t-test was conducted. Male students reported a mean satisfaction score of 4.30 (SD = 0.48), while female students recorded a mean of 4.27 (SD = 0.65). Statistical analysis confirmed that this difference was not significant,  $t = 0.16$ ,  $p = 0.87$ . The 95% CI for the mean difference [-0.32, 0.38] and the negligible effect size further validate that satisfaction with VLEs is equitable across genders within this institutional context

#### **Discussion**

The empirical findings of this study demonstrate that students at UiTM Cawangan Pulau Pinang report consistently high levels of satisfaction with virtual learning environments. The observed mean satisfaction score of 4.29, supported by a narrow 95% confidence interval [4.13, 4.45], provides robust inferential evidence that the true population mean lies significantly above the neutral threshold. These results corroborate the Technology Acceptance Model and e-learning success frameworks, which suggest that when users perceive digital platforms as both functional and supportive of their academic objectives, their overall satisfaction is significantly elevated (Al-Fraihat et al., 2019; Chung et al., 2020).

Furthermore, the high satisfaction levels highlight the critical role of pedagogical presence and instructional clarity in digital delivery. The positive feedback regarding lecturer explanations and communication effectiveness suggests that the "transactional distance" inherent in virtual settings has been successfully mitigated through effective instructional design (Martin et al., 2020). This aligns with broader research indicating that instructional support and system quality are primary drivers of positive student perspectives during the transition to online learning (Adnan, 2020; Dhawan, 2020). While national-level studies in Malaysia have reported varying degrees of satisfaction (Nasir et al., 2020), the localized findings from this campus suggest a stable and high-quality implementation of virtual learning protocols.

The absence of statistically significant gender differences ( $p = 0.87$ ) is a particularly notable finding. This suggests that the digital learning infrastructure at UiTM Cawangan Pulau Pinang is sufficiently inclusive, ensuring that factors such as technological self-efficacy do not create a satisfaction gap between male and female students. This outcome implies that when institutional support

systems are robustly applied, VLEs can provide equitable learning experiences regardless of demographic background.

Methodologically, this study advances the campus-level evaluation discourse by incorporating inferential estimation through 95% confidence intervals. By establishing the precision of the satisfaction estimates, this approach offers institutional stakeholders a more reliable basis for quality monitoring compared to simple descriptive summaries. However, several limitations remain. The sample size of 44 respondents and the concentration of participants within the Hotel and Tourism Management and Engineering faculties may restrict the broader generalizability of the results. Future research should adopt longitudinal designs with larger, multi-faculty samples to examine shifting satisfaction trends as digital platforms continue to evolve.

## **Conclusion**

This study systematically evaluated undergraduate students' satisfaction with virtual learning environments at UiTM Cawangan Pulau Pinang through an integrated descriptive and inferential statistical framework. The findings reveal a consistently high level of satisfaction among the student cohort, with a population mean estimated to be significantly above the neutral threshold. The 95% confidence interval [4.13, 4.45] further underscores the precision and robustness of these perceptions, suggesting that the digital transition at the campus has been effectively institutionalized. Moreover, the absence of statistically significant gender disparities implies that the current technological infrastructure provides an equitable pedagogical experience, successfully catering to diverse student demographics without creating a digital divide.

Beyond documenting satisfaction levels, this research offers methodological advancement for campus-level evaluation by moving beyond simple descriptive summaries to include rigorous interval estimation and hypothesis testing. By quantifying the precision of student feedback, institutional stakeholders are provided with a more reliable empirical basis for strategic decision-making and quality monitoring. The narrow confidence interval observed reflects a stable consensus among students regarding the efficacy of VLEs, validating the alignment between technological infrastructure and instructional delivery.

From an institutional perspective, these results provide strong justification for the continued integration and optimization of virtual learning platforms within the university's academic ecosystem. To sustain these high satisfaction levels, it is imperative for the institution to maintain proactive technical support, encourage continuous pedagogical innovation among faculty, and ensure consistent system reliability. As digital learning becomes a permanent fixture in higher education, such systematic evaluations should be embedded within institutional quality assurance frameworks to drive ongoing improvement.

Despite its contributions, this study is constrained by its relatively small sample size (n = 44) and its concentration within specific academic disciplines, which may limit the generalizability of the findings to the broader university population. Consequently, future research should aim to employ longitudinal designs and larger multi-faculty samples to track evolving satisfaction trends over time. Expanding the analytical scope to incorporate qualitative insights or correlations with academic performance metrics would further enrich the understanding of VLE effectiveness. In conclusion, this study reaffirms the success of virtual learning implementation at UiTM Cawangan Pulau Pinang and underscores the vital role of data-driven governance in enhancing the digital educational experience.

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## RECURRING ERRORS IN INTEGRATION BY SUBSTITUTION: THE NEED FOR PEDAGOGICAL INNOVATION BASED ON MATHEMATICAL DECISION SUPPORT

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### ABSTRACT

*Integration by substitution is a fundamental technique in integral calculus that frequently poses difficulties for students in higher education. Although this technique is taught systematically, many students continue to make recurring errors, particularly in the selection of appropriate substitution variables and the management of differentials. This phenomenon indicates that the difficulties encountered are not merely procedural in nature but are closely related to weaknesses in students' conceptual mathematical decision-making. Therefore, this study aims to discuss the forms of recurring errors in integration by substitution and to argue for the need for pedagogical innovation based on mathematical decision support. The discussion is grounded in a review of recent literature and reflections on calculus teaching experience. The findings indicate that teaching approaches that focus primarily on procedural memorisation are insufficient to help students understand the mathematical rationale underlying the substitution technique. Accordingly, pedagogical innovations that provide structured and visual decision support are proposed to reduce recurring errors and to enhance students' conceptual understanding and confidence in learning calculus.*

**Keywords:** *integration by substitution, recurring errors, pedagogical innovation, calculus, decision support*

### Introduction

Integration by substitution is one of the fundamental techniques in integral calculus that serves to simplify the integration of composite functions through variable substitution. This technique is formally taught at the higher education level and constitutes an essential prerequisite for mastering more advanced methods of integration. However, teaching experience indicates that many students continue to face difficulties in effectively mastering this technique. These difficulties are often manifested through recurring errors in problem solving, particularly in the selection of appropriate substitution variables, the management of differential symbols, and the re-substitution to the original variable, even after students have undergone repeated practice.

Previous studies in mathematics education have shown that students' errors in calculus often stem from weak conceptual understanding and a tendency to memorise procedures without comprehending the underlying mathematical rationale (Hiebert & Lefevre, 1986). Students are found to develop mechanical forms of understanding, especially in interpreting calculus symbols such as differentials, which directly affect their strategies for solving integration problems (Tall & Vinner,

1981; Nilsen & Knutsen, 2023). Furthermore, studies have reported that students who rely heavily on procedural memorisation struggle to adapt the integration by substitution technique when confronted with variations in problem structure and tend to exhibit lower levels of confidence in problem solving (Fonbuena, 2022).

Despite the extensive body of research addressing students' difficulties in calculus, a significant gap remains in understanding why errors in integration by substitution persistently recur and how weaknesses in mathematical decision-making contribute to this phenomenon. Most previous studies have evaluated student performance based primarily on test scores, without examining in depth the cognitive processes and decisions students make when selecting substitution variables. Traditional teaching approaches that emphasise mechanical practice have also been found to be insufficient in helping students grasp the rationale behind each step of the solution process. Consequently, there is a need to examine the issue of recurring errors from a pedagogical perspective and to argue for the necessity of instructional innovations grounded in mathematical decision support.

Accordingly, this study aims to identify the forms of recurring errors committed by students in the integration by substitution technique and to argue for the need for pedagogical innovation based on mathematical decision support as a potential approach to reducing such errors and enhancing students' conceptual understanding in calculus learning.

## **Literature Review**

The literature indicates that students' errors in learning calculus, particularly in the topic of integration, have long been a major focus of research in mathematics education. Tall and Vinner (1981) argued that students often construct concept images that are misaligned with formal mathematical definitions, leading to persistent conceptual misunderstandings. This issue provides a fundamental explanation for why students' errors tend to recur despite repeated practice.

Orton (1983) further demonstrated that errors in integration do not arise solely from computational weaknesses, but rather from a failure to understand underlying concepts and a tendency to memorise procedures. This finding is supported by Hiebert and Lefevre (1986), who distinguished between conceptual and procedural understanding, highlighting that learning environments that overly emphasise procedures without conceptual grounding make it difficult for students to adapt their knowledge to new situations.

In the context of modern calculus education, Nilsen and Knutsen (2023) found that students tend to interpret mathematical symbols such as differentials and integrals mechanically, without

understanding their conceptual meanings. This limited interpretation directly affects how students apply the integration by substitution technique, particularly in selecting substitution variables and managing the symbol  $dx$ . Their study highlights the need for pedagogical support that enables students to interpret mathematical symbols in a more meaningful way.

Fonbuena (2022) emphasised the importance of quantitative understanding in  $u$ -substitution, showing that when students are guided through scaffolding based on quantitative reasoning, they are better able to grasp the conceptual structure of substitution. This finding supports the need for instructional approaches that go beyond procedural steps and instead emphasise the mathematical decision-making process.

Empirical studies by Hanifah (2021) and Sulistyaningtyas et al. (2023) further revealed that although students are often able to perform integration steps, they exhibit weaknesses in strategy selection and reflective thinking during problem solving. The errors identified were found to be recurring, particularly in determining appropriate substitution variables and correctly replacing differentials. These findings point to a lack of systematic guidance that supports students in making conscious and well-structured mathematical decisions.

Additionally, Shamsuddin and Abdul Rahman (2020) reported that errors in integration by substitution tend to be recurring and consistent, indicating the presence of stable error patterns that are not being effectively addressed. Their study proposed the use of visual aids and structured pedagogical approaches to help students better understand the flow of mathematical reasoning.

Overall, the literature review reveals that while numerous studies have examined students' errors in calculus, there remains a significant gap in research focusing specifically on recurring errors and the need for mathematical decision support in integration by substitution, particularly at the higher education level. Therefore, this study is proposed to address this gap by emphasising pedagogical innovation that guides students to make mathematical decisions in a systematic and meaningful manner.

## **Methodology**

This study employed a qualitative descriptive research design to examine students' recurring errors in the integration by substitution technique and to understand the mathematical decision-making processes underlying these errors. The study sample consisted of 40 undergraduate engineering students at Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang who were enrolled in a calculus course and had been introduced to the topic of integration by substitution. Participants were selected using purposive sampling to ensure the relevance of the study context. Demographic data of the participants

were reported in the methodology section for respondent profiling purposes and were not discussed in the findings section, as the focus of the study was on recurring errors and students' solution strategies in line with the research objectives.

The research instrument consisted of a set of written problems specifically designed to elicit a variety of solution strategies and potential errors in integration by substitution, with particular emphasis on the selection of substitution variables, the management of differentials, and re-substitution to the original variable. The instrument was reviewed and pilot-tested to ensure clarity, appropriate difficulty level, and content validity. Data were analysed using qualitative error analysis supported by basic descriptive statistics such as frequencies and percentages to identify patterns of recurring errors among students. This analytical approach was chosen because it aligns with the exploratory and conceptual nature of the study and serves to substantiate the need for pedagogical innovation based on mathematical decision support.

## Results and Findings

Based on the analysis of students' written responses and observations of the solution strategies employed, three main findings were identified with respect to recurring errors in the integration by substitution technique. The findings focus on errors related to the selection of substitution variables, the management of differentials, and the consistency of solution steps, as summarised in Table 1 and visually illustrated in Figure 1.

Table 1: Types of Recurring Errors

Finding	Type of error	Brief Description
Finding 1	Error in selecting the substitution variable ( $u$ )	Students select $u$ based solely on visual form without considering the appropriateness of its derivative
Finding 2	Error in managing differentials ( $du$ and $dx$ )	Students fail to correctly replace $dx$ or ignore the derivative factor
Finding 3	Inconsistency in solution steps	Students do not substitute back to the original variable or skip essential steps

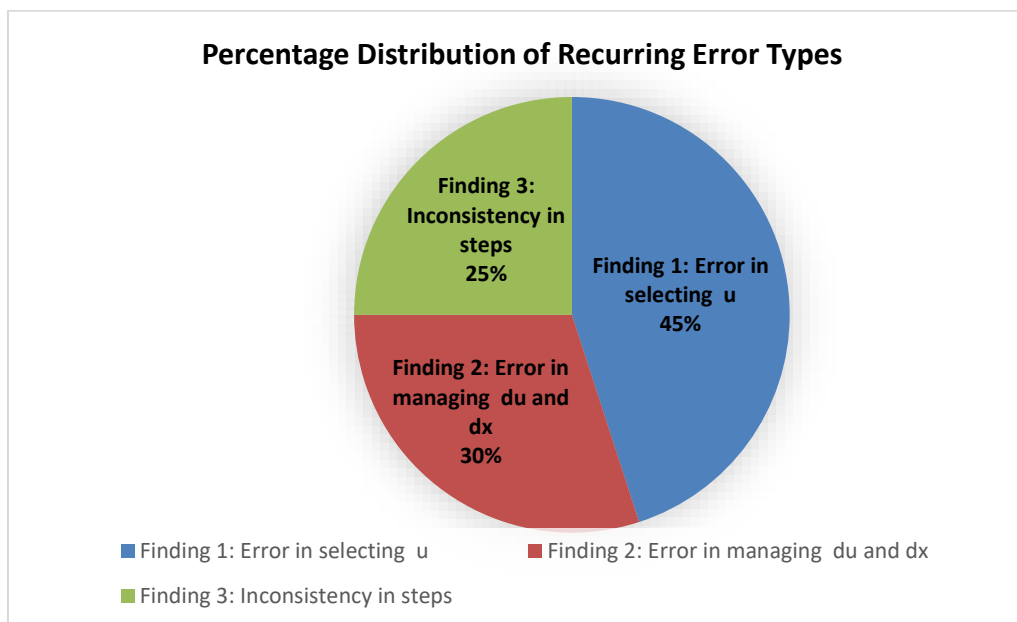


Figure 1: Pie Chart Showing the Percentage Distribution of Recurring Error Types in Integration by Substitution

As shown in Table 1, the findings indicate that the most dominant error is related to the selection of the substitution variable ( $u$ ). Students tend to choose  $u$  based on similarities with previous examples or the visual form of the integrand, without evaluating the relationship between the function and its derivative. This error occurs at the initial stage of problem solving and has a direct impact on the entire integration process. This finding is supported by Figure 1, which shows that 45% of students committed errors in selecting the substitution variable.

Subsequent findings reveal that 30% of students experienced difficulties in managing differentials, particularly in consistently replacing  $dx$  with  $du$ . Students were found to ignore the derivative factor or fail to properly incorporate  $du$  into the new integrand, reflecting weaknesses in the conceptual interpretation of calculus symbols. In addition, 25% of students were identified as making errors related to inconsistencies in solution steps, especially failing to substitute back to the original variable after integration or skipping essential steps.

Overall, the combined findings presented in Table 1 and the percentage distribution shown in Figure 1 indicate that students' recurring errors are concentrated at critical points in the mathematical decision-making process when applying the integration by substitution technique. These findings reinforce the need for pedagogical approaches that provide systematic and structured decision support to help students reduce recurring errors and develop stronger conceptual understanding.

### Example of Task Used for Analysis

To provide context for the analysis presented in Table 2, the following example represents a typical task given to students:

Evaluate the integral  $\int 2x \cos(x^2) dx$

This task was designed to elicit students' strategies in selecting an appropriate substitution variable, managing differentials, and performing re-substitution to the original variable.

Table 2: Examples of Analysis of Students' Responses and Types of Errors

Student	Excerpt from Student's Response (Clarified)	Type of Error	Error Category	Related Finding
P1	Let $(u = x)$ , hence $(du = dx)$ . The integral becomes $\int 2x \cos(x^2) dx$	Inappropriate choice of $(u)$	Error in selecting the substitution variable	Finding 1
P2	Let $(u = x^2)$ , $(du = 2x dx)$ . However, the final answer is written as $\int \sin(u) + C$ without substituting back.	Failure to substitute back to the original variable	Inconsistency in solution steps	Finding 3
P3	Let $(u = x^2)$ , but directly writes $(du = dx)$ .	Incorrect handling of differentials	Error in managing $(du/dx)$	Finding 2
P4	Proceeds to integrate directly as $\int \sin(x^2) dx$ without using substitution.	Incorrect choice of integration technique	Error in solution strategy	Finding 1
P5	Let $(u = x^2)$ , $(du = 2x dx)$ . The solution is completed correctly and consistently.	No error identified	Conceptual understanding	Reference comparison

Analysis of students' written responses in Table 2 indicates that the most prominent errors occur at the initial stage of problem solving, particularly in the selection of the substitution variable. Students tend to choose  $u$  based on visual elements or similarities with previous examples without considering the structure of the composite function, supporting Finding 1. Such errors compromise the entire integration process and reflect weaknesses in students' conceptual mathematical decision-making.

In addition, errors in managing differentials were identified when students failed to correctly match  $du$  with the original integrand or ignored the derivative factor. These findings reveal a procedural interpretation of the symbols  $dx$  and  $du$  without conceptual understanding, in line with Finding 2. Inconsistencies in solution steps were also observed when students failed to substitute back to the original variable after completing the integration, supporting Finding 3.

In contrast, the reference student's response demonstrates that conceptual understanding enables a systematic and complete solution process. Overall, this analysis confirms that students' recurring errors are concentrated at critical points in the mathematical decision-making process, thereby reinforcing the need for structured decision support in the teaching of integration by substitution.

## **Discussion**

The combined findings of the study indicate that recurring errors in integration by substitution stem from students' weaknesses in conceptual mathematical decision-making, encompassing the selection of substitution variables, the management of differentials, and the consistency of solution steps. Students tend to apply this technique through procedural memorisation, relying on visual similarities and previous examples without understanding the rationale underlying the relationship between a function and its derivative. These findings are consistent with recent studies reporting that reliance on procedural learning causes students to fail in adapting solution strategies when problem structures change (Bingölbali & Monaghan, 2021; Nilsen & Knutsen, 2023). Furthermore, weaknesses in interpreting the symbols  $dx$  and  $du$  meaningfully suggest that students view differentials as algebraic manipulation symbols rather than representations of mathematical relationships, as also reported in analyses of students' calculus thinking (Fonbuena, 2022). The identified inconsistencies in solution steps further reflect a lack of self-monitoring and reflective thinking structure, which are essential components of higher-level mathematical problem solving (Roh & Lee, 2020).

Overall, this discussion confirms that students' recurring errors in integration by substitution are not merely technical issues but are rooted in weak conceptual understanding and the absence of systematic mathematical decision support. These findings strengthen the argument that teaching approaches based primarily on procedural memorisation are insufficient for developing meaningful understanding of calculus. Consequently, pedagogical innovations grounded in mathematical decision support structuring the processes of selection, verification, and solution in a visual and stepwise manner have the potential to help students reduce recurring errors and develop more organised and reflective mathematical thinking in calculus learning.

## **Recommendations**

Based on the findings and discussion, recurring errors in integration by substitution are identified as arising from students' weaknesses in conceptual mathematical decision-making, particularly in the selection of substitution variables, the management of differentials, and the maintenance of consistent solution steps. Therefore, existing teaching approaches that overly emphasise procedural memorisation should be strengthened through pedagogical innovations that provide structured and meaningful mathematical decision support. Such approaches enable students to understand the rationale behind each step of the solution process, thereby reducing the recurring errors identified in the study. The implementation of these recommendations can be carried out by mathematics lecturers in higher education institutions through the integration of decision-support-based instructional tools, such as visual guides and decision flowcharts, into lectures, tutorials, and independent practice activities.

## Conclusion

This study addresses the issue of recurring errors in integration by substitution frequently encountered by higher education students in calculus learning. Based on the analysis of findings and discussion, students' errors are identified not merely as stemming from weaknesses in computational skills but are closely related to deficiencies in conceptual understanding and the ability to make systematic mathematical decisions.

Specifically, the study identifies that students' recurring errors are concentrated in three main aspects: the selection of substitution variables, the management of differentials, and inconsistencies in solution steps. These findings reinforce the argument that teaching approaches based solely on procedural memorisation are insufficient to help students meaningfully master the integration by substitution technique. Therefore, this study emphasises the need for pedagogical innovation based on mathematical decision support to assist students in developing stronger conceptual understanding, reducing recurring errors, and increasing confidence in calculus learning.

As an implication of the study, future research is recommended to focus on the development and evaluation of structured pedagogical interventions that emphasise students' thinking processes, particularly in supporting mathematical decision-making during calculus problem solving.

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# KEFAHAMAN HAD SEBAGAI ASAS PENGUASAAN HUKUM L'HÔPITAL

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## ABSTRACT

*Abstrak ini mengkaji kefahaman konseptual had (limit) sebagai asas kepada penguasaan aplikasi Hukum L'Hôpital dalam kalangan pelajar kalkulus. Walaupun had merupakan konsep asas, pengajaran Hukum L'Hôpital sering menumpukan langkah penyelesaian tanpa pemahaman konsep yang kukuh, menyebabkan kesalahan aplikasi. Kajian ini menggunakan pendekatan kualitatif melalui analisis kerja bertulis pelajar dan temu bual separa berstruktur dalam pengajaran kalkulus universiti. Dapatan menunjukkan kelemahan kefahaman konsep had menjejaskan keupayaan pelajar menentukan kesesuaian penggunaan Hukum L'Hôpital dan menjelaskan langkah penyelesaian. Kajian ini menekankan kepentingan pengajaran berasaskan kefahaman konsep dalam pembelajaran kalkulus.*

**Keywords:** *Had, Hukum L'Hôpital, Konsep, Kefahaman, Kalkulus*

## Pengenalan

Konsep had (limit) merupakan asas penting dalam kalkulus dan berfungsi sebagai prasyarat utama kepada pemahaman topik lanjutan seperti terbitan dan Hukum L'Hôpital. Kefahaman konseptual had membolehkan pelajar memahami tingkah laku fungsi apabila pemboleh ubah menghampiri sesuatu nilai serta membentuk penaakulan matematik yang bermakna. Namun demikian, dalam pengajaran kalkulus di peringkat universiti, Hukum L'Hôpital sering diajar secara prosedural dengan penekanan kepada langkah penyelesaian semata-mata, tanpa memastikan pelajar benar-benar memahami konsep had yang mendasari penggunaannya. Pendekatan ini berpotensi menyebabkan pelajar menguasai prosedur pengiraan tetapi lemah dari segi pemahaman konsep dan justifikasi matematik.

Dapatan kajian lepas secara umum menunjukkan bahawa pelajar sering mempunyai kefahaman konseptual had yang terhad dan cenderung menyamakan had dengan nilai fungsi pada sesuatu titik. Selain itu, pelajar didapati mengaplikasikan Hukum L'Hôpital secara rutin apabila berhadapan dengan bentuk tidak tentu, walaupun dalam situasi yang tidak memenuhi syarat penggunaannya. Pendekatan pengajaran yang terlalu berfokus kepada prosedur dikenal pasti sebagai antara faktor utama yang menyumbang kepada kesalahan aplikasi dan ketidakupayaan pelajar menjelaskan rasional di sebalik langkah penyelesaian. Walaupun terdapat kajian yang mencadangkan penggunaan visualisasi dan

pendekatan intuitif, huraian terperinci berkaitan dapatan ini dibincangkan dalam bahagian sorotan literatur.

Berdasarkan dapatan kajian lepas tersebut, masih wujud keperluan untuk penambahbaikan dari segi pendekatan pengajaran dan reka bentuk kajian. Khususnya, hubungan langsung antara kefahaman konseptual had dan keupayaan pelajar menentukan kesesuaian penggunaan Hukum L'Hôpital serta menjustifikasi langkah penyelesaian masih kurang diterokai secara mendalam, terutamanya melalui kajian kualitatif dalam konteks pengajaran sebenar di bilik darjah universiti. Kekurangan ini menimbulkan jurang dari segi empirikal dan metodologi yang perlu ditangani bagi memahami proses pembelajaran pelajar secara lebih holistik.

Sehubungan itu, kajian ini bertujuan meneroka kefahaman konseptual had sebagai asas kepada penguasaan aplikasi Hukum L'Hôpital dalam kalangan pelajar kalkulus. Secara khusus, kajian ini bertujuan meneliti bagaimana kefahaman konsep had mempengaruhi kesesuaian penggunaan Hukum L'Hôpital serta mengenal pasti kesalahan konseptual yang dilakukan pelajar semasa menyelesaikan masalah kalkulus. Dapatan kajian ini diharapkan dapat menyumbang kepada penambahbaikan pendekatan pengajaran kalkulus dengan memberi penekanan yang lebih sistematik kepada pembinaan kefahaman konsep sebagai asas kepada pembelajaran topik lanjutan.

## **Kajian Literatur**

Kajian-kajian lepas secara konsisten menunjukkan bahawa konsep had merupakan antara konsep paling mencabar dalam pembelajaran kalkulus kerana sifatnya yang abstrak dan memerlukan penaakulan tahap tinggi. Kajian awal oleh Tall dan Vinner (1981) menegaskan bahawa pelajar sering membentuk gambaran konsep dalam pemikiran mereka yang tidak selari dengan definisi formal konsep, menyebabkan salah faham berterusan terhadap konsep had. Dapatan ini diperkukuh oleh Cornu (1991) yang menyatakan bahawa kesukaran mempelajari had berpunca daripada cara pengetahuan matematik itu difahami dan dibina, dan tidak dapat diatasi melalui pengajaran prosedural semata-mata. Kedua-dua kajian ini menekankan kepentingan kefahaman konseptual, namun bersifat teoritikal dan tidak diuji berdasarkan data dan pemerhatian sebenar dalam konteks bilik kuliah.

Kajian empirik oleh Denbel (2014) menunjukkan bahawa pelajar cenderung menyamakan had dengan nilai fungsi pada sesuatu titik, iaitu satu salah faham yang memberi kesan kepada pembelajaran topik kalkulus lanjutan. Walaupun kajian ini berjaya mengenal pasti salah faham utama pelajar, ia tidak mengkaji secara khusus implikasi kelemahan kefahaman konsep had terhadap aplikasi kaedah tertentu seperti Hukum L'Hôpital, sekali gus meninggalkan kekurangan bukti kajian berasaskan data yang ketara dalam konteks tersebut. Kajian yang lebih terkini turut mengukuhkan dapatan ini. Sebagai contoh, Goredema et al. (2023) meneroka salah faham pelajar Gred 12 dan mendapati bahawa

kekeliruan tersebut berterusan hingga ke peringkat pengajian tinggi, sekali gus menjejaskan penaaakulan mereka dalam penyelesaian masalah kalkulus. Begitu juga, Julaihi (2025) mengenal pasti kesilapan berulang dalam kalangan pelajar universiti ketika menyelesaikan masalah had dan mencadangkan strategi khusus bagi mengatasinya.

Dalam konteks pengajaran Hukum L'Hôpital, Caglayan (2017) mendapati bahawa penggunaan paparan visual yang berubah secara interaktif membantu pelajar memahami konsep dengan lebih baik, manakala Yepes (2024) menegaskan bahawa pendekatan visual dan intuitif perlu mendahului latihan prosedural. Menyokong pandangan ini, ASEE Mathematics Division (2024) membentangkan bukti bahawa kaedah pengajaran berasaskan visual dan intuitif secara signifikan meningkatkan keupayaan pelajar mengaplikasikan Kaedah L'Hôpital secara bermakna. Walau bagaimanapun, kajian-kajian ini lebih menumpukan kepada strategi pengajaran Hukum L'Hôpital tanpa menguji secara langsung peranan kefahaman konseptual had sebagai prasyarat utama kepada penguasaan aplikasi hukum tersebut.

Secara keseluruhannya, sorotan literatur menunjukkan persamaan pandangan bahawa kelemahan kefahaman konseptual had merupakan punca utama kesukaran pelajar dalam pembelajaran kalkulus. Walau bagaimanapun, masih terdapat kekurangan kajian yang menghubungkan secara langsung kefahaman konsep had dengan penguasaan aplikasi Hukum L'Hôpital dalam konteks pengajaran sebenar di bilik darjah universiti. Oleh itu, kajian ini bertujuan mengisi jurang tersebut melalui penerokaan kualitatif tentang bagaimana kefahaman konseptual had mempengaruhi keupayaan pelajar mengaplikasikan Hukum L'Hôpital secara bermakna dan berjustifikasi.

## **Metodologi**

Kajian ini menggunakan reka bentuk kajian tindakan kelas dengan pendekatan kualitatif bagi meneroka kefahaman konseptual had dan implikasinya terhadap aplikasi Hukum L'Hôpital. Peserta kajian terdiri daripada 40 orang pelajar ijazah sarjana muda dalam bidang kejuruteraan di UiTM Cawangan Pulau Pinang yang sedang mengikuti kursus kalkulus dan telah diperkenalkan kepada topik had serta Hukum L'Hôpital. Pemilihan peserta dibuat secara persampelan bertujuan, selaras dengan konteks kajian dan objektif penyelidikan. Maklumat demografi peserta dihuraikan dalam bahagian metodologi dan tidak dilaporkan dalam dapatan kajian kerana fokus kajian adalah kepada kefahaman konsep, bukan kepada profil responden.

Kajian ini dilaksanakan melalui beberapa kitaran kajian tindakan yang melibatkan empat fasa utama, iaitu perancangan, tindakan, pemerhatian dan refleksi. Pada fasa perancangan, aktiviti pengajaran dirangka dengan penekanan kepada penerokaan konsep had secara visual dan konseptual sebelum pengenalan Hukum L'Hôpital. Fasa tindakan melibatkan pelaksanaan aktiviti pengajaran

seperti analisis graf, perbincangan berfokus dan penyelesaian masalah terbuka, yang menggalakkan pelajar membuat keputusan matematik secara berasaskan kefahaman.

Sepanjang fasa pemerhatian, respons dan kefahaman pelajar direkodkan bagi mengenal pasti corak pemikiran dan kesalahan konseptual yang berulang. Fasa refleksi pula digunakan untuk menilai keberkesanan pendekatan pengajaran yang dilaksanakan serta mengenal pasti aspek yang perlu ditambah baik dalam kitaran seterusnya.

Data kajian dikumpulkan melalui analisis kerja bertulis pelajar, pemerhatian pengajaran dan pembelajaran, serta temu bual separa berstruktur. Instrumen kajian dibangunkan berdasarkan objektif kajian dan disemak dari segi kesesuaian kandungan sebelum digunakan. Data dianalisis secara tematik bagi mengenal pasti pola kefahaman dan kesalahan konseptual pelajar, selaras dengan pendekatan kajian kualitatif seperti yang dicadangkan oleh Merriam (2009).

## Hasil dan Dapatan

Bahagian ini membentangkan dapatan kajian berkaitan kefahaman konseptual had dan implikasinya terhadap aplikasi Hukum L'Hôpital dalam kalangan pelajar kalkulus. Dapatan kajian diperoleh melalui analisis kerja bertulis pelajar, pemerhatian semasa pengajaran dan pembelajaran, serta temu bual separa berstruktur. Jadual 1 memaparkan ringkasan dapatan utama kajian berdasarkan tema-tema yang dikenal pasti melalui analisis tematik.

Jadual 1: Ringkasan Dapatan Kajian

Tema Utama	Huraian Dapatan	Contoh Bukti / Petikan Pelajar
Kefahaman konseptual had yang terhad	Pelajar cenderung menyamakan limit dengan nilai fungsi pada sesuatu titik dan tidak memahami konsep menghampiri nilai.	“Limit itu sama dengan nilai fungsi di titik tersebut.”
Aplikasi Hukum L'Hôpital secara prosedural	Pelajar menggunakan Hukum L'Hôpital secara rutin apabila menemui bentuk tidak tentu tanpa menilai kesesuaian penggunaannya.	“Kalau dapat bentuk 0/0, saya terus guna Hukum L'Hôpital.”
Kesukaran menjustifikasi langkah penyelesaian	Pelajar sukar memberikan justifikasi konseptual terhadap langkah penyelesaian dan hanya menumpukan kepada pengiraan.	“Saya ikut langkah kira sahaja, tak pasti kenapa perlu guna cara itu.”
Hubungan antara kefahaman had dan kesalahan aplikasi	Kelemahan kefahaman konsep limit menyumbang secara langsung kepada kesalahan dalam aplikasi Hukum L'Hôpital.	Kesalahan berulang berlaku apabila pelajar tidak memahami makna limit sebelum menggunakan hukum.

Berdasarkan Jadual 1, dapatan kajian menunjukkan bahawa kefahaman konseptual had dalam kalangan pelajar masih tidak mantap. Pelajar didapati cenderung menyamakan konsep had dengan nilai fungsi pada sesuatu titik tanpa memahami makna menghampiri nilai. Salah faham ini jelas ditunjukkan

melalui respons pelajar yang mengaitkan nilai had secara langsung dengan nilai fungsi, sekali gus mencerminkan pemahaman yang bersifat permukaan dan tidak selari dengan definisi formal konsep had.

Selain itu, dapatan kajian menunjukkan bahawa Hukum L'Hôpital diaplikasikan secara prosedural dan rutin oleh kebanyakan pelajar. Apabila berhadapan dengan bentuk tidak tentu seperti  $0/0$ , pelajar cenderung menggunakan Hukum L'Hôpital secara automatik tanpa menilai kesesuaian penggunaannya. Corak ini menunjukkan bahawa pelajar membuat keputusan matematik berdasarkan pengecaman corak soalan, bukan berdasarkan pertimbangan konsep had yang mendasari masalah tersebut.

Dapatan kajian turut menunjukkan bahawa pelajar menghadapi kesukaran menjustifikasi langkah penyelesaian secara konseptual. Walaupun pelajar mampu melaksanakan pengiraan dengan betul, mereka tidak dapat menjelaskan sebab sesuatu kaedah digunakan atau menghubungkannya dengan konsep had. Kesukaran ini menandakan kewujudan jurang yang ketara antara penguasaan prosedur dan kefahaman konsep asas.

Secara keseluruhan, dapatan kajian memperlihatkan hubungan yang jelas antara kelemahan kefahaman konseptual had dan kesalahan dalam aplikasi Hukum L'Hôpital. Pelajar yang tidak memahami konsep had secara mendalam didapati lebih cenderung melakukan kesalahan dalam menentukan kesesuaian penggunaan hukum serta gagal memberikan justifikasi yang tepat terhadap langkah penyelesaian. Dapatan ini menegaskan bahawa kefahaman konsep asas merupakan prasyarat penting kepada penguasaan prosedur lanjutan dalam pembelajaran kalkulus.

## **Perbincangan**

Perbincangan kajian ini menunjukkan bahawa kelemahan kefahaman konseptual had merupakan faktor utama yang mempengaruhi cara pelajar mengaplikasikan Hukum L'Hôpital. Dapatan kajian menunjukkan pelajar cenderung menyamakan konsep had dengan nilai fungsi, menyokong pandangan Tall dan Vinner (1981) bahawa pelajar sering membina gambaran konsep dalam pemikiran yang tidak selari dengan definisi formal matematik. Kekeliruan ini menyebabkan pelajar gagal memahami makna sebenar proses menghampiri nilai, seterusnya menjejaskan keupayaan mereka untuk membuat keputusan matematik yang tepat dalam situasi yang melibatkan konsep had.

Selain itu, kecenderungan pelajar mengaplikasikan Hukum L'Hôpital secara rutin apabila menemui bentuk tidak tentu mencerminkan dominasi pendekatan pengajaran yang berfokus kepada prosedur. Dapatan ini selari dengan hujah Cornu (1991) yang menyatakan bahawa pengajaran matematik yang terlalu menekankan prosedur tidak berupaya membantu

pelajar mengatasi kesukaran memahami konsep abstrak seperti had. Tanpa kefahaman konsep yang kukuh, penggunaan Hukum L'Hôpital menjadi bersifat mekanikal dan tidak bermakna, sekali gus meningkatkan risiko kesalahan aplikasi.

Kesukaran pelajar menjustifikasi langkah penyelesaian secara konseptual turut mencerminkan jurang yang ketara antara penguasaan prosedur dan kefahaman konsep asas. Walaupun pelajar mampu melaksanakan pengiraan, ketidakupayaan mereka menjelaskan rasional di sebalik langkah penyelesaian menunjukkan bahawa pembelajaran yang berlaku adalah bersifat permukaan. Dapatan ini menyokong kajian Denbel (2014) yang mendapati bahawa salah faham terhadap konsep had boleh berlanjutan ke topik kalkulus lanjutan dan menjejaskan kualiti penaakulan matematik pelajar.

Secara keseluruhannya, hubungan yang jelas antara kelemahan kefahaman konseptual had dan kesalahan dalam aplikasi Hukum L'Hôpital menegaskan bahawa pembinaan kefahaman konsep asas perlu diberi keutamaan sebelum pengenalan prosedur formal. Pendekatan pengajaran yang mengintegrasikan penerokaan konsep, visualisasi dan perbincangan reflektif, seperti yang dicadangkan oleh Yepes (2024), berpotensi meningkatkan kefahaman pelajar secara lebih bermakna. Oleh itu, dapatan kajian ini menyokong keperluan peralihan daripada pengajaran yang berasaskan prosedur semata-mata kepada pendekatan pengajaran kalkulus yang menekankan kefahaman konseptual di peringkat pengajian tinggi.

## **Kesimpulan**

Kajian ini meneliti kefahaman konseptual had sebagai asas kepada penguasaan aplikasi Hukum L'Hôpital dalam kalangan pelajar kalkulus di peringkat pengajian tinggi. Berasaskan pendekatan kajian tindakan kelas secara kualitatif, kajian ini menunjukkan bahawa konsep had masih mencabar untuk difahami dan memberi kesan langsung terhadap cara pelajar membuat keputusan matematik serta mengaplikasikan Hukum L'Hôpital.

Dapatan kajian menunjukkan bahawa kelemahan kefahaman konsep had menyebabkan pelajar menyamakan had dengan nilai fungsi, mengaplikasikan Hukum L'Hôpital secara rutin tanpa menilai kesesuaian penggunaannya, dan menghadapi kesukaran menjustifikasi langkah penyelesaian. Hal ini menegaskan bahawa penguasaan prosedur pengiraan semata-mata tidak mencukupi tanpa kefahaman konsep yang kukuh.

Secara keseluruhannya, kajian ini mengesahkan bahawa kefahaman konseptual had merupakan prasyarat penting kepada penguasaan Hukum L'Hôpital. Dapatan kajian ini memberi implikasi signifikan terhadap amalan pengajaran kalkulus dengan menekankan keperluan peralihan daripada

pengajaran berasaskan prosedur kepada pendekatan yang berfokus kepada pembinaan kefahaman konsep. Kajian lanjutan dicadangkan bagi menilai keberkesanan intervensi berasaskan konsep merentasi topik-topik kalkulus yang lain.

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## HAAR WAVELET TRANSFORM FOR FREQUENCY DATA DECOMPOSITION AND ANALYSIS

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### ABSTRACT

*Frequency data analysis is fundamental in engineering, science, and applied mathematics. While the Fourier transform has traditionally dominated this field, its assumption of signal stationarity and lack of time localization limit its effectiveness for transient and discontinuous signals. The Haar wavelet, introduced by Alfred Haar in 1910, provides a simple yet powerful alternative through time–frequency localization and multi resolution analysis. Defined by piecewise constant scaling and wavelet functions, the Haar transform decomposes signals into approximation and detail coefficients across multiple scales, enabling efficient detection of abrupt changes and localized frequency variations. Its computational simplicity and effectiveness in handling non-stationary data have made it widely applicable in signal processing, image compression, biomedical engineering, communications, and artificial intelligence. Despite advantages such as low computational complexity and strong time localization, Haar wavelets exhibit limitations, including poor representation of smooth signals and coarse frequency resolution. These shortcomings led to the development of smoother wavelet families such as Daubechies and Symlets. Nevertheless, the Haar wavelet remains a foundational tool and conceptual milestone in modern frequency data analysis and computational signal processing.*

**Keywords:** Haar wavelet, frequency data analysis, multi resolution analysis, signal processing

### 1.0 Introduction

Frequency data analysis plays a critical role in engineering, science, and applied mathematics. Traditional approaches, particularly the Fourier transform, have long been used to decompose signals into their frequency components. Fourier-based approaches are powerful, but they presuppose signal stationarity and lack temporal localization, making them ineffective for evaluating transient or discontinuous signals.

A wavelet is a mathematical function that splits data into frequency and time domain layers. In comparison to the Fourier transform, the wavelet has the benefit of being localized in both the time and frequency domains, as well as providing a practical and efficient manner of describing complicated signals. Wavelet transformations allow educators to monitor and interpret data at various scales. The wavelet approach divides a signal into different spectrums by taking its averages and differences. Alfred Haar began the research of Haar wavelets in 1910 as described in Schumaker and Webb (1995), who developed the first known wavelet basis by demonstrating that any continuous function  $f(x)$  can be

approximated by a series of step functions, as illustrated in Figure 1. However, the Haar transform has the disadvantage of being neither continuous nor differentiable.



Figure 1: Haar wavelet function

One of the most popular wavelets in the world of signal and image processing is still the Haar wavelet (Van, 2008). This paper examines how Haar wavelets transformed frequency data analysis and continue to influence modern computational techniques.

## 2.0 Mathematical Foundation of Haar Wavelets

According to Pinsky (2002), Haar Wavelets is composed of two wavelets, father wavelet  $\phi(t)$  which is also known as scaling function and is defined as:

$$\phi(t) = \begin{cases} 1, & 0 < t < 1 \\ 0, & \text{otherwise} \end{cases}$$

and mother wavelet  $\Psi(t)$  which is represented by:

$$\Psi(t) = \begin{cases} 1, & 0 < t < \frac{1}{2} \\ -1, & \frac{1}{2} < t < 1 \\ 0, & \text{otherwise} \end{cases}$$

The Haar wavelet is the simplest orthogonal wavelet, defined using a piecewise constant function. Using these functions, a signal can be decomposed into approximation and detail coefficients

at multiple scales. This structure enables multi-resolution analysis, allowing both coarse trends and fine details to be captured efficiently.

The wavelet transform is an effective approach to remove white noise from a signal. The approach involves applying one of the discrete wavelet transformations to the data and then running a threshold algorithm to modify the detail coefficients. After modifying the coefficients, the inverse transform is applied; the resulting output is a representation of the signal with much decreased noise (Wirsing, 2021). Figure 2 below shows the frequency responses of the scaling and wavelet function for Daubechies level 2 wavelet. Therefore, the wavelet function is a high pass filter and the scaling function is a low pass filter.

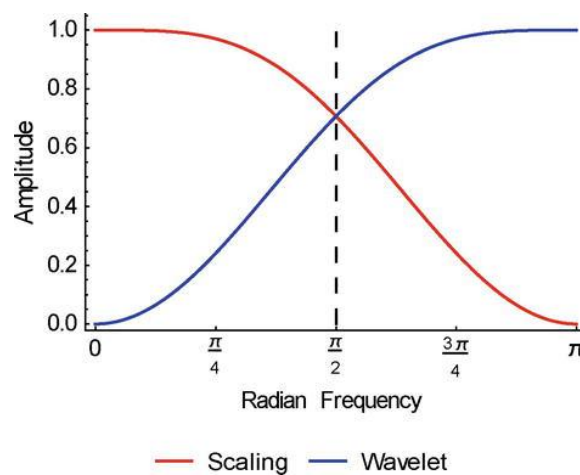


Figure 2: Frequency response of scaling function (red) and wavelet function (blue) for Daubechies level 2 wavelet.

### 3.0 Haar Wavelets and Frequency Data Analysis

#### 3.1 Multiresolution Analysis

A major contribution of Haar wavelets is the concept of multiresolution analysis. Signals are decomposed hierarchically into different levels of resolution, enabling analysts to observe frequency characteristics at varying scales. This approach is particularly effective for identifying localized frequency changes.

#### 3.2 Time frequency Localization

Unlike Fourier transform, which provides frequency information without temporal context, Haar wavelet offers precise localization in time. This property allows the detection of sudden transitions,

edges, and singularities within frequency data. According to Cohen (2019), when the signal is not stationary then the Fourier transform loses precision.

#### 4.0 Comparison with Fourier Methods

Table 1 focuses on the benefits of the study by comparing the Fourier transform and the Haar wavelet transform across several important analytical features.

Table 1: Benefits of the Fourier Transform and the Haar wavelet transform

Feature	Fourier Transform	Haar Wavelet Transform
Signal assumption	Stationary	Non-stationary
Time localization	None	Strong
Frequency resolution	High	Moderate
Discontinuity handling	Poor	Effective
Computational complexity	Moderate	Low

This comparison clearly illustrates why Haar wavelets represent a revolutionary step beyond traditional frequency analysis methods, particularly in the analysis of non-stationary and discontinuous signals.

#### 5.0 Applications of Haar Wavelets

The practical significance of Haar wavelets extends to various sectors, and Table 2 highlights their applications across these different domains. These domains include signal processing, image compression, biomedical engineering, data analysis, and financial modeling, where Haar wavelets are employed for tasks such as feature extraction, noise reduction, pattern recognition, and efficient data representation. Their simplicity, computational efficiency, and ability to detect abrupt changes make them particularly suitable for real-world problems involving large and non-stationary datasets.

Table 2: Applications of Haar Wavelets Across Various Domains

Domain	Applications of Haar Wavelets
Signal Processing	Detection of transient events, abrupt frequency changes, and signal discontinuities
Image Processing	Image compression, edge detection, and feature extraction
Biomedical Engineering	Analysis of biomedical signals such as electrocardiograms (ECG) and electroencephalograms (EEG)

Communications	Noise suppression and efficient signal representation
Data Science and Artificial Intelligence	Feature encoding, dimensionality reduction, and fast preprocessing for learning algorithms

## 6.0 Limitations and Future Directions

Despite their numerous advantages, Haar wavelets exhibit several inherent limitations. Due to their piecewise constant nature, they provide a poor representation of smooth or highly oscillatory signals, where gradual variations and fine frequency details are important. In addition, Haar wavelets offer relatively coarse frequency resolution, which restricts their effectiveness in accurately capturing subtle spectral features. Another notable drawback is the introduction of block-like artifacts in reconstructed signals, particularly in image and signal compression applications. These limitations motivated the development of smoother and more advanced wavelet families, such as Daubechies and Symlets, which offer improved frequency localization and better performance for continuous and complex signals.

In contemporary applications, Haar wavelets remain relevant due to their simplicity and interpretability. They are frequently used as baseline models, fast preprocessing tools, and components within hybrid machine learning systems. Haar-like features, for example, are widely employed in pattern recognition and object detection tasks.

## 7.0 Conclusion

The Haar wavelet revolutionized frequency data analysis by introducing localized, multi-scale signal decomposition. Its ability to handle non-stationary data efficiently marked a decisive break from classical Fourier-based methods. Although more advanced wavelets have since been developed, the Haar wavelet remains a fundamental tool and a conceptual cornerstone in modern signal processing and data analysis.

Furthermore, a variety of software is available for wavelet transform experiments. The wavelet transform is accessible in Mathematica, Matlab, and PyWavelets, whereas the discrete and stationary wavelet transforms are available in Maple, Matlab, R, and PyWavelets.

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# TRANSFORMASI DAN IMPLIKASI KECERDASAN BUATAN DALAM EKOSISTEM AKADEMIK: PENGGUNAAN AI TERHADAP PENYIAPAN TUGASAN PELAJAR

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## ABSTRACT

*Transformasi ekosistem akademik yang didorong oleh kecerdasan buatan (AI) generatif telah mencetuskan perubahan ketara cara pelajar menyiapkan tugas. Penelitian penggunaan AI dalam pembelajaran memberi tumpuan kepada keseimbangan antara manfaat dan risiko. Dari sudut positif, AI mempercepatkan pencarian maklumat, meningkatkan kualiti bahasa, menyediakan idea tambahan, serta menyokong pembelajaran sendiri dan inklusif. Namun, penggunaan yang tidak terkawal menimbulkan isu serius seperti kebergantungan kognitif, kemerosotan daya fikir kritis, pelanggaran integriti akademik melalui plagiat, halusinasi data, serta tekanan psikososial akibat technostress dan pengurangan interaksi bersemuka. Analisis perbandingan menunjukkan bahawa tugas dengan bantuan AI lebih cepat dan efisien, tetapi berisiko menghakis kebebasan berfikir pelajar. Oleh itu, institusi pendidikan perlu merangka garis panduan etika yang adil dan seimbang bagi pihak pelajar dan pendidik, melaksanakan mekanisme pengesanan plagiarisme dengan lebih cekap berkesan, dan paling penting mendidik pelajar tentang penggunaan AI secara bertanggungjawab dan berhemah. Kesimpulannya, AI harus dilihat sebagai alat sokongan yang transformatif, bukan pengganti usaha intelektual demi memastikan kesejahteraan ekosistem akademik dan pembentukan modal insan yang lebih seimbang.*

**Keywords:** *Kecerdasan Buatan, Tugas Akademik, Integriti Akademik, Halusinasi AI, Kesejahteraan psikososial*

## Pengenalan

Lanskap pendidikan tinggi global sedang menempuh satu fasa peralihan yang paling radikal sejak penemuan internet, didorong oleh penyebaran pantas teknologi Kecerdasan Buatan (AI) generatif. Fenomena ini bukan sekadar evolusi peralatan digital, malah merupakan anjakan paradigma bagaimana ilmu pengetahuan dijana, diproses, dan dipersembahkan oleh pelajar dalam tugas akademik mereka (Hendri, 2024). Sejak pelancaran model bahasa besar (LLM) seperti ChatGPT pada akhir tahun 2022, institusi pendidikan di seluruh dunia, termasuk di Malaysia, berhadapan dengan dilema antara memanfaatkan kecekapan teknologi dan memelihara integriti intelektual yang menjadi tunjang akademik (BERNAMA, 2024). Penggunaan AI dalam menyiapkan tugas telah meresap ke dalam pelbagai disiplin ilmu, daripada sains komputer hingga ke sastera, membawa bersama impak yang

bersifat dwi-fungsi, dari sudut positif sebagai pemangkin inovasi dan sebaliknya menjadi ancaman kepada kemahiran berfikir secara bebas (Vieriu & Petrea, 2025).

### **Evolusi Mekanisme Penyiapan Tugas**

Sebelum kehadiran AI generatif, penyiapan tugas akademik bergantung sepenuhnya kepada keupayaan pelajar untuk mencari sumber rujukan, memahami teks, dan mensintesis maklumat secara manual. Kehadiran AI telah memendekkan kitaran kerja ini secara signifikan. Pelajar kini menggunakan AI sebagai "rakan pembelajaran" yang berupaya merumuskan artikel ilmiah yang panjang, mencadangkan struktur esei, dan memberikan penjelasan segera bagi konsep-konsep yang sukar difahami (Salsa, 2025). Kajian yang dikemukakan oleh Profesor Madya Ts. Dr. Md Fauzi Ahmad pensyarah kanan dari Universiti Tun Hussein Onn Malaysia (UTHM) menunjukkan 60% pelajar universiti di Rantau Asia telah mula mengintegrasikan AI dalam proses penyiapan tugas, walaupun terdapat tahap ketidakpastian yang tinggi mengenai sempadan etika penggunaan tersebut (Harian Metro, 2025).

Mekanisme penggunaan AI dalam tugas boleh dikategorikan kepada dua bentuk utama yang melibatkan bantuan eksekutif dan bantuan instrumental (Bergdahl & Sjöberg, 2026). Bantuan eksekutif merujuk kepada tindakan pelajar menggunakan AI untuk mendapatkan jawapan pantas dengan usaha minima membawa kepada pemintasan proses pembelajaran yang sebenar. Bantuan instrumental pula melibatkan penggunaan AI untuk memperjelaskan konsep, membina kemahiran, dan menyokong pembelajaran sendiri. Kecenderungan pelajar untuk memilih salah satu daripada kategori ini sangat dipengaruhi oleh bimbingan daripada pendidik dan dasar yang ditetapkan oleh institusi masing-masing melibatkan transformasi menyeluruh terhadap pedagogi yang diamalkan selama ini. Jadual 1 menunjukkan perbandingan penyiapan tugas secara manual berbanding penggunaan AI yang dilihat dari aspek masa, kualiti bahasa, idea dan kreativiti, pemahaman konsep, beban kerja, akses ilmu serta kebebasan berfikir.

Jadual 1: Perbandingan Penyiapan Tugas Secara Manual Berbanding Penggunaan AI

<b>Aspek</b>	<b>Tugas Manual</b>	<b>Tugas dengan AI</b>
<b>Masa</b>	Lebih lama kerana perlu mencari, menyusun dan menyemak sendiri.	Lebih cepat kerana AI boleh meringkaskan, mencari data menyemak secara automatic.
<b>Kualiti Bahasa</b>	Bergantung pada kemahiran individu.	AI membantu menyemak tatabahasa, struktur ayat dan gaya penulisan dengan lebih tepat.
<b>Idea &amp; Kreativiti</b>	Terhad kepada pengetahuan pelajar.	AI boleh mencadangkan sudut pandang suatu topik secara meluas dengan lebih kreatif.

Aspek	Tugas Manual	Tugas dengan AI
<b>Pemahaman Konsep</b>	Perlu pembacaan yang teliti dari pelbagai sumber untuk membina kefahaman.	AI berupaya menjelaskan suatu konsep dengan ringkas dan mudah difahami.
<b>Beban Kerja</b>	Tinggi, terutama yang melibatkan tugas besar.	Berkurangan kerana AI membantu menganalisis, membuat ringkasan dan menyampaikan dalam bentuk info grafik.
<b>Akses Ilmu</b>	Bergantung pada bahan rujukan yang ada.	AI membuka akses kepada sumber global dan terkini.
<b>Kebebasan Berfikir</b>	Lebih tinggi kerana hasil asli dari pelajar.	Risiko bergantung terlalu banyak pada AI, menjadikan pelajar bersifat kurang kritis jika tidak dikawal

### Impak Positif Penggunaan AI Dalam Penyiapan Tugas

Dari sudut pandang yang optimistik, penggunaan AI dalam tugas menawarkan potensi yang tidak terbatas dalam meningkatkan kualiti pembelajaran secara keseluruhan. AI bertindak sebagai pemangkin kepada pendemokrasian ilmu, di mana maklumat yang dahulunya sukar dicapai atau difahami kini boleh diterjemahkan dan dijelaskan mengikut tahap kognitif pelajar (Pamungkas, 2024). Berikut adalah antara manfaat yang diperolehi hasil penggunaan AI dalam penyiapan tugas:

- **Mempercepat proses**

AI boleh membantu mencari maklumat, merumuskan isi, atau menyusun draf dengan lebih pantas berbanding kaedah manual. AI menyediakan maklum balas segera yang membolehkan pelajar mengenal pasti kesilapan dalam tugas mereka dan memperbaikinya sebelum penghantaran akhir dilakukan (Pamungkas, 2024).

- **Meningkatkan kualiti penulisan**

AI berperanan sebagai alatan yang sangat membantu dalam merapatkan jurang linguistik. Aplikasi seperti Grammarly dan Wordtune membolehkan pelajar memperhalusi struktur ayat, membetulkan ralat sintaksis dan meningkatkan kejelasan komunikasi dalam tugas bertulis yang dihasilkan (Mazlan, 2025).

- **Menyediakan idea tambahan**

AI berupaya memberi cadangan mengenai suatu topik, contoh atau sudut pandang baharu yang mungkin tidak terlintas pada fikiran pelajar. Tugas yang memerlukan pengumpulan data, analisis awal, atau penjana grafik boleh dipermudah dengan bantuan AI. AI membantu dalam penjana idea atau "*brainstorming*" awal, yang sering kali menjadi fasa yang paling mencabar bagi pelajar dalam memulakan penulisan sesuatu projek atau esei (Mazlan, 2025).

- **Sokongan terhadap pembelajaran sendiri dan inklusif**

AI berperanan sebagai tutor peribadi yang adaptif. Sistem pembelajaran berkuasa AI mampu menganalisis corak pembelajaran pelajar dan mencadangkan sumber rujukan yang paling relevan dengan keperluan sendiri mereka. Sebagai contoh, pelajar yang lemah dalam matematik boleh meminta AI untuk memberikan langkah-langkah penyelesaian secara terperinci atau menjelaskan formula dalam bahasa yang lebih mudah difahami termasuk melalui analogi atau ringkasan (Radeva, 2024).

### **Impak Negatif Penggunaan AI Dalam Penyiapan Tugas**

Di sebalik lonjakan kecekapan, penggunaan AI yang tidak terkawal dalam penyiapan tugas membawa risiko yang besar terhadap pembangunan sahsiah dan intelektual pelajar. Berikut adalah risiko penggunaan AI terhadap ekosistem akademik yang wajar diberi perhatian secara tuntas untuk mengelak ancaman lebih besar terhadap pembentukan modal insan:

- **Risiko kebergantungan dan kemerosotan kualiti intelek**

Kebimbangan utama adalah mengenai kebergantungan kognitif yang berlebihan di mana pelajar memindahkan beban berfikir kepada mesin tanpa berusaha memahami konsep asas (Jose et al., 2025). Pakar pendidikan di Malaysia telah memberi amaran bahawa kebergantungan yang melampau kepada AI boleh menjadikan pelajar "bijak mesin tetapi tidak berjiwa" (Pusat Jaminan Kualiti UPM, 2026). Ini boleh melemahkan kemahiran berfikir kritis dan penyelesaian masalah.

- **Isu plagiat dan integriti akademik**

Integriti akademik merupakan mangsa utama dalam revolusi AI. Penggunaan kandungan yang dijana AI tanpa pengisytiharan yang telus dianggap sebagai satu bentuk penipuan akademik yang melanggar integriti akademik secara langsung. Pada tahun 2024, Turnitin telah mengeluarkan laporan yang menunjukkan lebih daripada 22 juta tugas pelajar di seluruh dunia dikenal pasti mengandungi elemen penulisan yang dihasilkan melalui perisian AI (Pusat Jaminan Kualiti UPM, 2026). Laporan ini menjadi bukti jelas bahawa penggunaan AI semakin berleluasa dalam bidang akademik, sekali gus menimbulkan persoalan tentang kesahihan dan keaslian hasil kerja pelajar yang memaksa institusi untuk mengambil tindakan disiplin yang lebih tegas.

- **Halusinasi dan Ketidaktepatan Data**

Menurut Tim Keary (2024), Pakar Teknologi di Techopedia, halusinasi AI adalah keadaan di mana model bahasa besar (LLM) seperti GPT-4 daripada OpenAI atau PaLM daripada Google mereka-reka maklumat palsu atau fakta yang tidak berasaskan data atau peristiwa sebenar. AI sering kali memberikan rujukan daripada artikel yang tidak wujud atau petikan yang salah, jika tidak disemak silang oleh pelajar, sudah pasti ia akan merosakkan kualiti ilmiah sesuatu tugasan. Pelajar yang kurang mahir sering kali menerima output AI secara bulat-bulat, membawa kepada penyebaran maklumat yang salah dalam kerja kursus mereka.

- **Domain kesejahteraan psikososial**

Kesan penggunaan AI dalam penyiapan tugas turut melangkaui aspek akademik dan memasuki domain kesejahteraan psikososial. Pada dasarnya, AI bertujuan untuk mengurangkan beban kerja, tetapi AI mencetuskan bentuk tekanan baharu yang dikenali sebagai *technostress* (Klimova & Pikhart, 2025). Pelajar merasa tertekan untuk menghasilkan tugas yang setanding dengan kesempurnaan output AI, dalam masa yang sama bimbang dituduh melanggar integriti akademik walaupun AI digunakan untuk tujuan yang sah (Al-kumaim et al., 2025). Salah satu impak yang paling membimbangkan adalah pengurangan interaksi bersemuka antara pelajar dan pendidik. Laporan menunjukkan bahawa penggunaan AI dalam kelas membuatkan pelajar berasa kurang terhubung dengan guru mereka, di mana mesin mula mengambil alih peranan sebagai pemberi maklum balas utama (Vilcarino & Langreo, 2025). Pelajar yang menghabiskan masa yang lama berinteraksi dengan skrin untuk menyiapkan tugas dengan bantuan AI lebih berisiko mengalami keletihan digital dan pengasingan diri daripada dunia nyata.

## **Kesimpulan**

Penggunaan AI oleh pelajar dalam menyiapkan tugas adalah satu realiti yang tidak boleh dihindari dalam era digital kini. AI menawarkan peluang transformatif untuk meningkatkan kecekapan, mengoptimimumkan ruang pembelajaran sendiri dan merapatkan jurang literasi secara global. Tidak dapat dinafikan, melalui sokongan AI, pelajar dapat menumpukan lebih banyak masa kepada pemikiran kritis, kreativiti, dan refleksi mendalam terhadap tugas mereka, sekali gus menjadikan proses pembelajaran lebih inklusif, efisien, dan berdaya saing dalam menghadapi cabaran pendidikan abad ke-21. Namun, manfaat ini hadir dengan harga yang tinggi jika tidak diuruskan dengan bijak. Risiko kemahiran berfikir kritis pelajar yang semakin terhakis, krisis integriti akademik dan isu kesejahteraan psikososial perlu ditangani dengan bijak oleh semua pihak demi menjamin kesejahteraan ekosistem akademik secara keseluruhan. Oleh itu, institusi pendidikan perlu merangka garis panduan etika yang adil dan seimbang bagi pihak pelajar dan pendidik, melaksanakan mekanisme pengesanan plagiarisme

dengan lebih cekap berkesan, dan paling penting mendidik pelajar tentang penggunaan AI secara bertanggungjawab dan berhemah. Kesimpulannya, AI harus dilihat sebagai alat sokongan yang transformatif, bukan pengganti usaha intelektual demi memastikan kesejahteraan ekosistem akademik dan pembentukan modal insan yang lebih seimbang.

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# A STATISTICAL INVESTIGATION OF AI TOOLS' ACCURACY IN SOLVING ALGEBRA, CALCULUS, AND STATISTICS PROBLEMS: COMPARATIVE ANALYSIS OF CHATGPT AND GEMINI

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## ABSTRACT

*This study presents a descriptive comparative investigation of the mathematical accuracy of two widely used large language model (LLM) tools, ChatGPT and Gemini, across three core domains: Algebra, Calculus, and Statistics. The increasing adoption of generative AI in higher education has raised concerns about the reliability of AI-generated mathematical solutions, particularly when outputs appear coherent but contain hidden reasoning gaps. To examine domain-specific performance, both tools were tested using an identical prompt protocol, and only first responses were recorded to reflect typical student usage. Accuracy was evaluated using final-answer correctness and summarized using descriptive statistics, reported as percentage of correct solutions by domain. Results indicate that both tools achieved consistently high accuracy across all domains, exceeding 88%. ChatGPT demonstrated higher accuracy in Algebra (97.22%) compared to Gemini (91.67%), suggesting stronger performance on symbolic manipulation and structured equation-based tasks. In contrast, Gemini achieved perfect accuracy in both Calculus and Statistics (100% each), outperforming ChatGPT in those domains (88.89% and 94.44%, respectively). These findings indicate that LLM effectiveness in mathematics is domain-dependent rather than uniform, with each system exhibiting distinct strengths. Overall, the study suggests that AI tools can serve as useful computational assistants in mathematics learning and practice, but domain sensitivity implies that outputs should be interpreted cautiously and verified, especially in formal assessment contexts. Future work should expand the problem set, incorporate step-validity scoring, and evaluate performance under reworded and out-of-distribution problem conditions to better assess reasoning robustness.*

**Keywords :** ChatGPT, Gemini, AI, Large Language Models, Mathematical Accuracy.

## 1.0 Introduction

The rise of Artificial Intelligence (AI) has revolutionized many fields, including education, where AI-driven systems such as ChatGPT and Gemini are becoming essential tools for students and educators alike. With the increasing integration of these systems into learning environments, it is crucial to evaluate their mathematical accuracy and reasoning capabilities. This study aims to provide a comparative analysis of two leading AI models ChatGPT and Gemini across three mathematical domains: Algebra, Calculus, and Statistics.

The purpose of this research is to assess the mathematical performance of these AI systems by evaluating their accuracy in solving university-level mathematics questions. By comparing the

performance of ChatGPT and Gemini, the study seeks to identify strengths and weaknesses in each model, as well as to understand how AI tools perform across different mathematical domains. Given that mathematics involves both procedural tasks and reasoning-based problem-solving, examining how these AI systems handle multi-step reasoning challenges is particularly important.

This paper is structured as follows: Section 3 outlines the methodology employed in this study, Section 4 presents the results and analysis, and Section 5 discusses the implications of the findings for educational use. Through this comparative analysis, the study contributes to a growing body of literature on the efficacy of AI in mathematics education and aims to provide insight into the limitations and potential applications of these models

## **2.0 Literature Review**

The integration of AI in education has grown significantly over the past decade, particularly with the introduction of large language models (LLMs) such as OpenAI's GPT series and Google DeepMind's Gemini models. These models are trained on vast datasets and are capable of performing tasks that range from simple computational problems to complex reasoning exercises. However, while these tools demonstrate impressive capabilities, their performance in mathematics remains a topic of ongoing research (Duan et al., 2025; Jahin et al., 2025).

Previous studies have highlighted the strengths and limitations of LLMs in mathematical problem-solving. For instance, Brown et al. (2020) demonstrated that GPT-based models excel in symbolic manipulation tasks, such as solving algebraic equations and performing basic arithmetic. Their ability to perform step-by-step transformations in well-structured algebraic problems is often seen as a significant advantage. On the other hand, Lin et al. (2022) cautioned that LLMs tend to struggle with tasks requiring deep logical reasoning or those that deviate from typical patterns seen during training. This limitation can lead to errors in more complex areas, such as calculus and statistics, where multi-step reasoning and formula-based application are essential.

Further research by Boye and Moëll (2025) and Edwards (2025) explored how LLMs, despite generating correct final answers, can still exhibit reasoning flaws that undermine the validity of intermediate steps. This is particularly evident in tasks that require nuanced deductive processes or reasoning through unfamiliar problem types. Given this, it becomes essential not only to evaluate the final accuracy but also to investigate whether the underlying logical steps are valid.

Gemini, a newer AI model from Google DeepMind, has been positioned as a competitor to GPT-based systems. Preliminary findings suggest that Gemini models exhibit superior performance in domains that require procedural accuracy, such as calculus and statistics (DesignTalks, 2024). The

model's ability to maintain consistency in solving integration and differentiation problems aligns with its design, which emphasizes computational proficiency and accuracy. However, questions remain regarding Gemini's handling of more complex, multi-step problems in algebraic reasoning (Jahin et al., 2025).

Given these findings, this study seeks to bridge the gap in existing literature by providing a direct comparison of ChatGPT and Gemini in terms of their mathematical accuracy across algebra, calculus, and statistics. It aims to clarify the strengths and weaknesses of each model and to explore how task-specific characteristics, such as the need for procedural versus symbolic reasoning, influence AI performance.

### **3.0 Methodology**

This study employed a quantitative descriptive comparative design to evaluate and compare the mathematical accuracy of ChatGPT and Gemini across three domains: Algebra, Calculus, and Statistics. The methodological structure was aligned with the performance outcomes presented in Figure 1, where comparison is based on domain-level percentage accuracy. The main purpose was to describe observable performance differences between the two AI systems rather than to generalize statistically beyond the tested dataset.

#### **3.1 Research Design**

A cross-sectional task-based evaluation was conducted. Both AI tools were tested using the same set of mathematics questions under standardized conditions. This approach reflects common benchmarking strategies used in LLM evaluation, where models are compared by performance across subject categories to identify domain-specific strengths and weaknesses (Duan et al., 2025; Jahin et al., 2025). The decision to separate Algebra, Calculus, and Statistics was motivated by evidence that LLM mathematical performance is not uniform and often varies depending on task structure and reasoning requirements (Lin et al., 2022; John, 2025).

A structured set of university-level questions was developed to represent the three domains. Algebra questions emphasized symbolic manipulation and multi-step transformations, calculus questions emphasized procedural application of differentiation and integration rules, and statistics questions emphasized probability and computational statistics. The problem set intentionally included multi-step items to ensure that the tools were evaluated on tasks requiring sequential reasoning rather than only single-step computation. This decision is consistent with recent literature noting that multi-step mathematical reasoning is a common failure point for LLMs even when outputs appear fluent and confident (Boye & Moëll, 2025; Edwards, 2025).

### 3.2 Data Collection Procedure

Each question was entered into ChatGPT and Gemini using identical prompt wording to reduce prompt-induced bias. Only the first response produced by each tool was recorded, and no follow-up prompts, hints, or iterative corrections were provided. This procedure was chosen to mirror typical student usage, where users frequently rely on the first generated output and may not systematically verify intermediate reasoning steps (Urban et al., 2024). All AI outputs were saved verbatim and compared against verified answer keys prepared before testing.

Performance was evaluated using final-answer correctness only. Each response was coded as correct (1) or incorrect (0) based on agreement with the validated solution. For each tool, the total number of correct responses was computed within each domain and converted into percentage accuracy, which forms the basis of the comparative results displayed in Figure 1. Accuracy-percentage reporting is widely used in mathematical AI benchmarking because it provides a direct, transparent summary of observed performance across categories (Duan et al., 2025; Jahin et al., 2025).

### 3.3 Data Analysis

The study used descriptive statistics. Results were summarized using frequencies of correct versus incorrect responses and percentage accuracy by domain for each AI tool. Domain-level summaries were then presented visually to highlight performance differences across Algebra, Calculus, and Statistics. No inferential statistical tests were conducted because the goal was to describe tool performance within the collected dataset rather than to estimate population parameters.

This methodology was designed to capture domain-dependent performance variation, consistent with findings that LLMs may succeed in well-structured procedural tasks but show instability when reasoning demands increase or when problems deviate from learned patterns (Lin et al., 2022; John, 2025). By applying standardized prompts and reporting domain-specific accuracy descriptively, the study provides a clear comparison of how ChatGPT and Gemini perform across distinct mathematical disciplines, while remaining aligned with established LLM benchmarking approaches (Duan et al., 2025; Jahin et al., 2025).

#### 4.0 Results & Discussion

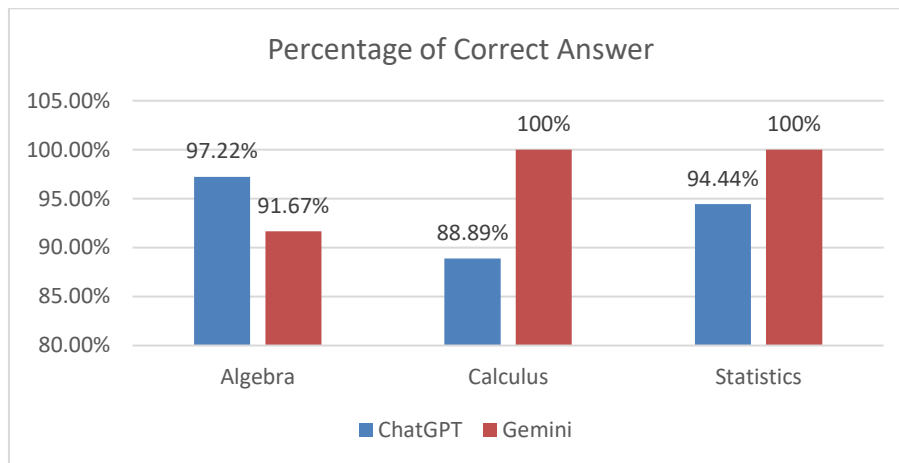


Figure 1: Comparative accuracy rates of ChatGPT and Gemini across three mathematical domains.

Figure 1 presents the percentage of correct answers obtained by ChatGPT and Gemini across three mathematical domains: Algebra, Calculus, and Statistics. Overall, both models demonstrate high levels of accuracy, exceeding 88% in all domains. However, clear domain-specific performance differences are observed.

In Algebra, ChatGPT achieved an accuracy rate of 97.22%, outperforming Gemini, which recorded 91.67%. This finding is consistent with prior evaluations indicating that GPT-based models perform strongly in structured symbolic tasks that involve rule-based transformations and equation manipulation (Brown et al., 2020; Jahin et al., 2025). Algebra problems often follow recognizable procedural patterns, and LLMs trained on large mathematical corpora tend to generalize well in such contexts. Duan et al. (2025) similarly reported that GPT-series models exhibit stable performance in symbolic and structured reasoning tasks when intermediate steps align with common transformation patterns. The higher algebra accuracy observed for ChatGPT in this study therefore aligns with existing empirical evidence suggesting relative strength in structured symbolic domains.

In contrast, Gemini demonstrated superior performance in Calculus and Statistics, achieving 100% accuracy in both domains, while ChatGPT obtained 88.89% in Calculus and 94.44% in Statistics. The substantial gap in Calculus, exceeding 11 percentage points, suggests stronger procedural consistency by Gemini in this dataset. This observation is supported by comparative benchmark studies showing that Gemini models perform competitively in computation-heavy tasks and structured reasoning benchmarks (DesignTalks, 2024; Jahin et al., 2025). Procedural calculus tasks such as differentiation and integration often require the correct application of standard formulas, and LLMs can achieve high accuracy when problem-solving pathways are well-defined (Duan et al., 2025). Gemini's

perfect accuracy in Statistics also aligns with findings that some models exhibit strong performance in numerical and formula-based computations under controlled problem conditions (Jahin et al., 2025).

Despite the high correctness rates, previous research cautions that final answer accuracy does not necessarily guarantee logically valid intermediate reasoning. Boye and Moëll (2025) demonstrated that large language models may arrive at correct mathematical answers while still containing subtle logical inconsistencies in step-by-step explanations. Similarly, Edwards (2025) highlights that simulated reasoning models can produce outputs that appear coherent yet fail to reflect genuine deductive processes. Therefore, while Gemini achieved 100% correctness in Calculus and Statistics in this study, such results should be interpreted within the broader context of known reasoning limitations in LLMs.

The domain-specific variation observed in Figure 1 supports the broader conclusion that LLM mathematical performance is context-dependent rather than uniformly robust. Lin et al. (2022) argue that language models optimize probabilistic token prediction rather than formal logical reasoning, which can lead to variability across domains. John (2025) further emphasizes that LLMs often display surface-level accuracy that deteriorates when problem structures deviate from familiar training distributions. The differences between ChatGPT and Gemini across Algebra, Calculus, and Statistics in this study reinforce the argument that model effectiveness depends heavily on task structure and problem type.

From an educational perspective, the consistently high accuracy levels may create a perception of reliability, potentially encouraging overreliance among students. Urban et al. (2024) found that students frequently accept AI-generated solutions without verifying intermediate steps, while Ateeq et al. (2024) warn that such dependence can undermine critical thinking and academic integrity. Given that both models achieved high percentages across domains, educators must emphasize validation of reasoning processes rather than sole reliance on final answers.

Based on the findings, the results demonstrate that both ChatGPT and Gemini exhibit strong mathematical performance, yet their strengths differ by domain. ChatGPT shows relatively stronger performance in Algebra, consistent with prior findings on symbolic reasoning capabilities. Gemini demonstrates superior performance in Calculus and Statistics within this dataset, aligning with benchmark studies reporting competitive performance in procedural and computation-heavy tasks. These findings support the growing body of literature indicating that LLM performance in mathematics is domain-sensitive and should be interpreted with careful attention to reasoning validity rather than final answer correctness alone.

## 5.0 Conclusion

This study examined the comparative accuracy of ChatGPT and Gemini in solving mathematical problems across three core domains: Algebra, Calculus, and Statistics. Using a descriptive quantitative approach, the findings show that both AI systems achieved consistently high accuracy, exceeding 88% in all tested domains. This outcome indicates that contemporary large language models can perform effectively on structured university-level mathematics tasks. The results also demonstrate clear domain-specific variation. ChatGPT performed more accurately in Algebra, suggesting relative strength in symbolic manipulation and structured transformation tasks. Gemini, in contrast, achieved perfect accuracy in Calculus and Statistics within the tested dataset, indicating strong consistency in procedural and formula-based computation. This domain-sensitive pattern aligns with prior evaluations reporting that LLM performance differs depending on task structure and the extent of multi-step procedural demands (Duan et al., 2025; Jahin et al., 2025).

However, high final-answer correctness should not be interpreted as proof of robust mathematical reasoning. The literature consistently cautions that LLMs may generate correct answers while still exhibiting hidden logical gaps, incomplete justifications, or unstable intermediate reasoning (Boye & Moëll, 2025; Edwards, 2025). Because LLM outputs are generated probabilistically, reliability may decline when problems are reworded or when the task deviates from familiar patterns (Lin et al., 2022; John, 2025). From an educational standpoint, these findings suggest that ChatGPT and Gemini can serve as useful computational assistants and learning supports, but they should not replace independent reasoning and verification. High apparent accuracy may encourage overreliance and reduce students' attention to validating solution logic, which can weaken conceptual learning and raise integrity concerns (Urban et al., 2024; Ateeq et al., 2024).

Taken together, the findings demonstrate that both ChatGPT and Gemini exhibit strong mathematical problem-solving capability, although their performance differs across domains. Future research should expand the number and difficulty of problems, include proof-oriented questions, and evaluate step-level validity to provide a deeper assessment of whether accuracy reflects genuine reasoning or surface-level pattern matching.

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# CHATGPT AS AN AI TUTOR IN LEARNING ENVIRONMENTS

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## ABSTRACT

*The integration of artificial intelligence (AI) in education has transformed how students access information, engage with content, and receive instructional support. Among AI tools, ChatGPT, a conversational large language model, has emerged as a promising AI tutor capable of providing personalized guidance, adaptive feedback, and interactive explanations tailored to students' learning needs. This paper examines the role of ChatGPT in supporting self-regulated learning and enhancing student engagement across diverse learning environments, including face-to-face, blended, and online contexts. While ChatGPT offers immediacy, scalability, and accessibility, its integration raises pedagogical and ethical challenges, including potential overreliance, misconceptions from AI-generated responses, and academic integrity concerns. An illustrative example from a MAT183 assessment demonstrates how students may use ChatGPT to obtain correct answers while diverging from prescribed instructional methods, highlighting both its potential and limitations. The study concludes that ChatGPT is most effective when implemented within a balanced, hybrid model, complementing human educators' guidance, fostering critical thinking, and supporting inclusive and meaningful learning experiences.*

**Keywords:** *Artificial Intelligence (AI), ChatGPT, AI Tutor, learning environments, mathematics*

## Introduction

The increasing integration of artificial intelligence (AI) into education has transformed how students access information, engage with content, and receive instructional support. Across various learning environments, including face-to-face classrooms, blended settings, and fully online platforms, educators are seeking innovative approaches to address student diversity and enhance learning effectiveness. Despite advances in educational technology, many learning environments continue to rely on uniform instructional methods that offer limited responsiveness to student's needs.

AI-based tutoring systems have emerged as a promising solution to support personalized learning by providing adaptive guidance, feedback, and explanations tailored to students' interactions. Among these systems, ChatGPT, a conversational AI powered by a large language model, has gained widespread attention for its ability to engage students through natural language interaction. ChatGPT enables students to ask questions, request clarification, and explore concepts in a dialogic manner, resembling aspects of one-to-one tutoring. For instance, if a student is having difficulty comprehending a particular mathematical concept, they could use the model to generate practice problems tailored to

their level of proficiency (Antonio Flores Limo et al., n.d., 2023). Hence, ChatGPT could be especially advantageous for individuals with learning disabilities, language barriers, and non-native speakers, providing them with a more accessible and personalized learning experience (Graefen & Fazal, 2025).

In learning environments, ChatGPT is increasingly used by students as a supplementary learning tool to support understanding during and beyond formal instruction. Its capacity to generate explanations at varying levels of complexity allows students to revisit concepts at their own pace and according to their individual learning preferences. As such, ChatGPT has the potential to function as an AI tutor that supports self-regulated learning, reinforces instructional content, and enhances student engagement. According to (Alshahrani & Qureshi, 2024), the successful integration of ChatGPT with interactive educational platforms represents a significant milestone in the field of education. Additionally, the integration of Chat GPT with virtual tools, such as a histology slide application, could provide real-time learning opportunities (Graefen & Fazal, 2025).

However, the integration of ChatGPT as an AI tutor also raises important pedagogical considerations. While AI tutors offer immediacy, scalability, and flexibility, they do not possess the pedagogical judgment, emotional awareness, or contextual understanding inherent to human educators. From the educators' viewpoint, the study goes beyond assessing ChatGPT's pros and cons by identifying the institutional training necessary for its effective integration into teaching. The effectiveness of ChatGPT as an AI tutor therefore depends on how it is positioned within learning environments and how its use is aligned with instructional goals and educator guidance.

AI tutors may reduce students' ability to think critically, solve problems independently, or engage in productive struggle because students frequently used ChatGPT to seek direct answers to multiple-choice questions (MCQs), answers of which cannot be found on the Internet (Durgungoz & Kharrufa, 2025). When students rely on AI for answers rather than reasoning processes, learning depth may be compromised. Besides that, AI tutors may generate incorrect, incomplete, or contextually inappropriate responses. Without proper guidance, students may accept AI-generated information uncritically, leading to misconceptions. Other than that, for ethical and academic integrity concerns, the use of AI tutors can raise issues related to plagiarism, originality, and academic honesty. Students may use AI to complete assignments rather than as a learning aid. Thus, as AI grows, teachers will need to develop emotional intelligence, information literacy, and higher-order thinking skills, all of which require professional training and lifelong learning to effectively implement personal learning environments according (Xu et al., 2023).

**An example demonstrating how ChatGPT is utilized as a tutor in student assessment activities**

Figure 1 presents the suggested answer scheme for the MAT183 assessment. In this assessment, students were explicitly taught to apply the chain rule method when solving related rates questions. The use of the chain rule method is emphasized as the correct problem-solving approach, and full marks are given to students who apply this method accurately in their solutions.

**PART A: Solving Analytically**  
 This section evaluates conceptual understanding, strategies, and manual calculations.

**QUESTION 1: Related Rates**

A conical container has a height of 0.5m and a base radius of 0.25m. Liquid flows out of the container at a rate of  $0.045 \text{ m}^3 \text{ min}^{-1}$ . Find the rate at which the height of the liquid is decreasing when the radius of the liquid is 15cm.

$\frac{dV}{dt} = -0.045 \text{ m}^3/\text{min}$ $\frac{r}{h} = \frac{0.25}{0.50} \quad \text{M1}$ $r = 0.5h$ $V = \frac{\pi}{3} (0.5h)^2 h$ $= \frac{0.25}{3} \pi h^3$ $\frac{dV}{dh} = 0.25\pi h^2 \quad \text{M1:differentiation}$ $\frac{dh}{dV} = \frac{1}{0.25\pi h^2} \quad \text{A1}$ $r = 0.15\text{m}$ $0.15 = 0.5h \quad \text{M1}$ $h = 0.3\text{m}$ $\frac{dh}{dt} = \frac{dh}{dV} \times \frac{dV}{dt} \quad \text{M1: chain rule}$ $= \frac{1}{0.25\pi (0.3)^2} \times -0.045 \quad \text{M2}$ $= -0.6366 \text{ m/min} \quad \text{A1}$	<p><b>8 marks</b></p>
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Figure 1: Suggested answer schemed of Assessment MAT183

Figure 2 shows a student’s solution to the related rates question. The student may have received assistance from ChatGPT, as the solution does not employ the chain rule method, which was the prescribed approach for solving this question. Instead, the student applied the implicit differentiation method to obtain the result. Although the final answer is consistent with the suggested answer scheme, the solution does not follow the method emphasized during instruction. Therefore, the student would not be awarded full marks for this question, as the assessment criteria require the correct use of the chain rule method.

**PART A: Solving Analytically**  
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**QUESTION 1: Related Rates**  
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**SOLUTION**

$H=0.5\text{m}$   $R=0.25\text{m}$   
 $\frac{dV}{dt} = -0.045 \text{ m}^3\text{min}^{-1}$   
 $\frac{R}{H} = \frac{0.25}{0.5} = \frac{1}{2}$   
 $r = \frac{1}{2}h$   
 $V = \frac{1}{3}\pi r^2 h$   
 $V = \frac{1}{3}\pi \left(\frac{1}{2}h\right)^2 h$   
 $V = \frac{1}{12}\pi h^3$   
 $\frac{dV}{dt} = \frac{1}{12}\pi(3h^2) \frac{dh}{dt}$

$\frac{dV}{dt} = \frac{1}{4}\pi h^2 \frac{dh}{dt}$   
 $r = 15 \text{ cm} = 0.15\text{m}$   
 $0.15 = \frac{1}{2}h$   
 $h = 0.3\text{m}$   
 $-0.045 = \frac{1}{4}\pi(0.3)^2 \frac{dh}{dt}$   
 $-0.045 = 0.0707 \frac{dh}{dt}$   
 $\frac{dh}{dt} = -0.637$

7

Figure 2: Student's solution

Although the student obtained the correct final answer, the solution diverged from the method emphasized during instruction. This suggests that while AI tutors like ChatGPT can support conceptual understanding, they may also encourage alternative problem-solving approaches that do not fully align with the lecturer's teaching. From a mathematical standpoint, the student demonstrated an understanding of the underlying relationships by applying implicit differentiation, which is a valid and logically sound method. However, from an instructional perspective, the assessment was designed not only to evaluate the correctness of the final answer but also to measure the student's ability to apply the specific method which is Chain Rule method. Hence, the student may not receive full marks despite arriving at the correct solution, which could affect overall academic performance and perceived achievement. However, the effect is not entirely negative. Exposure to alternative solution strategies may also enhance mathematical flexibility and adaptive thinking, which are valuable higher-order skills. The key issue is not the alternative method itself, but whether the student understands when and why a specific method is required.

## Conclusion

As a conclusion, ChatGPT represents both a significant opportunity and a substantial challenge for the education sector. Its capacity to provide instant feedback, personalized explanations, and adaptive support positions it as a powerful supplementary tool within contemporary learning environments. As an AI tutor, ChatGPT can enhance student engagement, promote self-regulated learning, and offer additional academic assistance beyond classroom hours. These features are particularly valuable in addressing diverse learner needs and supporting students who require flexible or individualized learning pathways. However, the integration of ChatGPT into education must be approached with careful pedagogical consideration. While AI can facilitate conceptual understanding and expose students to multiple problem-solving strategies, it may also create misalignment with instructional objectives if not properly guided. As illustrated in the assessment example, students may arrive at correct answers using alternative methods that diverge from those emphasized during instruction. Such situations highlight the importance of maintaining alignment between learning outcomes, teaching strategies, and assessment criteria. Furthermore, concerns regarding overreliance, reduced critical thinking, and academic integrity underscore the need for structured and responsible AI use. Ultimately, the effective implementation of ChatGPT as an AI tutor depends on a balanced, hybrid approach that leverages the strengths of AI while preserving the pedagogical oversight of educators.

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## GAYA PEMBELAJARAN PELAJAR PRA-DIPLOMA SAINS DALAM MATEMATIK BERDASARKAN MODEL VARK

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### ABSTRAK

*Kajian ini bertujuan untuk mengenal pasti gaya pembelajaran pelajar Pra-Diploma Sains dalam subjek Matematik berdasarkan Model VARK (Visual, Auditory, Read/Write dan Kinesthetic). Selain itu, kajian ini juga meneliti kecenderungan pelajar terhadap gaya pembelajaran unimodal atau multimodal serta pola umum skor VARK dalam kalangan pelajar. Reka bentuk kajian kuantitatif deskriptif digunakan dengan melibatkan seramai 30 orang pelajar Pra-Diploma Sains yang mengikuti kursus Matematik Pertengahan. Data dikumpulkan menggunakan soal selidik Model VARK dan dianalisis menggunakan statistik deskriptif seperti min, sisihan piawai, kekerapan dan peratusan. Ujian kebolehpercayaan instrumen menunjukkan nilai Cronbach's Alpha yang tinggi, iaitu 0.888. Dapatan kajian menunjukkan bahawa majoriti pelajar cenderung kepada gaya pembelajaran unimodal, dengan gaya Visual dan Kinestetik mencatatkan skor purata yang lebih tinggi berbanding gaya lain. Walaupun bilangan pelajar multimodal adalah kecil, kewujudan kumpulan ini menunjukkan kepelbagaian corak pembelajaran dalam kalangan pelajar Pra-Diploma Sains. Secara keseluruhannya, kajian ini memberikan gambaran awal tentang profil dan pola gaya pembelajaran pelajar dalam pembelajaran Matematik, yang boleh dijadikan asas kepada perancangan strategi pengajaran yang lebih pelbagai dan inklusif.*

**Kata kunci:** *Gaya pembelajaran, Model VARK, Pra-Diploma Sains, Matematik, kajian deskriptif*

### Pengenalan

#### *Pengenalan Kajian*

Pembelajaran Matematik di peringkat Pra-Diploma Sains menuntut pelajar untuk menguasai pelbagai konsep asas yang menjadi prasyarat kepada kursus-kursus lanjutan seperti Matematik Pertengahan. Namun, tahap penguasaan pelajar sering dipengaruhi oleh perbezaan cara mereka memproses maklumat dan memahami sesuatu konsep. Dalam konteks ini, gaya pembelajaran memainkan peranan penting dalam menentukan keberkesanan proses pengajaran dan pembelajaran. Mengetahui bagaimana pelajar belajar membantu pensyarah merangka pendekatan yang lebih sistematik, bersasar dan bersesuaian dengan keperluan pelajar. Model VARK (*Visual, Auditory, Read/Write, Kinesthetic*) merupakan salah satu kerangka yang paling banyak digunakan untuk mengenal pasti preferensi gaya pembelajaran pelajar. Model ini membahagikan gaya pembelajaran kepada empat kategori utama berdasarkan cara

pelajar menerima dan memproses maklumat. Kefahaman terhadap corak VARK dalam kalangan pelajar dapat membantu pendidik menyesuaikan strategi pengajaran supaya lebih efektif, seterusnya berpotensi meningkatkan motivasi, penglibatan, dan pencapaian Matematik. Sehubungan itu, kajian ini dijalankan untuk mengenal pasti gaya pembelajaran pelajar Pra-Diploma Sains dalam subjek Matematik berdasarkan Model VARK. Kajian ini memberi tumpuan kepada mengenal pasti kecenderungan gaya pembelajaran pelajar serta pola umum yang wujud dalam konteks pembelajaran Matematik bagi kumpulan sasaran tersebut.

### *Pernyataan Masalah*

Pelajar Pra-Diploma Sains datang daripada latar belakang akademik yang pelbagai dan menunjukkan perbezaan ketara dalam tahap penguasaan Matematik. Pensyarah sering berhadapan cabaran untuk menyesuaikan pendekatan pengajaran kerana tidak semua pelajar memberi tindak balas yang optimum terhadap kaedah pengajaran tradisional seperti kuliah, lembaran kerja, atau penerangan lisan. Walaupun Model VARK telah digunakan secara meluas bagi mengenal pasti gaya pembelajaran, kajian yang memfokuskan kepada corak gaya pembelajaran dalam kalangan pelajar Pra-Diploma Sains, terutamanya berkaitan pembelajaran Matematik adalah masih terhad. Kekurangan maklumat ini menyukarkan usaha untuk membuat penambahbaikan terhadap strategi pengajaran supaya selaras dengan keperluan pelajar. Justeru, kajian ini penting untuk mengenal pasti gaya pembelajaran dominan serta variasi gaya pembelajaran dalam kalangan pelajar, yang seterusnya dapat membantu meningkatkan keberkesanan pengajaran Matematik.

### *Objektif*

- i) Mengetahui gaya pembelajaran pelajar Pra-Diploma Sains dalam subjek Matematik berdasarkan Model VARK.
- ii) Menentukan sama ada pelajar menunjukkan kecenderungan kepada gaya pembelajaran unimodal atau multimodal.
- iii) Menganalisis pola gaya pembelajaran yang wujud dalam kalangan pelajar yang mengambil subjek Matematik di peringkat Pra-Diploma Sains.

### **Kajian Literatur**

Model VARK (*Visual, Auditory, Read/Write, Kinesthetic*) merupakan salah satu pendekatan yang paling banyak digunakan untuk memahami preferensi gaya pembelajaran pelajar. Model ini membahagikan cara pelajar menerima dan memproses maklumat kepada empat modaliti utama, iaitu visual, auditori, membaca/menulis dan kinestetik. Pendekatan ini relevan dalam membantu pendidik

merancang strategi pengajaran yang selaras dengan kecenderungan pelajar dalam memberi respons terhadap tugas pembelajaran.

Kajian terdahulu menunjukkan bahawa penggunaan pendekatan berasaskan VARK berpotensi meningkatkan penglibatan pelajar serta menyokong keberkesanan pengajaran dalam pelbagai konteks pendidikan (Najrul Jimatul Rizki et al., 2024). Selain itu, pembangunan bahan pembelajaran berasaskan VARK turut terbukti praktikal dan memberi manfaat merentasi modaliti, seperti yang dilaporkan dalam pembangunan buku teks tematik (Pungki Elvi Marta et al., 2021) serta bahan bacaan permulaan (Chandra et al., 2018).

Model VARK diperkenalkan oleh Fleming dan Mills (1992) sebagai kerangka untuk mengenal pasti kecenderungan pelajar dalam menerima maklumat melalui empat modaliti utama. Walaupun model ini tidak bertujuan mengkategorikan pelajar secara mutlak, ia menyediakan panduan praktikal kepada pendidik dalam mempelbagaikan pendekatan pengajaran. Fleming (2012) menegaskan bahawa penggunaan strategi pengajaran yang merangkumi pelbagai modaliti dapat membantu meningkatkan kefahaman serta menggalakkan penglibatan pelajar secara aktif dalam proses pembelajaran.

Seiring dengan itu, instrumen VARK telah diaplikasikan dalam pelbagai konteks pendidikan untuk mengelaskan pelajar kepada gaya pembelajaran tertentu. Pelajar yang menunjukkan kecenderungan kuat terhadap satu modaliti dikelaskan sebagai unimodal, manakala mereka yang memberi respons positif terhadap dua atau lebih modaliti dikategorikan sebagai multimodal. Dapatan kajian terdahulu melaporkan bahawa majoriti pelajar dalam banyak konteks pendidikan cenderung kepada gaya visual atau kinestetik, walaupun taburan sebenar bergantung kepada bidang pengajian dan latar pendidikan (Azizah & Widyartono, 2024; Prihaswati & Purnomo, 2021). Pendekatan multimodal turut mendapat sokongan kukuh dalam literatur kerana ia menyediakan variasi kaedah penyampaian yang lebih fleksibel dan sesuai untuk kumpulan pelajar yang heterogen.

Dalam konteks pembelajaran matematik, dapatan kajian menunjukkan bahawa gaya visual-spatial dan kinestetik sering memainkan peranan penting dalam meningkatkan kefahaman konsep, penyelesaian masalah dan keyakinan pelajar. Kajian di peringkat antarabangsa juga melaporkan hubungan antara gaya pembelajaran dan faktor afektif seperti minat serta keresahan matematik, yang seterusnya memberi kesan kepada prestasi pelajar. Oleh itu, memahami gaya pembelajaran pelajar Pra-Diploma Sains amat penting kerana kumpulan ini hadir dengan tahap keupayaan matematik yang berbeza-beza. Pengetahuan tentang taburan gaya pembelajaran mereka dapat membantu pensyarah merancang pendekatan pengajaran dalam kursus seperti Matematik Pertengahan dengan lebih bersasar dan responsif.

## **Metodologi**

Kajian ini menggunakan reka bentuk kuantitatif deskriptif bagi menilai gaya pembelajaran pelajar Pra-Diploma Sains dalam subjek Matematik. Seramai 30 pelajar yang mengikuti kursus Matematik Pertengahan dipilih melalui persampelan bertujuan, kerana mereka telah melengkapkan soal selidik gaya pembelajaran. Kajian ini menggunakan Soal Selidik Model VARK, yang mengandungi sebanyak 20 item bagi empat kategori pembelajaran: visual, auditori, membaca/menulis dan kinestetik. Setiap item dinilai menggunakan skala Likert 1–5, dan skor setiap kategori dijumlahkan untuk menentukan gaya pembelajaran dominan pelajar, sama ada unimodal atau multimodal. Pelajar dikategorikan sebagai unimodal apabila hanya satu dimensi mempunyai skor tertinggi secara mutlak. Sebaliknya, pelajar yang tidak menunjukkan satu skor dominan yang jelas (contohnya skor seri atau hampir seimbang antara dua atau lebih dimensi) diklasifikasikan sebagai multimodal.

Data dianalisis menggunakan statistik deskriptif seperti kekerapan, peratusan, min, dan sisihan piawai untuk menggambarkan corak gaya pembelajaran dalam kalangan pelajar. Analisis kebolehpercayaan (Cronbach's Alpha) dijalankan bagi menilai konsistensi dalaman soal selidik. Hasil analisis ini memberi gambaran jelas tentang taburan gaya pembelajaran dan kecenderungan unimodal atau multimodal pelajar.

### Analisa Kajian

Jadual 1: Statistik Ujian Kebolehpercayaan

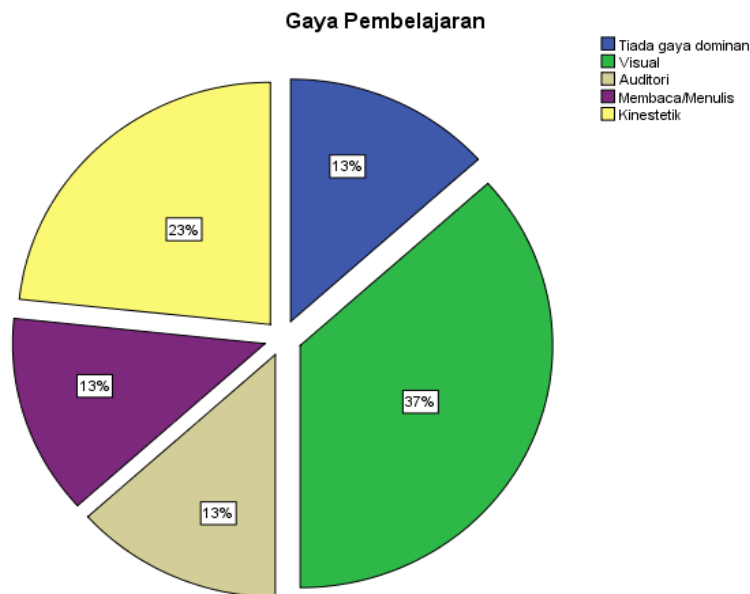
Cronbach's Alpha	Bilangan Item(N)
.888	20

Analisis kebolehpercayaan menggunakan pekali Cronbach's Alpha menunjukkan nilai 0.888 bagi 20 item soal selidik VARK, yang menandakan tahap konsistensi dalaman yang tinggi. Dapatan ini mengesahkan bahawa instrumen yang digunakan adalah sesuai dan boleh dipercayai untuk menilai gaya pembelajaran pelajar Pra-Diploma Sains.

Berdasarkan Rajah 1, majoriti pelajar Pra-Diploma Sains menunjukkan kecenderungan kepada gaya pembelajaran auditori, iaitu sebanyak 37%, menjadikannya gaya pembelajaran paling dominan dalam kalangan responden. Dapatan ini menunjukkan bahawa sebahagian besar pelajar lebih cenderung memahami konsep Matematik melalui penerangan lisan, perbincangan, dan interaksi verbal semasa proses pembelajaran.

Selain itu, 23% pelajar pula didapati mempunyai kecenderungan terhadap gaya pembelajaran kinestetik, yang menekankan pembelajaran melalui aktiviti praktikal dan pengalaman secara langsung. Sementara itu, gaya visual, membaca/menulis, dan kategori tiada gaya dominan masing-masing mencatatkan peratusan yang sama iaitu 13%. Ini menunjukkan bahawa walaupun terdapat kepelbagaian

gaya pembelajaran, kecenderungan terhadap gaya auditori dan kinestetik adalah lebih menonjol dalam konteks pembelajaran Matematik di peringkat Pra-Diploma Sains.



Rajah 1: Taburan Gaya Pembelajaran Pelajar Pra-Diploma Sains Berdasarkan Model VARK

Secara keseluruhan, dapatan ini menggambarkan bahawa pelajar Pra-Diploma Sains tidak bergantung kepada satu gaya pembelajaran yang seragam, sebaliknya mempamerkan pola gaya pembelajaran yang pelbagai. Kepelbagaian ini menyokong keperluan kepada pendekatan pengajaran Matematik yang fleksibel dan pelbagai bagi memenuhi keperluan pembelajaran pelajar yang berbeza.

Jadual 2 : Kecenderungan Gaya Pembelajaran Unimodal dan Multimodal

Kategori Pembelajaran	Bil pelajar (kekerapan)	Peratus (%)
Multimodal	4	13.3
Unimodal	26	86.7
Jumlah	30	100

Berdasarkan Jadual 2, majoriti pelajar Pra-Diploma Sains tergolong dalam kategori unimodal, iaitu seramai 26 orang pelajar (86.7%), manakala hanya 4 orang pelajar (13.3%) dikategorikan sebagai multimodal. Dapatan ini menunjukkan bahawa kebanyakan pelajar cenderung bergantung kepada satu gaya pembelajaran dominan dalam pembelajaran matematik. Walaupun bilangan pelajar multimodal adalah kecil, kewujudan kumpulan ini mencerminkan variasi corak pembelajaran dalam kalangan pelajar. Oleh itu, penggunaan pendekatan pengajaran yang mempelbagaikan kaedah penyampaian masih relevan bagi memenuhi keperluan semua pelajar.

Jadual 3: Statistik Deskriptif Skor VARK Pelajar Pra-Diploma Sains

Statistik	Visual (V)	Auditori (A)	Membaca/Menulis (R)	Kinesthetic (K)
Min	19.00	18.37	18.37	18.90
Median	19.50	19.00	18.00	19.00
Sisihan Piawai	4.49	2.46	3.26	3.89
Minimum	5.00	12.00	8.00	9.00
Maksimum	25.00	23.00	24.00	25.00

Jadual 3 menunjukkan statistik deskriptif skor gaya pembelajaran VARK bagi pelajar Pra-Diploma Sains. Secara keseluruhan, skor purata tertinggi dicatatkan bagi gaya *Visual* (min = 19.00), diikuti oleh kinestatik (min = 18.90). Skor purata bagi gaya auditori dan membaca/menulis adalah lebih rendah, masing-masing dengan min = 18.37. Dapatan ini menunjukkan bahawa pelajar cenderung sedikit ke arah gaya pembelajaran visual dan kinestetik dalam pembelajaran Matematik.

Dari segi variasi skor, gaya visual mencatatkan sisihan piawai tertinggi (SP = 4.49), menunjukkan tahap variasi skor yang lebih besar dalam kalangan pelajar. Sebaliknya, gaya auditory mempunyai sisihan piawai terendah (SP = 2.46), menandakan skor yang lebih konsisten. Julat skor minimum dan maksimum bagi semua komponen berada dalam lingkungan yang munasabah tanpa kehadiran nilai luar jangkaan yang ketara.

## Kesimpulan

Kajian ini telah dapat mengenal pasti gaya pembelajaran pelajar Pra-Diploma Sains dalam subjek Matematik berdasarkan Model VARK serta meneliti kecenderungan unimodal dan multimodal dalam kalangan pelajar. Dapatan menunjukkan bahawa majoriti pelajar mempunyai satu gaya pembelajaran dominan, manakala sebilangan kecil pelajar mempamerkan corak pembelajaran yang lebih seimbang merentasi beberapa modaliti. Dari segi pola skor VARK, gaya visual dan kinestatik didapati sedikit lebih menonjol berbanding gaya auditori dan membaca/menulis, iaitu menunjukkan kecenderungan pelajar terhadap pembelajaran yang melibatkan visualisasi dan aktiviti berasaskan pengalaman.

Walaupun kajian ini bersifat deskriptif dan melibatkan saiz sampel yang terhad, dapatan yang diperoleh memberikan gambaran awal yang penting tentang kepelbagaian gaya pembelajaran dalam kalangan pelajar Pra-Diploma Sains. Penemuan ini mencadangkan bahawa pendekatan pengajaran

matematik yang mempelbagaikan kaedah penyampaian masih relevan bagi memenuhi keperluan pelajar dengan corak pembelajaran yang berbeza. Kajian lanjutan dicadangkan untuk meneliti hubungan antara gaya pembelajaran dan pencapaian akademik atau keberkesanan strategi pengajaran tertentu, bagi memperkukuh pemahaman tentang peranan gaya pembelajaran dalam konteks pendidikan Matematik.

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## HEURISTIC APPROACHES FOR LAST-MILE DELIVERY OPTIMIZATION

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### ABSTRACT

*Last-mile delivery represents the final and most costly segment of the supply chain, accounting for a significant portion of total logistics expenditure. As e-commerce continues to expand globally, the pressure to optimize last-mile operations has intensified. Exact optimization methods, while ensuring optimal solutions, are computationally intractable for large-scale real-world instances. Heuristic approaches offer a practical alternative by producing good quality solutions within acceptable timeframes. This article reviews the principal heuristic methodologies applied to last-mile delivery problems, covering classical construction heuristics, metaheuristics, and hybrid approaches. The review highlights significant algorithmic contributions, discusses their strengths and limitations, and outlines new direction including the integration of machine learning with heuristic. Findings suggest that heuristics remain essential tools for practitioners and researchers seeking efficient, scalable delivery route planning.*

**Keywords:** last-mile delivery, heuristics, vehicle routing problem, metaheuristics, logistics optimization

### 1. Introduction

The last mile of the supply chain, referring to the movement of goods from a distribution hub to the final customer, is widely recognized as the most complex and expensive phase of the delivery process. Studies consistently estimate that last-mile logistics accounts for between 41% and 53% of total supply chain costs (Savelsbergh & Van Woensel, 2016). The explosive growth of e-commerce, accelerated by the COVID-19 pandemic, has amplified demand for fast, reliable, and cost-effective home delivery, making the optimization of last-mile operations a critical competitive priority for logistics companies worldwide.

At the heart of last-mile optimization lies the Vehicle Routing Problem (VRP) and its many variants. The VRP seeks to determine optimal routes for a fleet of vehicles to service a set of geographically dispersed customers subject to various constraints, such as vehicle capacity, time windows, and driver working hours. The VRP is NP-hard in the classical sense (Lenstra & Rinnooy Kan, 1981), meaning that exact algorithms such as branch-and-bound or dynamic programming quickly become computationally prohibitive as problem size grows. In real-world urban delivery scenarios involving hundreds or thousands of stops, exact methods are generally impractical.

Heuristic algorithms have therefore emerged as the dominant solution methodology for large-scale last-mile routing. Unlike exact methods, heuristics do not guarantee optimality but are designed to find high-quality solutions quickly. This makes them well-suited to the time-sensitive, large-scale nature of operational logistics planning. This article provides a comprehensive review of heuristic approaches applied to last-mile delivery, covering classical construction and improvement heuristics, population-based metaheuristics, and hybrid strategies. The article is organized as follows: Section 2 provides background on the problem landscape; Section 3 reviews classical heuristics; Section 4 discusses metaheuristics; Section 5 studies hybrid and adaptive approaches; Section 6 discusses emerging directions; and Section 7 conclusion.

## **2. The Last-Mile Delivery Problem**

The generic VRP, first formulated by Dantzig and Ramser (1959), has since produced several extensions to reflect real-world constraints. The Capacitated VRP (CVRP) considers vehicle load limits, while the VRP with Time Windows (VRPTW) requires customers to be served within specified time intervals. The Split Delivery VRP (SDVRP) allows a customer to be served by more than one vehicle, and the Multi-Depot VRP (MDVRP) considers fleets operating from multiple warehouses. More recently, variants addressing stochastic demand, dynamic customer requests, and electric vehicles have gained prominence (Braekers et al., 2016). A comprehensive review by Asghari and Mirzapour Al-E-Hashem (2021) further documents the rapid expansion of the Green VRP literature, highlighting the growing importance of sustainability objectives.

Last-mile delivery introduces additional real-world complexities beyond the classical VRP framework. Urban traffic congestion creates dynamic and uncertain travel times, customer availability constraints result in failed delivery attempts, and the increasing prevalence of same-day and on-demand delivery compresses planning horizons. Sustainability pressures require minimizing carbon emissions alongside distance and cost, while the rise of crowd-sourced delivery platforms introduces new workforce management considerations (Perboli et al., 2018). A wide-ranging review by Giuffrida et al. (2022) confirms that these complexities collectively demand solution methods that are not only computationally efficient but also flexible and robust.

## **3. Classical Heuristics**

### **3.1 Construction Heuristics**

Construction heuristics build a solution from scratch by iteratively adding customers to routes according to simple, greedy criteria. The Nearest Neighbor heuristic, one of the earliest and most intuitive methods, starts from the depot and repeatedly visits the closest unrouted customer until all customers

are served (Rosenkrantz et al., 1977). While computationally fast, running in  $O(n^2)$  time, it often produces solutions 20 to 25% above optimal due to its myopic nature.

The Clarke and Wright Savings Algorithm (1964) is arguably the most influential classical heuristic for the VRP. It begins with a solution in which each customer is served by a dedicated vehicle and iteratively merges routes based on the 'savings' achieved by combining two routes into one. The savings value for combining routes visiting customers  $i$  and  $j$  is computed as  $S_{ij} = c_{0i} + c_{0j} - c_{ij}$ , where  $c$  denotes travel cost and  $0$  denotes the depot. Routes with the highest savings are merged first, subject to capacity constraints. The savings algorithm is both simple to implement and produces solutions of reasonable quality, making it a popular choice for practitioners.

Insertion heuristics offer another family of construction methods. The cheapest insertion approach identifies the customer and position whose addition to an existing route incurs the smallest cost increase. Regret-based insertion variants, such as those used in the Large Neighborhood Search framework, prioritize customers whose exclusion from their best insertion position would be most costly, leading to improved solution quality (Ropke & Pisinger, 2006). A data-informed insertion heuristic specifically adapted for real-world last-mile sequencing was proposed by Özarık et al. (2024), representing that learning from historical route data can meaningfully improve construction quality.

### 3.2 Improvement Heuristics

Once an initial solution is constructed, improvement heuristics apply local search moves to reduce total cost. The 2-opt algorithm removes two edges from a route and reconnects the resulting segments in a different order, eliminating route crossings (Lin, 1965). The 3-opt extension considers removing three edges simultaneously, exploring a larger neighborhood. Or-opt moves relocate one, two, or three consecutive customers to a different position within the same or a different route, offering a complementary search strategy. These local search procedures are typically iterated until no improving move is found, yielding a local optimum.

The Lin-Kernighan heuristic (Lin & Kernighan, 1973) generalized  $k$ -opt exchanges into a variable-depth search strategy and became the foundation for some of the most powerful TSP solvers. Its VRP adaptation, combined with perturbation mechanisms, remains competitive with state-of-the-art metaheuristics on standard benchmarks.

## 4. Metaheuristics

### 4.1 Simulated Annealing

Simulated Annealing (SA) is a probabilistic local search method inspired by the annealing process in metallurgy (Kirkpatrick et al., 1983). Unlike pure local search, SA accepts worsening solutions with a

probability that decreases over time according to a 'temperature' schedule, allowing the algorithm to escape local optima. SA has been successfully applied to various VRP variants, with studies reporting solutions within 1 to 3% of optimal on standard benchmarks (Osman, 1993). Its main limitation is sensitivity to the cooling schedule, which requires careful parameter tuning.

#### **4.2 Tabu Search**

Tabu Search (TS), introduced by Glover (1986), is a local search metaheuristic that maintains a memory structure, known as the tabu list, to prevent revisiting recently explored solutions. By forbidding certain moves for a fixed number of iterations, TS encourages diversification and escape from local optima. Tabu Search has produced some of the best-known results on VRP benchmarks. The TABUROUTE algorithm by Gendreau et al. (1994) and the unified Tabu Search by Cordeau et al. (2001) are landmark contributions that demonstrated TS could consistently find near-optimal solutions across multiple VRP variants, including the VRPTW and the Periodic VRP. More recently, Sze et al. (2024) proposed an adaptive variable neighborhood search incorporating Tabu Search mechanisms to handle dynamic VRP settings in urban environments.

#### **4.3 Genetic Algorithms and Evolutionary Computation**

Genetic Algorithms (GAs) are population-based metaheuristics inspired by biological evolution. A population of candidate solutions (chromosomes) is evolved through selection, crossover, and mutation operators. For routing problems, specialized crossover operators that preserve route feasibility, such as the Order Crossover (OX) and the Partially Mapped Crossover (PMX), are critical to performance (Potvin & Bengio, 1996). GAs are naturally suited to parallel implementation and can effectively explore diverse regions of the solution space, though they typically converge more slowly than trajectory-based methods like Tabu Search.

Hybrid Genetic Algorithms that embed local search within the evolutionary process, known as memetic algorithms, have achieved outstanding results. The algorithm by Vidal et al. (2012) combines a population-based genetic search with a powerful local search component and has set benchmark records on hundreds of VRP instances. This work emphasizes the importance of tight integration between global exploration and local exploitation in effective metaheuristic design.

#### **4.4 Ant Colony Optimization**

Ant Colony Optimization (ACO) simulates the foraging behaviour of ants, which release pheromone trails on paths leading to food sources (Dorigo & Gambardella, 2002). In the context of routing, pheromone intensities reflect the desirability of including particular edges in a route. Ants probabilistically construct solutions guided by pheromone levels and heuristic information (typically

inverse distance), and pheromone levels are updated based on solution quality. ACO has proven effective for the VRP, particularly in dynamic environments where customer requests arrive in real time and frequent re-optimization is required.

#### **4.5 Large Neighborhood Search**

Large Neighborhood Search (LNS), introduced by Shaw (1998) and extended by Ropke and Pisinger (2006) into the Adaptive LNS (ALNS) framework, operates by repeatedly destroying and repairing portions of a solution. A set of destroy operators (e.g., random removal, worst removal, route elimination) and repair operators (e.g., greedy insertion, regret insertion) are applied adaptively, with operators that have historically performed well receiving higher selection probabilities. ALNS has become one of the most widely adopted frameworks for VRP variants, consistently producing state-of-the-art results due to its flexibility and ease of customization. A recent study by Ammouriova et al. (2022) further extended ALNS-based simheuristics to address uncertainty and dynamic conditions in last-mile scenarios.

### **5. Hybrid and Adaptive Approaches**

Modern heuristic research increasingly focuses on hybrid approaches that combine complementary strategies. Combining population-based methods with local search (memetic algorithms) utilizes global exploration for diversity and local search for intensification. Hybrid methods integrating exact solvers for subproblems within a heuristic framework, known as mathheuristics, have demonstrated the ability to close optimality gaps that pure heuristics cannot (Boschetti et al., 2009). For instance, column generation can be used to re-optimize a subset of routes within a large neighborhood search framework, yielding solutions of exceptional quality on structured problem instances.

Machine learning is increasingly being integrated with heuristic solvers to improve performance. Reinforcement learning agents have been trained to make destroy and repair operator selection decisions in ALNS frameworks, replacing manually designed adaptive weight mechanisms with learned policies (da Costa et al., 2021). Graph neural networks have been applied to predict promising edges for local search moves, reducing the neighborhood search space and improving computational efficiency. In the context of real-world routing, Özarık et al. (2024) presented that a machine-learning framework combining classical TSP heuristics with a trained regression model could prescribe high-quality last-mile delivery sequences without an explicitly defined objective function. These developments suggest that the boundary between classical heuristics and artificial intelligence is becoming increasingly permeable.

Data-driven optimization frameworks have also emerged as a complementary paradigm. Chu et al. (2023) proposed a smart predict-then-optimize approach that integrates machine learning

predictions directly into capacitated VRP solving, improving delivery time accuracy and route efficiency for online food delivery platforms. This line of research demonstrates that combining predictive analytics with heuristic optimization can produce tangible operational gains in dynamic, real-world last-mile settings.

## **6. New Directions and Challenges**

Several emerging trends are reforming the landscape of last-mile delivery optimization. The proliferation of electric vehicles (EVs) introduces range constraints and charging requirements as additional optimization dimensions. Asghari and Mirzapour Al-E-Hashem (2021) provide a comprehensive classification of Green VRP variants, show that metaheuristics and hybrid methods dominate solution approaches for these problems. Dönmez et al. (2022) further studied the mixed fleet VRP with partial recharging by multiple charger types using an adaptive large neighborhood search, illustrating the growing complexity of sustainable routing problems. The Green VRP and its variants seek to minimize energy consumption and emissions alongside traditional objectives (Erdoğan & Miller-Hooks, 2012). Drone and autonomous vehicle delivery introduces new routing topologies and operational constraints that existing heuristics must be adapted to address.

The growth of real-time and dynamic delivery environments, driven by same-day and on-demand delivery services, requires algorithms capable of rapid re-optimization as new orders arrive and traffic conditions evolve. Online heuristics that maintain and update solutions incrementally are gaining attention as practical tools for dynamic dispatch systems. A recent study introducing the Tabu-guided Adaptive Large Neighborhood Search with Rollout-based Real-Time Dispatch (T-ALNS-RRD) framework demonstrates how integrating congestion-penalized cost functions and rollout-based dispatch mechanisms can substantially improve delivery performance under volatile urban traffic conditions (Liu and Wang, 2025). Additionally, multi-objective optimization approaches that explicitly balance economic, environmental, and social objectives are receiving increasing research interest, reflecting the growing importance of sustainable logistics practices (Perboli et al., 2018).

## **7. Conclusion**

Heuristic approaches remain the cornerstone of practical last-mile delivery optimization. From simple construction methods to sophisticated metaheuristics and hybrid matheuristics, the field has produced a rich toolkit of algorithms capable of addressing the diverse and complex routing problems encountered in real-world logistics operations. Classical methods such as the Clarke-Wright savings algorithm and 2-opt local search continue to provide valuable benchmarks and practical starting points, while advanced metaheuristics including Tabu Search, Genetic Algorithms, Ant Colony Optimization, and Adaptive Large Neighborhood Search consistently deliver near-optimal solutions on large-scale

instances. The integration of machine learning with heuristic represents a high potential domain that is likely to provide significant advances in both solution quality and computational efficiency in the coming years. As the demands of modern e-commerce continue to evolve, the development and refinement of heuristic approaches for last-mile delivery will remain a vibrant and practically important area of research.

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# DYNAMICS OF DISCRETIONARY SPENDING: A STATISTICAL LEARNING ANALYSIS OF COFFEE CONSUMPTION AND FOOD EXPENDITURE AMONG MALAYSIAN UNDERGRADUATES

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## ABSTRACT

*As university students navigate escalating living costs, understanding the intersection of lifestyle-driven consumption and financial management is paramount. This study investigates the patterns of monthly food and coffee expenditures among students at Universiti Teknologi MARA Pulau Pinang through a quantitative lens. Utilizing descriptive statistics, confidence interval estimation, and independent samples t-tests, the analysis identifies a mean monthly food expenditure of RM322.60 and a mean coffee expenditure of RM59.78. Despite cultural perceptions of gendered spending, inferential analysis reveals no statistically significant difference in expenditure between male and female students. Furthermore, this research underscores a pedagogical shift by integrating real-world behavioral data into statistical learning, thereby enhancing data literacy and practical reasoning skills among students. These findings provide critical insights for university administrators and financial advisors regarding student economic well-being in an evolving "café culture" environment.*

**Keywords:** *Coffee Consumption, Food Expenditur, Student Lifestyles, Statistical Learning, University Students.*

## 1. Introduction

### 1.1 The Global and Local Context of Coffee Culture

In the contemporary higher education landscape, students navigate a complex balance between academic rigor and the socioeconomic pressures of campus life. Among the most visible discretionary expenses is coffee consumption, which has evolved from a simple dietary habit into a social and academic necessity. Globally, the "third wave" coffee movement has transformed the beverage into a premium commodity, emphasizing origin, artisanal preparation, and the "third place" experience a social environment outside of home and work/study.

In Malaysia, the rise of international coffee chains and a burgeoning local "café culture" has fundamentally shifted consumption patterns among the youth. Current trends indicate that 55.5% of consumers favor branded outlets over traditional options (Ramanathan & Ali, 2021). For students, these

spaces serve as makeshift study halls, social hubs, and productivity zones. Many students adopt the habit of "starting the day" (58.8%) or "boosting energy" (60.0%) during grueling academic schedules (Ramanathan & Ali, 2021).

### *1.2 Socioeconomic Pressures on the Modern Student*

While the culture around coffee grows, so do the financial pressures on Malaysian undergraduates. Many students belong to the B40 (Bottom 40% income group) and M40 (Middle 40%) demographics, relying on PTPTN loans or small scholarships to survive. Recent reports suggest that some Malaysian undergraduates face severe financial constraints, spending less than RM3.00 daily on meals to cope with rising inflation (Rasid et al., 2023).

Against this backdrop, the expenditure on coffee often priced at a premium in specialized outlets—presents a paradox. Is coffee an essential tool for academic survival, or is it a discretionary luxury that strains an already tight food budget? This study seeks to quantify this financial burden by analyzing expenditures at UiTM Pulau Pinang, while simultaneously demonstrating how such behavioral data can be leveraged as a tool for statistical learning in the classroom (Hilliam & Vines, 2021).

## **2. Literature Review**

### *2.1 Psychosocial Drivers of Coffee Consumption*

Prior research indicates that nearly 90% of students consume caffeine to enhance alertness during high-stress periods (Jamal, 2024). However, motivation is not purely physiological. Coffee consumption is deeply tied to social identity. For many, carrying a branded coffee cup is a signal of belonging to a specific modern lifestyle. Research has shown that 60.5% of Malaysian students consume coffee specifically to improve focus during academic tasks, but the "experience" of the café environment is often cited as a secondary motivator (Jamal, 2024; Ramanathan & Ali, 2021).

### *2.2 The Economics of Student Food Habits*

Food spending is typically the largest component of a student's non-tuition expenditure. However, student eating habits are often characterized by "food insecurity" or poor nutritional choices due to budget constraints (Rasid et al., 2023). The "antecedents of food spending" include peer influence, convenience, and proximity to campus facilities. In many cases, students prioritize convenience such as high-caffeine beverages and fast food over long-term financial health (Rasid et al., 2023).

### *2.3 Gender and Spending Behaviors*

Traditional stereotypes often suggest that female students may spend more on lifestyle items, including coffee and aesthetics, while male students might spend more on technology or substantial meals. However, academic studies on gender-based financial behavior in Malaysian universities have yielded mixed results. Some suggest that gender roles in spending are blurring as both male and female students face identical academic pressures and social media influences (Ramanathan & Ali, 2021).

#### *2.4 Statistical Learning in Higher Education*

The pedagogical aspect of this study focuses on "Statistical Learning." Traditional statistics education often relies on sterilized textbook datasets that lack relevance to the student's life. By using data generated from their own spending habits, students engage in "Project-Based Learning," which has been shown to improve attitudes toward data science and enhance retention of complex concepts like p-values and confidence intervals (Cujba & Pifarré, 2024; Hilliam & Vines, 2021).

### **3. Methodology**

#### *3.1 Research Design*

A quantitative, cross-sectional survey design was employed. This approach allowed for the collection of a snapshot of student spending patterns during a typical academic month.

#### *3.2 Participants and Sampling*

The sample consisted of 50 students from Universiti Teknologi MARA Pulau Pinang. A convenience sampling method was used, targeting students across different faculties. The final demographic profile included 9 male (18%) and 41 female (82%) respondents. While the gender ratio is imbalanced, it reflects the actual demographic distribution of many social science and business-related programs in the Malaysian university system.

#### *3.3 Instrument and Data Collection*

An online questionnaire was used to collect data. The instrument comprised three sections:

- i. Demographics: Gender, age, and faculty.
- ii. Financial Data: Monthly total food expenditure and monthly coffee-specific expenditure.
- iii. Behavioural Drivers: Likert-scale questions regarding the perception of coffee as a "wake-me-up tool" or a social necessity.

### 3.4 Data Analysis Plan

Data was analyzed using the following statistical techniques:

- i. Descriptive Statistics: To determine the mean, median, mode, and standard deviation.
- ii. Confidence Interval Estimation: To estimate the population mean with a 95% confidence level.
- iii. Levene's Test: To check for equality of variances between genders.
- iv. Independent Samples T-Test: To test the null hypothesis that there is no significant difference in spending between male and female students.

## 4. Results

### 4.1 Comprehensive Expenditure Profiles

The data revealed a wide range of spending behaviors. Figure 1 shows the average monthly food expenditure was recorded at RM322.60 (SD = 185.19), with a 95% confidence interval of [RM269.97, RM375.23]. This indicates that most students spend between RM270 and RM375 on food per month. For coffee-specific spending, the mean was RM59.78 (SD = 49.31), with a 95% confidence interval of [RM45.77, RM73.79].

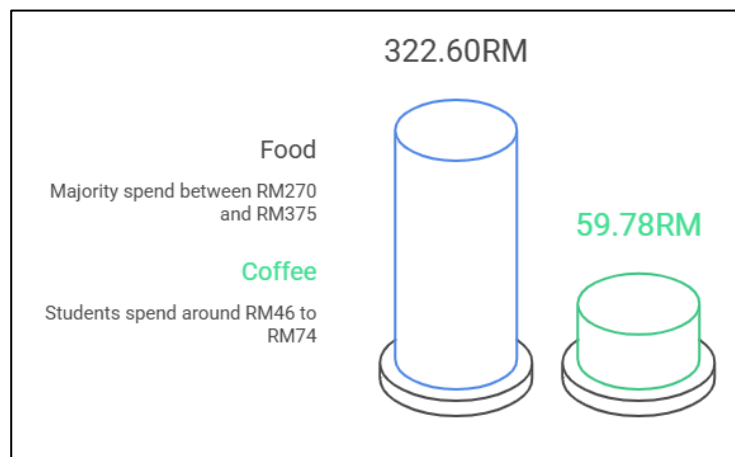


Figure 1: Monthly spending habits of students

### 4.2 Analysis of Central Tendency and Outliers

A critical finding of this study is the positive skewness of the expenditure data.

- i. Food Spending: The mean (RM322.60) is significantly higher than the mode (RM200.00) and the median (RM300.00). This gap suggests that while the "typical" student spends about RM200–RM300, a small group of students with very high expenditures (up to RM1,100) pulls the average upward. Figure 2 indicates that the distribution of monthly food expenditures is positively skewed.

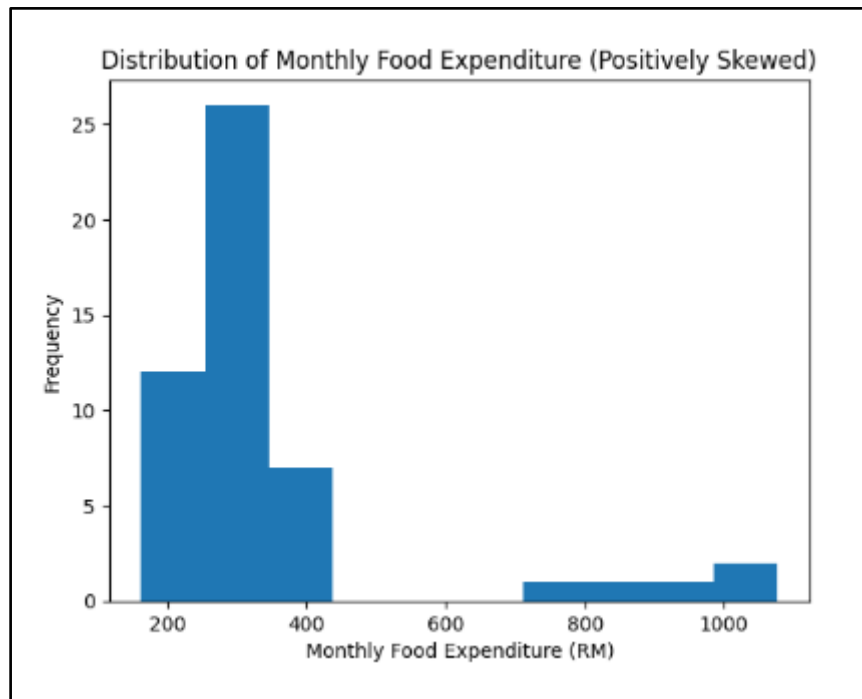


Figure 2: The distribution of monthly food expenditures

- ii. Coffee Spending: Similarly, the mode and median for coffee are both RM50.00, but some students report spending up to RM200.00 monthly. These high spenders likely represent frequent consumers of premium, branded coffee outlets. From Figure 3, we can conclude that the distribution of monthly coffee expenditures is skewed to the right.

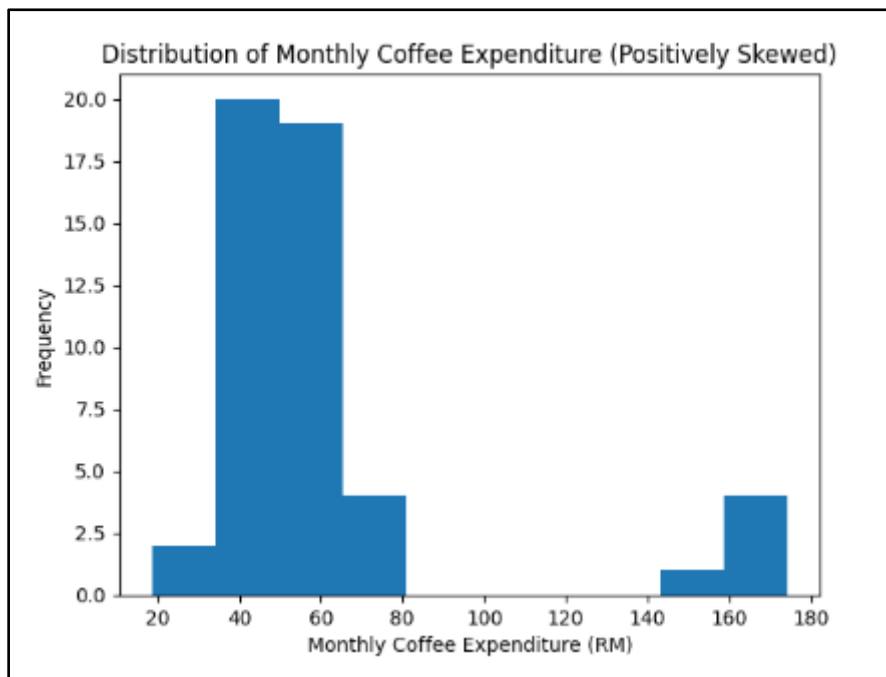


Figure 3: The distribution of monthly coffee expenditures

### 4.3 Inferential Analysis

To test if gender plays a role in spending, we analyzed the coffee expenditure of males ( $M = 64.44$ ,  $SD = 56.59$ ) versus females ( $M = 58.76$ ,  $SD = 48.24$ ).

- i. Levene's Test:  $F = 1.050$ ,  $p = 0.311$ . Since  $p > 0.05$ , equal variances were assumed.
- ii. T-test Results:  $t = 0.310$ ,  $p = 0.758$ .

Because the p-value (0.758) is significantly higher than 0.05, we fail to reject the null hypothesis. There is no statistically significant difference in the amount spent on coffee between male and female students at UiTM Pulau Pinang.

## 5. Discussion

### 5.1 The Economic Impact of the "Coffee Habit"

The findings indicate that coffee expenditure accounts for roughly 18.5% of a student's total food budget. This is a substantial portion of discretionary income for a demographic that is largely unemployed and reliant on loans. This spending behavior aligns with the "Sustainability of the Coffee Industry" report, which notes that students are a primary growth driver for the Malaysian coffee market (Ramanathan & Ali, 2021). Despite the financial strain, students prioritize this expense, suggesting that the perceived benefits of energy for study and social connectivity outweigh the monetary cost.

### 5.2 Comparison with National Spending Benchmarks

Comparing our findings to external literature reveals a stark contrast. While our study found a mean food spend of RM10.75 per day, Rasid et al. highlighted that a growing number of students live on less than RM3.00 per day due to extreme poverty (Rasid et al., 2023). This suggests that our sample may represent a more economically stable subset of the student population, or that students at UiTM Pulau Pinang are prioritizing "café-style" food and beverages over traditional low-cost options.

### 5.3 Pedagogical Implications: Statistics as a Life Skill

A major contribution to this study is its role in Statistical Learning. By having students analyze their own "messy" data (with outliers like the RM1,100 spender), they learn the importance of using the median over the mean in skewed distributions. This mirrors the work of Hilliam and Vines, who argue that simultaneous delivery of statistics to multiple audiences is most effective when the data is personally relevant (Hilliam & Vines, 2021). Students are no longer just calculating numbers; they are uncovering the financial realities of their own peers (Cujba & Pifarré, 2024).

#### 5.4 Limitations

The primary limitation is the small sample size (n=50) and the high percentage of female respondents. While this reflects certain campus demographics, it may not capture the spending habits of male students in more male-dominated faculties (e.g., Engineering). Additionally, self-reported data is subject to recall bias, as students may not track every small purchase accurately.

### 6. Conclusion and Recommendations

This study confirms that coffee consumption is a deeply embedded component of student lifestyle at Universiti Teknologi MARA Pulau Pinang, accounting for a notable proportion of monthly food expenditure. Despite common assumptions regarding gender-based financial behaviour, the findings reveal no statistically significant difference between male and female students, suggesting that spending patterns are more strongly influenced by shared academic demands and social environments than by gender.

The results further highlight the dual nature of coffee consumption as both a functional necessity for academic performance and a discretionary lifestyle choice, reflecting how students navigate financial constraints while prioritising perceived cognitive and social benefits. Importantly, this study also demonstrates that behavioural economic data can serve as an effective pedagogical tool, where the integration of real-world, student-generated datasets enhances data literacy, critical thinking, and applied statistical understanding.

From a practical standpoint, several recommendations emerge for key stakeholders. Universities should reassess the affordability and accessibility of on-campus food and beverage options, particularly by providing cost-effective yet conducive study environments that reduce students' dependence on premium café settings. Financial educators are encouraged to incorporate targeted financial literacy interventions that emphasise the cumulative impact of habitual spending behaviours, such as frequent coffee purchases, to promote more sustainable financial decision-making among students.

In addition, educators should continue to embed authentic, student-derived data into the teaching of statistics and mathematics, as this approach has been shown to improve engagement, conceptual understanding, and the ability to apply analytical techniques in real-life contexts. Collectively, these efforts can contribute to a more holistic development of students, encompassing both financial well-being and academic competency in an increasingly data-driven world.

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## EVALUATING STUDENTS' SPATIAL REASONING IN SETTING UP TRIPLE INTEGRALS

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### ABSTRACT

*Multivariable calculus is a critical component of STEM education, demanding sophisticated spatial reasoning and abstract geometric thinking to solve advanced problems related to multiple integrals – specifically double and triple integrals. However, the transition from single-variable to multivariable calculus presents significant cognitive challenges for students. This study investigates students' understanding and the underlying cognitive obstacles they face when setting up triple integrals to determine the volume of three-dimensional (3D) solids. A qualitative case study was conducted with undergraduate engineering students, whose written solutions were evaluated across four distinct phases: visualization, projection, coordinate selection, and algebraic setup. Utilizing the Action-Process-Object-Schema (APOS) theoretical framework as a diagnostic lens, the findings reveal that the primary learning obstacle is not a lack of procedural competence, but rather a fundamental deficit in 3D spatial visualization. While many students successfully executed dimension reduction and coordinate selection, they frequently failed to translate textual descriptions into accurate geometric boundaries, resorting instead to mechanical calculations characteristic of the APOS Action stage. To bridge this cognitive gap, the study recommends a pedagogical shift away from rote algorithmic drills toward instructional strategies that build spatial schema, specifically highlighting the integration of dynamic geometry software like GeoGebra and established pedagogical strategies, such as employing spatial metaphors to conceptualize the bounds of a solid.*

**Keywords:** *Calculus, multiple integrals, triple integrals, visualization spatial reasoning, APOS*

### Introduction

Multivariable calculus is a compulsory subject in Science, Technology, Engineering, and Mathematics (STEM) degree programs, equipping students with the mathematical tools required to model complex, multidimensional physical phenomena. Within this domain, the conceptualization and application of multiple integrals, specifically double and triple integrals, are critical for solving advanced problems related to volume, mass, moments of inertia, and surface areas of 3D objects (Milenković & Vučićević, 2024).

The transition from single-variable calculus to multivariable calculus represents a formidable cognitive leap, contrary to what most educators believe is a seamless generalization of previously learned calculus concepts (Martínez-Planell & Trigueros, 2021; Padayachee & Craig, 2020). While single-variable

integration often relies on straightforward two-dimensional (2D) graphical interpretations, multivariable integration demands a sophisticated synthesis of 3D spatial reasoning, advanced algebraic manipulation, and abstract geometric thinking.

The first part of solving multiple integrals involves the process of defining the integration area and setting boundaries for the variables. In multiple integral problems, students are given information about mathematical objects that define the integral function. To start calculating multiple integrals, they must utilize both the graphical and algebraic representations of those objects. They are also required to solve specific equations and inequalities to determine the boundaries for the multiple integral. Understanding the properties of different surfaces in space is a critical skill that must be acquired to successfully determine the boundaries of these integrals (Milenkovic et al., 2023).

Much work has been done on student understanding of multivariable functions over the past twenty years (Martínez-Planell & Trigueros, 2021). However, studies concentrated on students' understanding of multiple integrals are still lacking. A few of these studies, such as Gemechu et al. (2021), Padayachee (2020), and Martínez-Planell et al. (2025), used the Action-Process-Object-Schema (APOS) theory to investigate the levels of students' conception of double and triple integrals. This theory conceptualizes mathematical learning as a progression beginning with "Actions," which are externally driven, step-by-step algorithmic transformations of mathematical entities. Through repetition and cognitive reflection, students internalize these rigid procedures into a continuous "Process," thereby gaining autonomous internal control over the mathematical operations. When students are subsequently able to perform new actions upon these internalized processes, they encapsulate them into unified cognitive "Objects." Ultimately, these actions, processes, and objects are integrated into a broader cognitive framework called a "Schema," which students deploy to navigate and resolve complex mathematical problem situations.

To address these existing gaps in the literature, the primary aim of this study is to investigate the levels of students' understanding of multiple integrals. Specifically, this research focuses on their cognitive processes in defining the geometric integration area and setting up the precise limits of integration for triple integrals. Because triple integrals involve the integration of a function of three variables over a defined 3D solid region, they serve as a rigorous context to expose students' spatial and symbolic reasoning. Students' work will be evaluated across four distinct phases of setting up triple integrals: the visualization of the 3D solid region, the projection of the solid onto an appropriate coordinate plane, the selection of a coordinate

system, and the algebraic setup of the integral. Furthermore, APOS theory is utilized as a diagnostic lens to pinpoint the specific stage of students' understanding. Conducting an in-depth case study analysis regarding student understanding in the precise formulation and setup of triple integrals will provide essential insights into these learning obstacles, ultimately informing more effective, spatially grounded teaching strategies in multivariable calculus.

### Methodology

The purpose of this study was to analyze students' understanding of setting up triple integrals to determine the volume of a solid region. The participants were selected from a single class enrolled in the "Further Calculus for Engineers" course during the October 2025 to February 2026 academic semester at Universiti Teknologi MARA (UiTM) Pulau Pinang. The students were divided into eight small groups consisting of two to three members. Each group was randomly assigned one of eight different tasks requiring them to set up a triple integral across various coordinate systems to calculate the volume of a specific solid region. The groups were given 30 minutes to complete the task, and the problem-solving sessions were conducted in person under the direct observation of the lecturer. During this time, students were permitted to use the dynamic geometry software, GeoGebra, to plot surface graphs and assist in their integral setup.

To evaluate student performance, their written solutions were analyzed using a four-phase criteria framework. Table 1 outlines the rubric used to assess these four distinct phases: Visualization, Projection, Coordinate Selection, and Setup. Additionally, the APOS theory was utilized specifically as a diagnostic lens to classify the students' level of understanding. Based on the types of procedural and conceptual errors made during the integral setup, students' cognitive progression was categorized into the stages of APOS theory (Action, Process, Object or Schema stages) to better diagnose their learning obstacles.

Table 1: Assessment Rubric for Visualization, Projection, Coordinate Selection, and Setup

Phase criteria	Description
Visualization	The ability to translate text descriptions into a 3D geometric representation and identify all bounding surfaces
Projection	The ability to dimensionally reduce the 3D solid to a 2D region of integration on the appropriate coordinate plane with correct dimensions
Coordinate	The ability to choose the optimal coordinate system (Cartesian, cylindrical and spherical coordinates) and convert variables or differentials correctly
Setup	The ability to define precise integration limits to find the volume of a solid

## Results and Discussion

The overall evaluation of the eight student groups, utilizing the four-phase assessment rubric, revealed a wide variance in understanding levels. While the majority of the cohorts demonstrated a moderate to high proficiency across the setup process, only one group demonstrated complete conceptual and procedural mastery across all four phases. Conversely, two groups struggled significantly, failing to successfully initiate the basic visualization and projection requirements.

To better understand the cognitive mechanisms underlying these varying levels of success, three groups representing high, moderate, and low understanding were selected as case studies. Each case is discussed as follows:

### Case 1: High-understanding cohort

**Question:** Setup the triple integral to find the volume of the solid that is bounded above by  $z = 8 - x^2 - y^2$  and below by  $z = x^2 + y^2$ . Use suitable coordinates to setup the integral.

**Correct answer:**  $\int_0^{2\pi} \int_0^2 \int_{r^2}^{8-r^2} r \, dzdrd\theta$

Figure 1 illustrates the work of the cohort demonstrating a high level of understanding. This group successfully navigated the critical first step of geometric-to-algebraic translation by accurately identifying the solid's bounding surfaces: a lower paraboloid ( $z = x^2 + y^2$ ) and an upper paraboloid ( $z = 8 - x^2 - y^2$ ). Furthermore, they excelled in Phase 2 (Projection). Rather than guessing the bounds, they implemented an algebraic strategy, equating the two boundary surfaces to determine the intersection curve. This allowed them to accurately define the 2D region of integration as a circle with radius 2.

Demonstrating high coordinate fluency, the group seamlessly translated these Cartesian parameters into cylindrical coordinates, formulating the final triple integral without error. This case study highlights that when students possess strong foundational spatial visualization (Phase 1), the subsequent symbolic setup of the integral limits (Phase 4) naturally follows. Viewed through the lens of APOS theory, this cohort demonstrates cognitive behaviors consistent with the Process and Object stages; they have successfully interiorized the geometric transformations and can treat the bounded region as a unified mathematical object to construct an accurate integral.

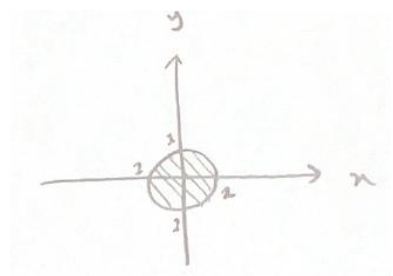
<p><b>Student work:</b>  <i>Projection of solid onto xy-plane</i></p>  $x^2 + y^2 = z$ $z = 8 - x^2 - y^2$ $x^2 + y^2 = 8 - x^2 - y^2$ $2(x^2 + y^2) = 8$ $x^2 + y^2 = 4$ $x^2 + y^2 = r^2$ $r^2 = 4$ $r = 2$	<p><i>Setup the triple integral in cylindrical coordinates</i></p> <p>r-limit  <math>0 \leq r \leq 2</math></p> <p><math>\theta</math>-limit  <math>0 \leq \theta \leq 2\pi</math></p> <p>z-limit  <math>r^2 \leq z \leq 8 - r^2</math></p> $\int_0^{2\pi} \int_0^2 \int_{r^2}^{8-r^2} r \, dz \, dr \, d\theta$
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Figure 1: Written Solution from the High-Understanding Cohort

**Case 2: Moderate-understanding cohort**

**Question:** Setup the triple integral to find the volume of the solid that is bound by the cylinder  $x^2 + y^2 = 1$ , the cone  $z = \sqrt{x^2 + y^2}$  and the xy-plane. Use suitable coordinates to setup the integral.

**Correct answer:**  $\int_0^{2\pi} \int_0^1 \int_0^r r \, dz \, dr \, d\theta$

Figure 2 illustrates the work of a cohort demonstrating a moderate level of understanding. This group was tasked with setting up a triple integral to determine the volume of a solid bounded below by the xy-plane, above by a cone ( $z = \sqrt{x^2 + y^2}$ ), and laterally by a cylinder ( $x^2 + y^2 = 1$ ). As evidenced by their written solution, the students experienced a significant geometric visualization failure. They misinterpreted the constraints of the solid, erroneously placing the cone as the lower bound and inventing a flat upper boundary at  $z = 1$  - a plane likely derived from the intersection of the cone and the cylinder.

Despite this profound spatial misconception, the group demonstrated resilience in their procedural execution. They successfully projected the solid onto the  $xy$ -plane, accurately identifying the 2D region of integration as a circle of radius 1 based on the cylinder's base. Additionally, the cohort correctly selected cylindrical coordinates as the optimal system and properly applied the volume formula. However, the students failed to convert the Cartesian expression  $\sqrt{x^2 + y^2}$  into its cylindrical equivalent within the inner integration limits. This case exemplifies the 'moderate' understanding profile: students who possess algorithmic fluency in dimension reduction (Phase 2) and coordinate selection (Phase 3) but lack the robust spatial-to-symbolic mapping skills required to correctly visualize the solid (Phase 1) and formalize its boundaries (Phase 4).

Analyzed through the lens of APOS theory, this profile strongly indicates an Action level conception. The students' approach relies heavily on substituting given equations into a memorized integral template as a step-by-step external procedure. The failure to unify the variables in the integrand, coupled with the algebraic invention of the  $z = 1$  boundary, demonstrates that they are executing disconnected algebraic actions rather than interiorizing the coordinate transformation and geometric constraints as a cohesive mathematical process.

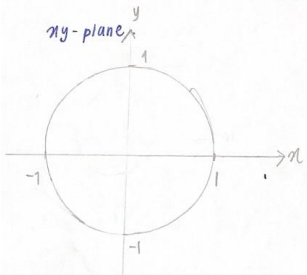
<p><b>Student work:</b>  <i>Projection of solid onto <math>xy</math>-plane</i></p> 	<p><i>Setup the triple integral in cylindrical coordinates</i></p> <p> <math>r \sqrt{x^2 + y^2} \leq z \leq 1</math> ✗  <math>0 \leq \theta \leq 2\pi</math> ✓  <math>0 \leq r \leq 1</math> ✓         </p> <p> <math display="block">\iiint_Q 1 \, dV = \iiint 1 \, dz \, dA</math> <math display="block">= \int_0^1 \int_0^{2\pi} \int_{\sqrt{x^2 + y^2}}^1 1 \, r \, dz \, d\theta \, dr</math> <math display="block">= \int_0^{2\pi} \int_0^1 \int_{\sqrt{x^2 + y^2}}^1 1 \, r \, dz \, dr \, d\theta</math> </p>
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Figure 2: Written Solution from the Moderate-Understanding Cohort

**Case 3: Low-understanding cohort**

**Question:** Setup the triple integral to find the volume of the solid that is bounded above the sphere  $x^2 + y^2 + z^2 = 2$  and below the paraboloid  $z = x^2 + y^2$ . (Use cylindrical coordinates).

**Correct answer:**  $\int_0^{2\pi} \int_0^1 \int_{r^2}^{\sqrt{2-r^2}} r \, dz \, dr \, d\theta$

Figure 3 illustrates the work of a cohort demonstrating a low level of understanding. The students were tasked with finding the volume of a solid bounded below by a paraboloid ( $z = x^2 + y^2$ ) and above by a sphere ( $x^2 + y^2 + z^2 = 2$ ). Their written solution shows major struggles with both visualizing the shape and setting up the mathematics. When defining the upper spherical boundary, they made a sign error, writing  $\sqrt{x^2 + y^2 - 2}$  instead of  $z = \sqrt{2 - x^2 - y^2}$ . Furthermore, they misidentified the lower boundary by using a constant limit of  $z = 1$  instead of the paraboloid equation, showing they could not correctly identify the geometric base of the solid. Although their sketch showed a correct 2D circular region with a radius of 1, they could not prove this dimension through calculation. They failed to find the intersection of the two surfaces algebraically, requiring the lecturer to step in and show the correct steps.

During the final Phase 4 setup, they experienced further issues writing the integral. Even though they explicitly listed the formulas for cylindrical coordinates, they did not use them, leaving Cartesian variables inside their integration limits. Most importantly, they misunderstood the volume formula itself. Instead of integrating the function 1, they inserted the sphere's equation directly into the integral. This highlights a serious confusion between finding a volume and integrating a specific function, marking a complete failure in setting up the problem. Viewed through the framework of APOS theory, these students exhibit pre-Action conception; they attempt rote memorization but are entirely unable to coordinate external actions to initiate the problem-solving process.

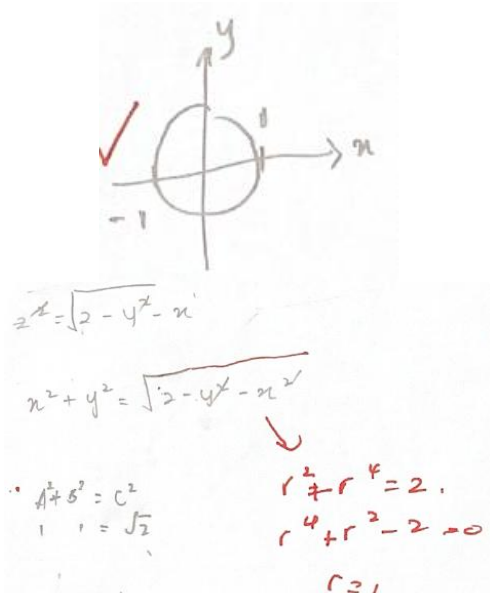
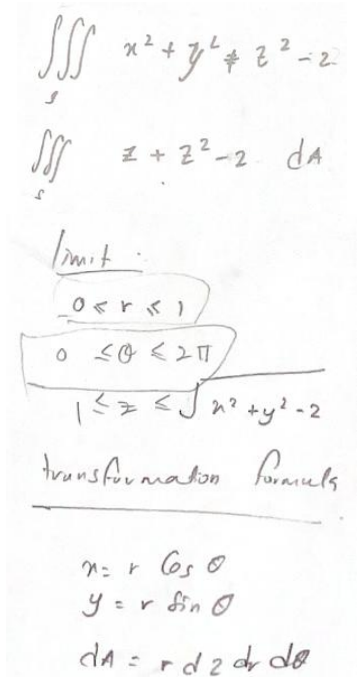
<p><b>Student work:</b>          Projection of solid onto <math>xy</math>-plane</p>  <p> <math>z^2 = 2 - y^2 - x^2</math>  <math>x^2 + y^2 = \sqrt{2 - y^2 - x^2}</math>  <math>r^2 + r^2 = 2</math>  <math>r^4 + r^2 - 2 = 0</math>  <math>r = 1</math> </p>	<p>Setup the triple integral in cylindrical coordinates</p>  <p> <math>\iiint_V (x^2 + y^2 + z^2 - 2) dz dA</math>  <math>\iiint_V (z + z^2 - 2) dA</math>          limit:  <math>0 \leq r \leq 1</math>  <math>0 \leq \theta \leq 2\pi</math>  <math>1 \leq z \leq \sqrt{x^2 + y^2 - 2}</math>          transformation formulas  <math>x = r \cos \theta</math>  <math>y = r \sin \theta</math>  <math>dA = r dz dr d\theta</math> </p>
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Figure 3: Written Solution from the Low-Understanding Cohort

The findings indicate that the majority of students experienced significant difficulty in visualizing 3D solids. They struggled to translate textual descriptions into 3D geometric representations and to identify the correct bounding surfaces, highlighting a fundamental weakness in spatial reasoning. Viewed through the lens of APOS theory, this poor spatial reasoning prevented students from progressing to the Process stage. Instead, they remained at the Action stage, tending to memorize procedures from prior examples and rigidly applying them to new situations (Gemechu et al., 2021). This aligns closely with the observations of Gemechu et al. (2021), who noted that most of their respondents struggled with the algebraic representation of integration regions. Similarly, Padayachee and Craig (2020) highlighted that students frequently fail to recognize the region of integration due to a lack of geometric understanding. Ultimately, these procedural and setup failures are deeply rooted in inadequate spatial reasoning abilities.

To address these cognitive obstacles, instructional strategies must adapt. Martínez-Planell and Trigueros Gaisman (2012) observed that students develop a much better understanding of multivariable functions when they are explicitly exposed to their graphical representations. Building on this, to assist

students in correctly setting up the limits of integration, Martínez-Planell et al. (2025) suggest employing spatial metaphors, such as identifying the "floor" and "ceiling" of a solid, which specifically helps students conceptualize the bounding surfaces required for the inner limits of a triple integral. Therefore, teaching should place a stronger emphasis on connecting the algebraic equations of surfaces with their visual graphs, particularly focusing on the intersections between different surfaces. This geometric understanding can then be significantly enhanced through the use of dynamic geometric software applications like GeoGebra. Supporting this approach, Lepellere (2025) reported that integrating GeoGebra into university-level multivariable calculus courses led to a marked improvement in the overall delivery and effectiveness of the teaching.

### Conclusion

In conclusion, this study reveals that the primary learning obstacle in setting up triple integrals is visualizing the 3D solid, rather than a lack of procedural competence. While students can often project solids onto 2D planes and select appropriate coordinate systems, they fundamentally struggle to translate textual descriptions into accurate 3D geometries, frequently resulting in invented boundaries or inappropriate constant limits. Viewed through the lens of APOS theory, this behavior indicates that many students remain restricted to the Action stage, performing mechanical calculations instead of developing a deeper geometric understanding. To address this, instruction must pivot from rote calculation toward pedagogies that emphasize spatial reasoning. Educators are encouraged to integrate dynamic geometry software like GeoGebra and adopt established pedagogical strategies, such as the "floor" and "ceiling" spatial metaphors recommended by Martínez-Planell et al. (2025). These interactive tools and conceptual frameworks allow students to visualize complex surface intersections, helping them build the robust spatial schema necessary to translate geometric realities into precise algebraic boundaries.

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# EXPLORING ACADEMIC READINESS AND MOTIVATION AMONG PRE-DIPLOMA COMMERCE STUDENTS IN UITM CAWANGAN PULAU PINANG: A SURVEY STUDY

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## ABSTRACT

*The progression from secondary education to tertiary studies represents a transformative period frequently characterized by significant academic and personal obstacles. This study explores the level of academic readiness and learning motivation among pre-diploma commerce students at Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang. Utilizing survey design, data was collected from 69 students during the October 2025 to February 2026 semester using a structured questionnaire adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) and the Academic Motivation Scale (AMS). The instrument demonstrated high reliability, with Cronbach's alpha coefficients of 0.836 for academic readiness and 0.898 for learning motivation. The findings indicate that students generally possess high levels of academic readiness and an overwhelmingly strong motivation to succeed, with over 95% agreement across all motivation items. However, independent study skills were identified as a key area for improvement, with 31.8% of students lacking confidence in autonomous learning. The study concludes that a significant positive relationship exists between readiness and motivation. These insights suggest that institutions should prioritize structured academic support to bridge experiential gaps, particularly for first-generation students.*

**Keywords:** *Academic Readiness, Learning Motivation, Pre-Diploma Students, Higher Education, Independent Learning.*

## Introduction

The transition from secondary school to higher education is often regarded as a critical stage in students' academic journey. For many students, entering university represents an important aspiration, as higher education is closely associated with better career opportunities and improved quality of life (Marginson, 2016; OECD, 2019). However, the transition is not always smooth. Some students face academic performance gaps, personal challenges, or socioeconomic constraints that prevent them from gaining direct entry into diploma programmes. As a result, alternative pathways are necessary to ensure that students are not left behind in their pursuit of higher education. In Universiti Teknologi MARA (UiTM), foundation and bridging programmes have been established to widen access and provide second-chance opportunities for students who require additional preparation before progressing to mainstream tertiary education. The program is called Pre-Diploma Programme. This programme is designed to strengthen

students' foundational academic knowledge while also preparing them in terms of study skills, learning strategies, and psychological readiness to continue into diploma-level studies at UiTM.

Nevertheless, providing access alone may not be sufficient to ensure students' academic success. Students entering pre-diploma programmes often come from diverse educational backgrounds and may differ in terms of preparedness for independent learning and academic demands. Academic readiness, which includes the ability to manage time, regulate learning, and cope with coursework expectations, plays an essential role in determining students' ability to succeed in higher education. At the same time, learning motivation influences the extent to which students are willing to engage, persist, and strive for achievement (Pintrich & De Groot, 1990; Tinto, 2012). Understanding both constructions is therefore crucial in evaluating the effectiveness of pre-diploma programmes.

Although pre-diploma programmes are designed to prepare students for diploma-level studies, there is limited empirical evidence examining whether students enrolled in such programmes are academically ready and sufficiently motivated to cope with tertiary education demands. Most existing studies in the Malaysian context focus on undergraduate or diploma students, with less attention given to those in bridging or preparatory pathways. Without a clear understanding of students' academic readiness and motivational levels, institutions may face challenges in designing targeted academic support interventions. Furthermore, the relationship between readiness and motivation among pre-diploma students remains underexplored. Given that these students represent a potentially vulnerable yet high-potential group, it is important to investigate whether academic preparedness influences their motivation to succeed.

Therefore, this study seeks to explore the level of academic readiness and learning motivation among pre-diploma students in a public higher education institution, as well as to determine the relationship between these two constructs. The findings are expected to provide evidence-based insights to support institutional strategies aimed at enhancing student preparedness and academic progression.

## **Literature Review**

Academic readiness refers to students' preparedness to cope with the intellectual, behavioral, and self-regulatory demands of higher education. Kurlaender, Reed, and Hurtt (2019) emphasise that college readiness extends beyond subject knowledge to include study skills, time management, and self-regulated learning competencies. Similarly, Cox (2019) found that first-time college students often struggle with independent learning expectations despite meeting entry requirements, suggesting that readiness is multidimensional. In Southeast Asian contexts, Cuy and Salinas (2019) reported that while many senior high school students expressed strong aspirations to pursue college degrees, not all demonstrated adequate academic preparedness. More recently, Seisa and Galabo (2023) highlighted

that aspiration and readiness do not always align, as students may be highly motivated but insufficiently equipped with academic competencies necessary for tertiary success.

Within the Malaysian setting, Sharifah Zannierah et al. (2011) assessed readiness among pre-diploma students at Universiti Teknologi MARA (UiTM) Pahang. Their findings suggested that although students generally perceived themselves as ready to pursue diploma studies, certain areas such as independent learning and academic adjustment required further attention. This indicates that readiness among pre-diploma students remains an important area of investigation.

On the other hand, learning motivation plays a central role in shaping students' engagement, persistence, and academic performance. Pintrich and De Groot (1990) established that motivational beliefs, particularly self-efficacy and intrinsic motivation, significantly predict students' use of cognitive strategies and academic achievement. Their work underscores the interconnection between motivation and self-regulated learning. Tinto (2012) further argues that students' persistence in higher education is strongly influenced by their commitment to educational goals and institutional integration. Students who possess strong academic aspirations and internal drive are more likely to remain engaged and complete their studies.

Studies focusing on aspiration and achievement also support this perspective. Goswami and Singh (2020) found a positive relationship between academic aspiration and academic performance, suggesting that students with clear educational goals demonstrate higher levels of achievement. Similarly, Cuy and Salinas (2019) reported that students' aspirations to pursue higher education are closely linked to their motivation to succeed academically. However, while motivation is crucial, prior research indicates that aspiration alone may not guarantee academic success if students lack sufficient readiness and study competencies (Seisa & Galabo, 2023).

## **Methodology**

The study enrolled a sample of 69 pre-diploma students during the October 2025 to February 2026 semester. Participants of both genders (male and female) were recruited via convenience sampling. The survey was distributed via a google form to all students in attendance at the CGCT talk. The research instrument was a structured questionnaire adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Pintrich & De Groot, 1990) and the Academic Motivation Scale (AMS) (Vallerand et al., 1992). Items assessing academic readiness were specifically adapted from Pintrich (2004) and Martin & Linnenbrink-Garcia (2011), with minor modifications made to align with the pre-diploma context. The final instrument comprised eight questions measuring Academic Readiness and Learning Motivation. Responses were recorded on a 4-point Likert scale, ranging from 1 (Strongly Disagree) to 4 (Strongly Agree). The specific items used to measure Academic Readiness and Learners' Motivation are detailed in Table 1.

Table 1: Summary of Questionnaire Items

<b>Academic Readiness</b>	
B1	I can manage my study time effectively.
B2	I know how to study independently without constant guidance from lecturers.
B3	I understand what is expected of me as a pre-diploma student.
B4	I feel confident completing academic tasks such as assignments and quizzes.
B5	I am able to take good notes during lectures.
B6	I revise my lessons regularly.
B7	I know where to seek help when I face academic difficulties.
B8	I can cope with the academic workload in the pre-diploma programme.
<b>Learners' Motivation</b>	
C1	I am motivated to do well in my studies.
C2	I enjoy learning new things in my programme
C3	I study hard because I want to succeed in the future.
C4	I put effort into my studies even when the subjects are difficult.
C5	Getting good grades is important to me
C6	I feel excited to attend my classes.
C7	I believe education will improve my quality of life.
C8	I plan to continue my studies after completing the pre-diploma programme.
<b>Perceived Challenges</b>	
D1	I feel stressed by academic demands
D2	I find it difficult to adapt to college-level learning
D3	Language of instruction affects my understanding of lessons.
D4	I feel confident asking questions during class

Internal consistency for the instrument was evaluated using Cronbach's alpha ( $\alpha$ ) coefficients. The results indicated high reliability for both scales. The Academic Readiness scale, consisting of 8 items, yielded an  $\alpha = 0.836$ . Similarly, the Learners' Motivation scale (8 items) demonstrated strong internal consistency with an  $\alpha = 0.898$ . These values exceed the conventional threshold of 0.70, confirming that the adapted scales are reliable measures for the pre-diploma student population. Analyses were conducted with SPSS 21.0.

Table 2: Cronbach's Alpha ( $\alpha$ ) value

Variable	Cronbach's Alpha ( $\alpha$ )	Interpretation
Academic Readiness	0.836	Good
Learners' Motivation	0.898	Very Good

## Result and Discussion

Total of 69 pre-diploma students participated in this study. Of the respondents, 45% were male and 55% were female, indicating a slightly higher representation of female students (Table 3). The demographic findings also indicate that 31.9% of the respondents were first-generation students in higher education. This is an important consideration, as previous research suggests that first-generation students often face unique transitional challenges when entering tertiary education. Without parental experience in higher education, these students may have limited access to academic guidance, institutional knowledge, and informal support systems that facilitate adjustment to university expectations (Tinto, 2012).

Table 3: Demographic

		Frequenc	
		y	Percent
Gender	Female	38	55.1
	Male	31	44.9
	Total	69	100.0
Age	18	67	97.1
	19	1	1.4
	20	1	1.4
Parents Education	At least one parent attended higher education	47	68.1
	First-generation student (parents did not attend higher education)	22	31.9
Sibling Education	At least one sister/brother in higher education	43	62.3
	No sister/brother in higher education	26	37.7

Despite these potential challenges, the present study found high levels of both academic readiness and learning motivation among respondents. This may suggest that the pre-diploma programme plays a supportive role in bridging experiential gaps for first-generation students. Existing literature indicates that motivation can serve as a protective factor for students who may lack structural advantages (Pintrich & De Groot, 1990). In this context, strong motivational orientation may help compensate for possible deficits in academic social capital.

Furthermore, given that a substantial proportion of students do not have siblings currently enrolled in university, institutional support mechanisms may be particularly important. Structured academic guidance, mentoring systems, and study skills development initiatives could enhance students' confidence and reinforce their readiness for diploma-level progression.

Table 4: Frequency Table of Academic Readiness among Students

	Strongly Disagree		Disagree		Agree		Strongly Agree	
	Frequency	%	Frequenc y	%	Frequenc y	%	Frequenc y	%
B1	0	0.0	3	4.3	53	76.8	13	18.8
B2	1	1.4	21	30.4	41	59.4	6	8.7
B3	1	1.4	0	0.0	54	78.3	14	20.3
B4	0	0.0	3	4.3	53	76.8	13	18.8
B5	0	0.0	0	0.0	63	91.3	6	8.7
B6	0	0.0	3	4.3	59	85.5	7	10.1
B7	0	0.0	3	4.3	58	84.1	8	11.6
B8	0	0.0	2	2.9	59	85.5	8	11.6

The frequency analysis indicates that students generally demonstrated strong academic preparedness across most items. A very high percentage of students agreed or strongly agreed that they were able to manage their study time effectively (95.6%), felt confident completing academic tasks (95.6%), and understood what was expected of them as pre-diploma students (98.6%). Similarly, more than 95% reported that they were able to take good notes during lectures (100%), revise lessons regularly (95.6%), knew where to seek help when facing academic difficulties (95.7%), and were able to cope with the academic workload (97.1%).

However, the item measuring independent study skills (B2) showed comparatively lower agreement. While 68.1% agreed or strongly agreed that they knew how to study independently, 31.8% (n = 22) either disagreed or strongly disagreed. This suggests that although overall academic readiness is high, a substantial minority of students may still require guidance in developing autonomous learning skills. Overall, the frequency findings are consistent with the high mean score for academic readiness (M = 3.07), indicating that students generally perceive themselves as academically prepared, with independent learning emerging as the main area requiring improvement.

Table 5: Frequency table of Learning Motivation among Students

	Strongly Disagree		Disagree		Agree		Strongly Agree	
	Frequenc y	%	Frequenc y	%	Frequenc y	%	Frequenc y	%
C1	0	0.0	3	4.3	51	73.9	15	21.7
C2	0	0.0	0	0.0	51	73.9	18	26.1
C3	0	0.0	0	0.0	34	49.3	35	50.7
C4	0	0.0	0	0.0	44	63.8	25	36.2
C5	0	0.0	0	0.0	31	44.9	38	55.1
C6	0	0.0	0	0.0	50	72.5	19	27.5
C7	0	0.0	0	0.0	34	49.3	35	50.7
C8	0	0.0	0	0.0	27	39.1	42	60.9

The results indicate an overwhelmingly high level of learning motivation among respondents. For all motivation items (C1–C8), more than 95% of students either agreed or strongly agreed with the statements. A particularly strong finding is that 60.9% strongly agreed that they plan to continue their studies (C8), and 55.1% strongly agreed that good grades are important (C5). These responses reflect strong intrinsic and future-oriented motivation.

Table 6: Frequency Table of Perceived Challenges among Students

	Strongly Disagree		Disagree		Agree		Strongly Agree	
	Frequenc y	%	Frequenc y	%	Frequenc y	%	Frequenc y	%
D1	6	8.7	41	59.4	18	26.1	4	5.8
D2	4	5.8	38	55.1	25	36.2	2	2.9
D3	4	5.8	38	55.1	24	34.8	3	4.3
D4	3	4.3	13	18.8	48	69.6	5	7.2

The findings from perceived challenges section (Table 6) present a contrasting but important perspective. A majority of students disagreed that they felt stressed by academic demands (68.1%) and similarly disagreed that they found it difficult to adapt to college-level learning (60.9%). Additionally, 60.9% disagreed that the language of instruction affected their understanding of lessons. However, when asked about confidence in asking questions during class (D4), 76.8% agreed or strongly agreed, suggesting generally positive classroom engagement. Although the majority reported minimal stress and adaptation difficulties, approximately one-third of students indicated some level of agreement with stress and adaptation challenges. This suggests that while overall adjustment appears positive, a subgroup of students may still require academic or emotional support.

## Conclusion

This study concludes that pre-diploma students in the selected public higher education institution demonstrate high levels of academic readiness and learning motivation. More importantly, a strong and significant positive relationship exists between these two constructs. The findings suggest that academic readiness plays a meaningful role in fostering students' motivation toward learning. While students appear highly motivated, enhancing their academic preparedness may further strengthen their engagement and persistence in higher education. Therefore, institutions offering pre-diploma programmes should continue to emphasise structured academic support mechanisms to ensure that students are not only motivated but also adequately equipped to succeed academically.

Future research may consider expanding the sample size, including multiple institutions, or examining additional variables such as academic performance or self-efficacy to provide a more comprehensive understanding of pre-diploma students' learning experiences.

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## DATA ANALYTIC FOR BUSINESS BASED PREDICTION

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### ABSTRACT

*Currently, business processes are perceived not merely as a sequence of activities responding to an event to generate output, but as a complex system involving the interplay of individuals, technologies, strategies, and business rules to attain certain business outcomes. Consequently, the analysis of a substantial volume of data is essential not only for present operations and several years ahead but also for future trends and long-term objectives. This study aims to present the concept of data analytics within the business domain, integrating it with a business framework specifically for operational purposes, and incorporating machine learning for predictive analytics, culminating in the evaluation of classification predictions. Information is a crucial asset that enables future business planning through a data-driven methodology and demonstrates the importance of business analytics for future success.*

**Keywords:** *Business Process, Data Analytics, Machine Learning, Predictive Analytics, Business Intelligence*

### Introduction

In the era of digital transformation, organizations generate vast amounts of data from operational systems, online transactions, and customer interactions. Transforming this raw data into actionable insights has become a strategic priority for organizations seeking competitive advantage. As a result, Business Intelligence has emerged as an important approach for collecting, integrating, and visualizing organizational data to support managerial decision making (Abusweilem & Abualous, 2019; Delen & Zolbanin, 2018).

While Business Intelligence primarily focuses on descriptive analysis and historical reporting, organizations increasingly rely on Business Analytics to perform deeper analytical processes that support strategic and operational decisions. Business analytics incorporates statistical analysis, data modelling, and computational techniques to extract insights from complex datasets and support data-driven decision making (Suri, 2021; Tsai et al., 2015).

A critical component of business analytics is Data Mining, which focuses on discovering hidden patterns, relationships, and knowledge from large volumes of data. Data mining techniques such as classification, clustering, and association rule learning allow organizations to uncover meaningful insights that may not be visible through traditional analytical approaches (Liao et al., 2012; Hall et al., 2022; Fayyad et al., 1996).

To ensure that data mining projects are conducted systematically and effectively, structured methodologies are often adopted. One widely used methodology is the Cross-Industry Standard Process for Data Mining (CRISP-DM), which provides a comprehensive framework consisting of business understanding, data understanding, data preparation, modelling, evaluation, and deployment phases (Chapman P., 2000).

Building upon these analytical foundations, Predictive Analytics enables organizations to forecast future trends, customer behaviour, and operational outcomes based on historical data. Predictive analytics commonly utilizes machine learning algorithms and statistical models to identify patterns that can be used to predict future events and support proactive decision making (Shmueli & Koppius, 2011; Siegel, 2020).

Given the increasing importance of predictive capabilities in modern organizations, this study explores the implementation of business analytics using the CRISP-DM framework to support predictive modelling. The research further examines the application of machine learning algorithms, analytical tools, and visualization techniques in modelling and analysing predictive outcomes for business decision support.

### **CRISP-DM as a framework for business analytic**

CRISP-DM defined the framework that data mining professionals first use to plan their data mining projects. In 1996, it was first revealed by the NCR Corporation and OHRA for the first time to provide the data and mining community with their first business-oriented, repeatable, and reliable framework (Wirth & Hipp, 2000). The CRISP-DM is considered as the most structured, iterative, and domain-neutral methodology to derive and implement a framework for a data-driven project. The application of CRISP-DM is still widely accepted and followed in the fields of data mining and predictive analytics. The CRISP-DM was built with the flexibility to span across multiple projects and therefore was adapted into the education and financial assistance systems, among many other industries. In CRISP-DM, there are 6 phases that span across business and data understanding, data preparation, model building, and evaluation and deployment, which are the most common data mining business processes to present in a process framework.

Figure 1 shows that business understanding starts with project goals definition and aligning them with the organizational priorities for the project to succeed. Further Table 1 elaborates starting from top level of understand the business and next drill out the data in data understanding phase, where the raw data is collected and explored to judge data quality and find patterns or anomalies. The most labour intensive phase of data science is data preparation, where data is cleaned, transformed and structured to make a usable dataset. After the data is ready, during the modelling usually statistical and

machine learning techniques used to refine models so that they best perform. In the evaluation phase, the developed models are compared to the predefined criteria to ensure that they deliver against the business objectives. Finally, the results are deployed into decision making processes like generating reports, or automating the workflows, so that it can be put into practice and continuously improved for future projects (Schröer et al., 2021).

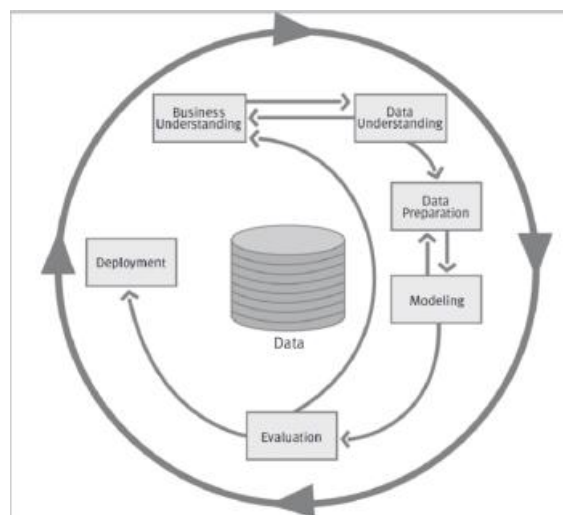


Figure 1: Phases of the CRISP-DM reference model (Huber et al., 2019; Chapman, 2000)

Table 1: The detail roles of each phase in CRISP-DM

CRISP-DM Phases	Description
1. Business Understanding	During this stage, it is important to comprehend the project's requirements and business objectives. It comprises defining the issue and determining the objectives. Gaining a thorough grasp of the business environment in which the data mining project will be implemented is the main goal.
2. Data Understanding	The origins of the data are being determined at this stage. Additionally, the initial data collecting has been completed. Consequently, it also entails looking into and comprehending the connections among the facts.
3. Data Preparation	These phases are involving several steps which is cleaning, transforming and the pre-processing the data to make it suitable for do the analysis.
4. Modelling	Various modeling techniques may be chosen and used to the prepared data during this phase. Apart from that, the project's particular modeling technique will be chosen.
5. Evaluation	In this phase, the chosen model will be assessed according to predetermined standards. Depending on the evaluation's findings and the process review, the following actions must be decided.

6. Deployment	The completed model is delivered to a production environment during the deployment phase. A final report will be generated from the deployment.
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### **Machine learning algorithms for predictive implementation**

One of the earliest components of predictive analytics involved the use of classification algorithms. These algorithms understood a priori the technique needed to predict what the different classifications of the data would be and how to organise the data into various groups, based on what patterns were learned during the training phase.

There are machine learning algorithms that are robust mechanisms that allow systems to learn from data and autonomously predict or choose without direct programming. These algorithms are designed to uncover hidden patterns and relationships in the data thereby making them important to solving difficult problems in industries such as healthcare, finance, food and beverage. Businesses can use machine learning to mine important insights, optimize processes, and enhance customer experiences - increasingly crucial to decision making in dynamic markets (Jordan & Mitchell, 2015). With additional data, machine learning is a major benefit that allows it to improve. Machine learning uses a repetitive learning approach to improve prediction accuracy and help in decision making in data driven way. They provide a solid foundation to move from intuition based to analytics-based decision making in what has to do with anticipating customer preferences, better resource allocation or predicting sales trends. Machine learning is used by businesses to deal with problems related to data accuracy and quality, optimize processes, and increase overall efficiency (Surur et al., 2025).

Classification algorithms are collection of algorithms used to predict the data based on an attribute that was known as target attribute. Random Forest, Decision Trees, and Naive Bayes are the most used classification models in varies predictive domain of studies such as healthcare, education, entertainment and many more. Naive Bayes is especially known for its effectiveness in using it for processes where the initial input was categorical (Karthikeyan & Rani, 2022). When the concept of optimal search of this algorithm is based on statistical probabilities of the event occurred among target attribute and input attributes, this algorithm has proven to be efficient for moderate range of data and less complex attributes.

Meanwhile the tree-based models most used were ID3, C4.5, and CART. They are easy to use for parameter tuning and visually interpretable (Han et al., 2011). The produced model has been used to make sense of the logic behind each prediction to validate the prediction of classification problems. The logic was necessary for validating such as an event of several classes. The models used human-like reasoning, as the trees split the data into branches using values of the attributes.

Random Forest was the first and most recognized ensemble model to build multiple trees and aggregate the prediction of each tree (Breiman, 2001). It improved the predictive accuracy and reduced

overfitting. It was perfectly applicable to the data with different kinds of profiles of the applicants and highly correlated variables. The Random Forest model was shown to be one of the most applicable and dependable models for problems of financial aid classification and, applied to, realistic data.

### **Comparison of tools and visualisation aids for business analytic**

Data mining is also crucial in elucidating the patterns of business application data as it helped to construct classifications and data visualizations. These technologies help in the construction of predictive models for business classification and in the provision of insights to assist the manager in decision-making. Different tools had varying capabilities in terms of data processing, model construction, and presentation. These tools were considered optimal for the given purpose.

Power BI is a business intelligence and data presentation tool developed by Microsoft. It is primarily used for dashboards and data visualizations. It did not directly train machine-learning models but was a great tool for the presentation of machine learning model outputs. In this case, Power BI is used to create a user-friendly interactive dashboard to represent the data and to classify and summarize apps. It has a great multi-level filtering option and interactive dashboard that to present data in the holistic output and reveal the hidden pattern for visualisation.

RapidMiner offers a visual interface with data mining capabilities and a variety of machine learning tools including Naïve Bayes, Decision Trees, and Random Forest. Users could design workflows for data prep and model training with relative ease. This made it handy for people who didn't know how to code. Because of this, it is particularly useful for developing and testing classification models in a fast and flexible way in educational settings (Han et al., 2011).

WEKA (Waikato Environment for Knowledge Analysis) is one of the first tools offered for free to the public for data mining. The University of Waikato developed it and the data mining tool became quite popular. The tool is appropriate for educational settings and small data collections as it offers a variety of algorithms, preprocessing methods, evaluation tools, and even some visualization methods (Hall et al., 2022).

Like Power BI, Tableau is also used primarily for data visualization. Tableau is popular for its capacity to make interactive charts and dashboards. Tableau also has some predictive capabilities including trend lines and forecasting, but for more advanced modelling, Tableau is used in conjunction with other tools such as R or Python. The comparison of all the above mentioned algorithms was further compared in table 2.

Table 2: Comparison table of Various Types of Data Mining Tools

Tool	Functionality	Strengths	Limitations	Suitability for
Power BI	Data visualization, dashboard reporting	<ul style="list-style-type: none"> <li>• User-friendly interface</li> <li>• Real time interactivity</li> <li>• Strong integration with Excel</li> </ul>	<ul style="list-style-type: none"> <li>• Limited built-in modelling</li> <li>• Requires external models for prediction</li> </ul>	Best for dashboard development and presenting model results to stakeholders
Rapid Miner	Full data mining process: data preparation, modeling, evaluation	<ul style="list-style-type: none"> <li>• Drag-and-drop interface</li> <li>• Supports many ML algorithms</li> <li>• No coding needed</li> </ul>	<ul style="list-style-type: none"> <li>• Memory-intensive</li> <li>• May have limitations for large datasets</li> </ul>	Suitable for building and testing predictive classification models
WEKA	Machine learning experimentation and educational tool	<ul style="list-style-type: none"> <li>• Lightweight</li> <li>• Great for teaching and experimentation</li> <li>• Many built-in classification methods</li> </ul>	<ul style="list-style-type: none"> <li>• Basic visualization</li> <li>• Limited scalability</li> </ul>	Ideal for models Comparison in early testing phase
Tableau	Advanced data visualization and analytics	<ul style="list-style-type: none"> <li>• Visually rich dashboard designs</li> <li>• Strong storytelling features</li> </ul>	<ul style="list-style-type: none"> <li>• Limited modelling support</li> <li>• Requires external tool for advanced predictions</li> </ul>	Alternative to Power BI for presentation; less integration with academic systems

Business intelligence systems provided users with visualisation tools that enabled them to comprehend intricate information. To facilitate the effective, timely and transparent functioning of the business case studies, visualisation tools assisted in converting the results of predictive model classifications into dashboards and reports.

Power BI, a product of Microsoft and one of the primary tools used in this initiative, it's able to combine numerous data systems and user-responsive dashboards and interactive reports containing critical charts and maps. Stedman (2020) asserts that organizations Power BI's visualization capabilities for real-time data and dynamic reporting to improve decision-making and streamline actionable insights.

Another important visualisation tool is Tableau, which has similar features but centred more on visual story creation. Tableau is appreciated more for its pleasing visual dashboard designs as well as its interactive filter designs. Tableau was used mostly in academic and corporate settings to share analyses in an engaging way. Both tools had intuitive interfaces designed to cater to the non-technical user, such as administrators, officers, and other stakeholders. More importantly, they facilitated the

visibility and explainability of the data in ways that increased the efficiency and equitable allocation of business in a fair and evidence-based manner.

### Modelling and Analysis of the predictive results

The modelling process could not succeed without the proper test framework, which outlined how the predictive models would be trained, evaluated, and in what ways the models' accuracy and fairness would be verified. In Table 3 the evaluation framework consists of the following components:

Table 3: Test Structure Element with Description

Element	Description
Train-Test Split	The dataset is divided into 80% and 20% for training and 20% and 30 % for testing. The training set will be used to build a model; however, the test set will be used afterwards to test the generalization capability of the model.
Cross-Validation	10-fold cross-validation is planned to improve model robustness by rotating training and validation across 10 data subsets and averaging the results.
Stratified Sampling	To address any class imbalance, stratified sampling may be used to maintain proportional representation of each zakat category in both training and test datasets.
Confusion Matrix	A matrix is used to visualize true positives, false positives, true negatives, and false negatives to assess prediction performance per zakat category.
Evaluation Metrics	Model performance is measured using classification metrics such as accuracy, precision, recall, and F1- score to evaluate predictions across categories.

In assessing the performance of the models, two primary objects are used: confusion metrics and model evaluation metrics. The confusion matrix captured the essence of the predictions of the model along the lines of true predictions and false predictions (positives/negatives) for the respective target attribute. The model provides a good basis for comparison of the actual classifications of predictors against the predictions of the model for classifications.

Furthermore, computations of metrics, for example, evaluation of total model performance, are done by model class metrics to gauge the performance of the models per class, along computation of measurement of precision, measurement of the true positives (actual true positions and false positions), and measurement of false negatives (actual true negatives and false negatives), and the model evaluation metric on the total model performance: the model evaluation metric on the false negatives (actual true

negatives and false negatives/ true negatives). Table 4 show Standard Classification Evaluation Metrics for two classes of target attribute.

Table 4: Standard Classification Evaluation Metrics

Metric	Description
Accuracy	Measures the overall correctness of the model across all target attribute values (nominal) known as classes.
Precision	Indicates how many students predicted to belong to a specific class.
Recall (Sensitivity)	Shows how many actual values of specific class are correctly identified by the model.
F1-Score	Provides a balance between precision and recall; especially useful for imbalanced datasets.

Meanwhile, each metric is calculated using the following formulas in Figures 5. These statistical formulas ensured a comprehensive assessment of the model’s effectiveness across all classes in target attribute in the classifications of testing and training. In case of imbalance data are expected between classes, metrics like the F1-score and class-wise precision and recall are especially important in evaluating model fairness and effectiveness in supporting classification decisions.

Figure 5: Formula for Calculating Classification Task

• Precision for class $i$ :	$\text{Precision}_i = \frac{TP_i}{TP_i + FP_i}$
• Recall for class $i$ :	$\text{Recall}_i = \frac{TP_i}{TP_i + FN_i}$
• F1-Score for class $i$ :	$F1_i = \frac{2 \cdot \text{Precision}_i \cdot \text{Recall}_i}{\text{Precision}_i + \text{Recall}_i}$
• Overall Accuracy:	$\text{Accuracy} = \frac{\text{Total Correct Predictions}}{\text{Total Number of Predictions}}$

## Conclusion

In conclusion, the integration of Business Intelligence, Business Analytics, Data Mining, and Predictive Analytics has transformed the way organizations utilize data for strategic decision making. While Business Intelligence provides visibility into historical and operational data, advanced analytical

techniques enable organizations to uncover patterns and predict future outcomes. As emerging technologies such as artificial intelligence, big data, and cloud computing continue to evolve, the role of data-driven analytics will become even more critical. Organizations that effectively adopt these analytical approaches will be better positioned to identify opportunities, mitigate risks, and maintain sustainable competitive advantages in an increasingly data-oriented business environment.

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## PERBANDINGAN PELAJAR DARIPADA PROGRAM KEJURUTERAAN BERBEZA MENJAWAB SOALAN PEPERIKSAAN AKHIR BAGI TOPIK PERMASALAHAN NILAI SEMPADAN

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### ABSTRAK

*Permasalahan Nilai Sempadan (Boundary Value Problems, BVP) merupakan salah satu topik penting dalam kursus matematik lanjutan kerana aplikasinya yang meluas dalam analisis haba, getaran, mekanik bendalir dan sistem elektrik. Namun demikian, tahap penguasaan pelajar terhadap topik ini sering menunjukkan variasi yang ketara. Kajian ini bertujuan membandingkan prestasi pelajar daripada program kejuruteraan yang berbeza dalam menjawab soalan peperiksaan akhir berkaitan Permasalahan Nilai Sempadan. Kajian ini menggunakan reka bentuk kuantitatif berbentuk perbandingan. Sampel terdiri daripada 27 orang pelajar ijazah sarjana muda daripada tiga program kejuruteraan, iaitu Kejuruteraan Awam, Kejuruteraan Mekanikal dan Kejuruteraan Kimia, Universiti Teknologi MARA Cawangan Pulau Pinang. Data diperolehi daripada markah soalan BVP dalam peperiksaan akhir dan dianalisis menggunakan statistik deskriptif serta ujian ANOVA satu hala. Dapatan menunjukkan terdapat perbezaan min markah antara program, namun perbezaan tersebut tidak signifikan pada aras keertian 0.05.*

***Kata kunci: Permasalahan Nilai Sempadan, pendidikan kejuruteraan, analisis perbandingan, pencapaian pelajar, persamaan pembezaan.***

### Pengenalan

Matematik lanjutan merupakan komponen teras dalam kurikulum program kejuruteraan kerana ia menjadi asas kepada pemodelan dan analisis sistem fizikal. Antara topik yang memainkan peranan penting ialah Permasalahan Nilai Sempadan (*Boundary Value Problems, BVP*), yang lazimnya dibincangkan dalam kursus Persamaan Pembezaan Lanjutan atau Matematik Kejuruteraan.

Permasalahan Nilai Sempadan melibatkan penyelesaian persamaan pembezaan bersama syarat sempadan tertentu dan digunakan secara meluas dalam model konduksi haba, getaran sistem mekanikal, aliran bendalir serta analisis litar elektrik. Sebagai contoh, topik ini memerlukan kefahaman yang kukuh terhadap konsep persamaan pembezaan, kemahiran manipulasi algebra, serta kebolehan mentafsir syarat fizikal kepada bentuk matematik. Kaedah pemisahan pembolehubah (*separation of variables*) juga merupakan kaedah yang lazim digunakan dalam penyelesaian persamaan pembezaan separa (*Partial Differential Equation*).

Perbezaan struktur kurikulum dan penekanan bidang dalam program kejuruteraan yang berbeza berkemungkinan mempengaruhi tahap penguasaan pelajar terhadap topik ini. Oleh itu, kajian ini dijalankan bagi mengenal pasti sama ada terdapat perbezaan signifikan dalam pencapaian pelajar daripada program kejuruteraan yang berbeza dalam menjawab soalan BVP dalam peperiksaan akhir.

## Kajian Literatur

Permasalahan Nilai Sempadan merupakan lanjutan kepada topik persamaan pembezaan biasa (ODE) dan sering dikaitkan dengan aplikasi dunia sebenar dalam bidang kejuruteraan. Kajian terdahulu menunjukkan bahawa pelajar sering menghadapi kesukaran dalam memahami konsep abstrak yang melibatkan hubungan antara model matematik dan fenomena fizikal. Kekurangan pemahaman tentang konsep matematik asas mungkin menghalang pelajar daripada menggunakan konsep tersebut dengan berkesan dalam menyelesaikan pelbagai masalah kejuruteraan. Seterusnya, ia boleh memberikan kesan negatif terhadap prestasi mereka dalam jurusan akademik dan profesional (Voon, Niu dan Wong, 2024).

Beberapa penyelidikan dalam pendidikan matematik kejuruteraan mendapati bahawa kesilapan pelajar boleh dikategorikan kepada dua bentuk utama, iaitu kesilapan konseptual dan kesilapan prosedural. Kesilapan konseptual merujuk kepada ketidakfahaman terhadap makna syarat sempadan atau sifat penyelesaian, manakala kesilapan prosedural pula melibatkan manipulasi algebra dan langkah penyelesaian yang tidak sistematik. Kesilapan prosedural kerap menjadi topik kajian (Geary, 2011; Ancheta & Subia, 2020; Tu et. al., 2020; Rong & Mononen, 2022). Ryan, Wilcox dan Pollock (2018) menggunakan kerangka kerja yang bernama **ACER** (*Activation, Construction, Execution, Reflection*) untuk menganalisis proses penyelesaian masalah pelajar dalam soalan gelombang elektromagnet. Pelaksanaan (*Execution*) dalam model **ACER** melaporkan bahawa pelajar bergelut dan melakukan kesalahan dalam memudahkan indeks matematik. Sebagai contoh, pelajar membatalkan (*cancel out*) sebutan eksponen secara tidak wajar apabila sempadan tidak terletak pada titik sifar ( $z=0$ ). Manakala, pelajar tidak memahami langkah penting dalam kaedah pemisahan pembolehubah dan penyelesaian umum untuk persamaan pembezaan separa (*Partial Differential Equation*) dalam prinsip superposisi di mana setiap komponen tidak dapat memenuhi syarat sempadan dan syarat awal. Prosedural matematik yang memerlukan kaedah Fourier juga menjadi halangan utama bagi pelajar-pelajar (Tu et. al., 2020).

Selain itu, Wilcox dan Pollock (2015) mengkaji pelajar peringkat junior fizik menghadapi pelbagai kesukaran dalam menggunakan kaedah pemisahan pembolehubah (*separation of variables*) untuk menyelesaikan persamaan Laplace dalam elektrostatik. Sebahagian daripada kajian penyelidikan mereka juga terlibat dengan syarat sempadan (*Boundary Condition*). Hasil kajian mereka menunjukkan bahawa beberapa orang pelajar menghadapi kesukaran untuk mengenal pasti dan menyatakan syarat sempadan yang sesuai apabila ia tidak dinyatakan secara eksplisit dalam pernyataan masalah. Hal ini

demikian juga diutarakan oleh Eynde et al. (2022). Penyelidikan yang dijalankan oleh Eynde et al. (2022) melibatkan penyelesaian persamaan haba dalam konteks fizik dan matematik. Dua isu besar yang dikenal pasti dalam penyelesaian masalah haba ialah memahami syarat sempadan dan kekeliruan antara konsep jumlah dan kadar perubahan.

Kajian perbandingan antara bidang kejuruteraan pula menunjukkan bahawa latar belakang kurikulum, pendekatan pengajaran, serta tahap aplikasi matematik dalam kursus teras boleh mempengaruhi pencapaian pelajar. Namun demikian, kajian yang secara khusus membandingkan prestasi pelajar dalam topik Permasalahan Nilai Sempadan masih terhad, justeru mewajarkan kajian ini dilaksanakan.

### Metodologi Kajian

Kajian ini menggunakan pendekatan kuantitatif berbentuk perbandingan (comparative study) bagi menilai perbezaan pencapaian antara kumpulan pelajar daripada program kejuruteraan yang berbeza.

Sampel kajian terdiri daripada 27 orang pelajar semester empat hingga enam yang mengambil kursus Matematik Lanjutan daripada program Kejuruteraan Awam, Kejuruteraan Kimia dan Kejuruteraan Mekanikal. Pemilihan sampel adalah berdasarkan persampelan bertujuan (purposive sampling) kerana semua responden telah menduduki peperiksaan akhir pada semester yang sama.

### Dapatan Kajian

Jadual 1 menunjukkan pemerhatian dari statistik deskriptif dimana pelajar daripada Program Kejuruteraan Mekanikal mempunyai min paling rendah. Manakala pelajar daripada Program Kejuruteraan Awam menunjukkan min paling tinggi. Namun sisihan piawai agak besar, dimana variasi markah tinggi dalam setiap kumpulan.

Jadual 1: Statistik Deskriptif

Program	N	Min	Sisihan Piawai
Kejuruteraan Mekanikal	9	5.33	7.87
Kejuruteraan Kimia	9	10.89	7.42
Kejuruteraan Awam	9	11.56	8.71
Keseluruhan	27	9.26	8.22

Jadual 2 menunjukkan Analisis ANOVA satu hala dimana tidak terdapat perbezaan yang signifikan dalam markah Permasalahan Nilai Sempadan antara ketiga-tiga program,  $F(2,24) = 1.63$ ,  $p = 0.217$ . Oleh kerana nilai  $p$  melebihi aras keertian 0.05, hipotesis nol gagal ditolak. Ini menunjukkan bahawa

pencapaian pelajar dalam menjawab soalan Permasalahan Nilai Sempadan adalah setara secara statistik antara program.

Jadual 2: Keputusan ANOVA Satu Hala

Sumber Variasi	SS	df	MS	F	P
Antara Kumpulan	210.20	2	105.10	1.63	0.217
Dalam Kumpulan	1545.06	24	64.38		
Jumlah	1755.26	26			

Walaupun bagaimanapun, saiz kesan adalah sederhana,  $\eta^2 = 0.12$ , menunjukkan bahawa 12% varians markah boleh dijelaskan oleh perbezaan program pengajian. Walaupun tidak signifikan secara statistik, perbezaan ini mungkin mempunyai implikasi praktikal dalam konteks pendidikan.

### Perbincangan

Dapatan kajian menunjukkan bahawa tidak terdapat perbezaan yang signifikan dalam pencapaian pelajar daripada tiga program kejuruteraan dalam menjawab soalan Permasalahan Nilai Sempadan. Ini mencadangkan bahawa tahap penguasaan topik tersebut adalah relatif sama antara program, walaupun terdapat sedikit perbezaan min secara deskriptif.

Namun demikian, nilai sisihan piawai yang tinggi menunjukkan variasi dalaman yang besar dalam setiap kumpulan. Kehadiran beberapa markah sifar dalam semua program turut mempengaruhi penyebaran data dan meningkatkan varians dalam kumpulan. Keadaan ini berkemungkinan mengurangkan keupayaan ujian statistik untuk mengesan perbezaan sebenar antara kumpulan.

Program Kejuruteraan Mekanikal mencatatkan min yang lebih rendah berbanding Program Kejuruteraan Kimia dan Program Kejuruteraan Awam. Perbezaan ini mungkin dipengaruhi oleh faktor seperti latar belakang matematik pelajar, tahap kesiapan akademik atau pendekatan pengajaran yang diterima. Namun begitu, memandangkan perbezaan tersebut tidak signifikan secara statistik, ia tidak boleh disimpulkan sebagai perbezaan yang kukuh dari sudut inferensi.

Saiz kesan sederhana ( $\eta^2 = 0.12$ ) menunjukkan bahawa walaupun ujian tidak signifikan, program pengajian masih mempunyai pengaruh praktikal terhadap pencapaian pelajar. Kemungkinan besar, saiz sampel yang kecil ( $n = 9$  bagi setiap kumpulan) menjadi faktor utama yang menyumbang kepada keputusan tidak signifikan ini. Dengan sampel yang lebih besar, keputusan yang lebih jelas mungkin dapat diperolehi.

Secara keseluruhannya, dapatan ini menunjukkan bahawa cabaran utama dalam topik Permasalahan Nilai Sempadan bukan terletak pada perbezaan program semata-mata, tetapi mungkin berkaitan dengan variasi individu pelajar serta penguasaan asas persamaan pembezaan dan manipulasi algebra.

## Kesimpulan

Walaupun tiada perbezaan signifikan antara program, analisis menunjukkan variasi pencapaian yang tinggi dalam setiap kumpulan. Oleh itu, intervensi pengajaran yang memfokuskan kepada pengukuhan konsep dan kemahiran prosedural disarankan bagi meningkatkan pencapaian pelajar secara menyeluruh.

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## KAJIAN TERHADAP SIKAP PELAJAR DALAM MATEMATIK: SIKAP POSITIF DAN NEGATIF

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### ABSTRAK

*Matematik merupakan komponen asas dalam kurikulum pendidikan dan memainkan peranan penting dalam pembangunan pemikiran logik serta penyelesaian masalah. Pembelajaran dan prestasi pelajar dalam matematik dipengaruhi oleh beberapa faktor, termasuk sikap pelajar terhadap subjek, amalan pengajaran guru, dan persekitaran sekolah. Namun begitu, ramai pelajar menunjukkan persepsi dan sikap negatif terhadap subjek ini yang membawa kepada penurunan minat, motivasi, dan pencapaian. Kajian ini bertujuan untuk mengenal pasti punca utama kurangnya sikap positif pelajar terhadap subjek Matematik serta kesan yang timbul akibat sikap tersebut terhadap pencapaian akademik dan pilihan kerjaya pelajar. Melalui kaedah kajian tinjauan dan soal selidik yang melibatkan 50 orang pelajar yang mengambil mata pelajaran matematik, dapatan menunjukkan bahawa faktor seperti kaedah pengajaran tradisional, pengaruh sosial, serta kebimbangan terhadap Matematik memainkan peranan besar dalam membentuk sikap pelajar. Bagi menangani isu ini, dicadangkan beberapa intervensi berasaskan bukti, seperti penggunaan pendekatan pembelajaran berpusatkan pelajar, latihan profesional untuk pensyarah dalam membina persekitaran pembelajaran yang menyokong emosi pelajar, serta strategi sokongan afektif untuk mengurangkan kebimbangan dan meningkatkan keyakinan pelajar terhadap Matematik. Kajian ini menekankan bahawa perubahan sikap terhadap Matematik memerlukan pendekatan holistik yang melibatkan aspek kognitif dan emosi dalam proses pembelajaran*

**Keywords:** *sikap, positif, negatif, pencapaian akademik, kerjaya,*

### Pengenalan

Sikap mempunyai perkaitan rapat dengan pencapaian seseorang di dalam pembelajarannya. Sikap ialah sesuatu yang abstrak dan hanya dapat dilihat atau dirasa melalui tindakan yang diambil. Sikap pelajar terhadap matematik memainkan peranan penting dalam menentukan tahap pencapaian mereka dalam subjek tersebut. Memahami sikap pelajar terhadap subjek matematik amatlah penting bagi membentuk mereka supaya memahami konsep matematik, membangunkan kemahiran, dan seterusnya menghayati matematik dalam penghidupan seharian, kerana matematik mempunyai ciri ilmu yang mampu menyelesaikan masalah. Walaupun matematik merupakan subjek asas dalam sistem pendidikan dan amat diperlukan dalam pelbagai bidang kerjaya, ramai pelajar menunjukkan minat yang rendah serta kebimbangan yang tinggi terhadap subjek ini. Fenomena ini menimbulkan kebimbangan dalam kalangan pendidik dan pembuat dasar kerana ia memberi kesan langsung kepada prestasi pelajar serta pemilihan aliran kerjaya pada masa hadapan.

Sikap positif terhadap matematik merujuk kepada pandangan, perasaan, dan tingkah laku yang membina dan menyokong pembelajaran serta penguasaan subjek ini. Contoh seperti minat dan seronok belajar matematik, ingin tahu dan ingin mencuba serta tekun dan terus mencuba. Manakala sikap negatif pula merujuk kepada perasaan, pemikiran, atau tingkah laku yang menghalang seseorang daripada belajar dan menguasai mata pelajaran ini dengan baik. Ianya seperti kurang keyakinan diri, takut dan gentar serta cepat putus asa dan tidak sabar. Keberkesanan pengajaran dan pembelajaran boleh ditingkatkan sekiranya pendidik dapat memahami sikap pelajar terhadap mata pelajaran diajarinya (Erma & Leong, 2014).

Menurut Yiew dan Sofwan (2021) sikap positif atau negatif pelajar dipengaruhi oleh tanggapan atau persepsi mereka terhadap pembelajaran matematik. Manakala menurut Ayob & Yasin (2017), sikap positif terhadap pembelajaran matematik di kalangan pelajar dapat meningkatkan pencapaian matematik manakala sikap negatif pula akan menghalang pembelajaran yang berkesan dan mempengaruhi hasil pembelajaran dan seterusnya prestasi pelajar dalam peperiksaan. Berdasarkan kajian Norulbiah dan Effandi (2016), sikap pelajar terhadap penyelesaian masalah dan keupayaan menyelesaikan masalah matematik adalah pada tahap yang sederhana yang mana pelajar didapati mudah putus asa apabila tidak dapat menyelesaikan masalah matematik.

### **Metodologi**

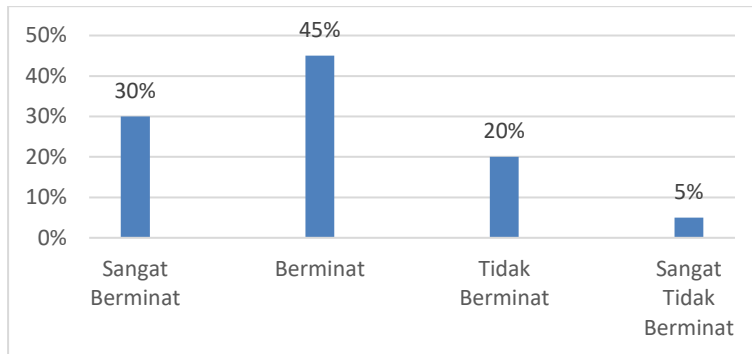
Kajian ini dilaksanakan dengan menggunakan pendekatan kuantitatif berbentuk deskriptif, yang bertujuan untuk meneroka sikap pelajar terhadap mata pelajaran Matematik secara sistematik dan objektif. Ini membolehkan pensyarah mendapat gambaran keseluruhan tentang corak dan kecenderungan sikap yang terdapat dalam kalangan pelajar berdasarkan analisis data numerik (Creswell, 2014). Kajian ini melibatkan 50 orang pelajar dari dua program kejuruteraan di Universiti Teknologi Mara, Cawangan Pulau Pinang. Kaedah pensampelan bertujuan digunakan, iaitu memilih pelajar yang sedang mengambil mata pelajaran Matematik dan menunjukkan kesediaan untuk terlibat dalam kajian. Pemilihan ini adalah sejajar dengan keperluan penyelidikan yang ingin mendapatkan maklum balas daripada responden yang relevan dengan topik kajian (Palinkas et al., 2015). Terdapat aktiviti yang dilakukan secara berkumpulan dalam kajian ini.

Data yang diperoleh dianalisis menggunakan perisian Statistical Package for the Social Sciences (SPSS) versi 27. Statistik deskriptif seperti purata (min), peratusan dan sisihan piawai digunakan untuk menggambarkan profil sikap pelajar.

### **Analisa data dan Hasil Dapatan Kajian**

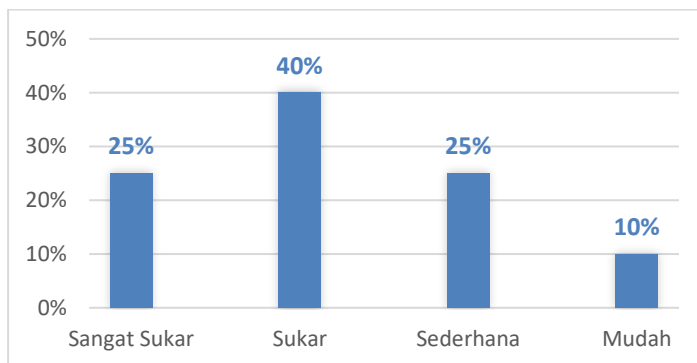
Hasil dari soal selidik yang dijalankan, analisa ini dipecahkan berdasarkan beberapa kategori.

### 1. Minat pelajar terhadap matematik



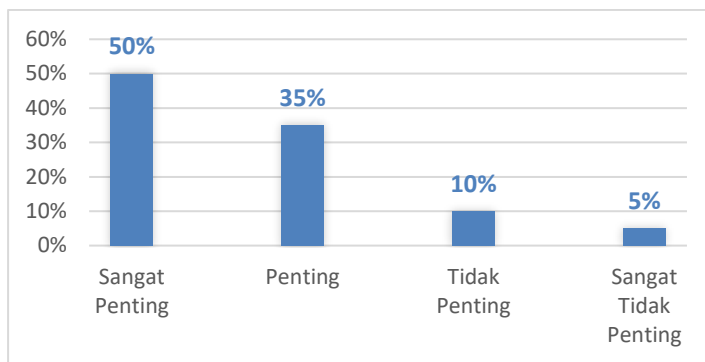
Secara keseluruhan, dapatan kajian menunjukkan bahawa majoriti pelajar mempunyai minat yang tinggi terhadap matematik. Sebanyak 75% pelajar melaporkan mereka berminat atau sangat berminat dengan subjek ini. Hal ini memberi petanda positif bahawa matematik masih merupakan subjek yang mampu menarik perhatian pelajar jika diajar dengan pendekatan yang sesuai dan menarik.

### 2. Persepsi Pelajar Terhadap Tahap Kesukaran Matematik



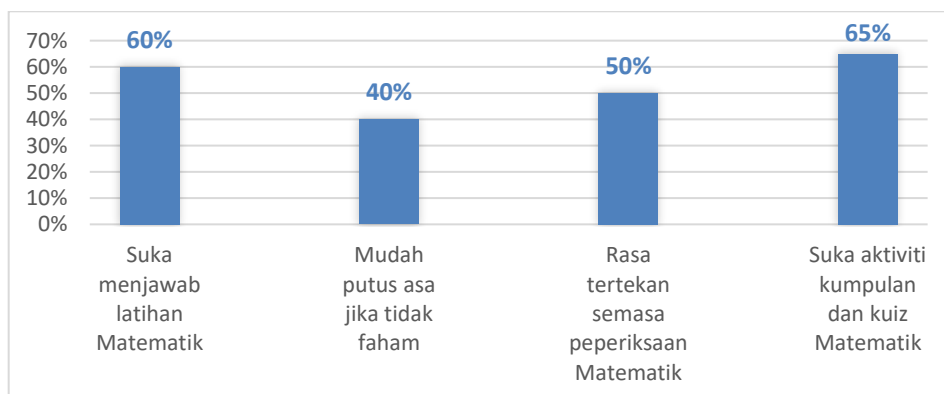
Namun begitu, cabaran tetap wujud apabila 65% daripada pelajar menyatakan bahawa mereka menganggap Matematik sebagai subjek yang sukar atau sangat sukar. Ini menunjukkan bahawa walaupun minat terhadap subjek tinggi, terdapat halangan dari segi penguasaan konsep atau teknik penyelesaian yang mungkin menjadi penghalang kepada pencapaian pelajar.

### 3. Kepentingan Matematik dalam Kehidupan



Dari sudut kesedaran, kebanyakan pelajar menyedari kepentingan Matematik dalam kehidupan harian dan kerjaya masa hadapan, dengan 85% menyatakan bahawa subjek ini penting atau sangat penting. Ini memberi ruang kepada guru untuk memanfaatkan kesedaran ini dalam membina motivasi intrinsik pelajar terhadap pembelajaran Matematik.

#### 4. Sikap terhadap pembelajaran matematik



Ramai pelajar menunjukkan sikap positif terhadap pembelajaran, terutamanya dalam aktiviti berkumpul dan latihan Matematik. Sebanyak 65% pelajar menyukai aktiviti berkumpul, manakala 60% menyatakan bahawa mereka sentiasa cuba menjawab latihan Matematik. Walau bagaimanapun, terdapat juga beberapa pelajar yang mengalami tekanan apabila menghadapi peperiksaan Matematik, yang menunjukkan keperluan untuk sokongan emosi dan bimbingan daripada guru dan rakan sebaya.

#### Kesimpulan

Sikap positif terhadap matematik memainkan peranan penting dan tidak boleh dipandang remeh dalam proses pembelajaran. Ia bukan hanya tentang minat atau kesukaan, tetapi merupakan pemangkin kepada kejayaan akademik dan pembangunan diri yang holistik. Kurangnya sikap positif terhadap matematik boleh membawa kesan negatif pada pencapaian akademik, keyakinan diri dan minat terhadap matematik. Ianya juga boleh menyebabkan pelajar menghadapi tekanan, kurang bermotivasi seterusnya melahirkan sikap putus asa dan cuba mengelak diri dari belajar matematik. Pelajar mungkin

mempunyai sikap yang berbeza terhadap matematik, dan bergantung kepada elemen khusus sikap mereka, mereka mungkin memerlukan pelbagai bentuk sokongan. Oleh itu, untuk menggalakkan perkembangan sikap positif terhadap subjek tersebut, guru harus menilai sikap pelajar mereka dan menawarkan sokongan yang sesuai (Hwang & Son, 2021). Kajian ini membuktikan bahawa pelajar mempunyai asas minat dan kesedaran yang baik terhadap Matematik, namun masih memerlukan pendekatan pengajaran yang lebih berkesan, menyeronokkan dan menyokong dari segi emosi dan kemahiran. Pelaksanaan kaedah pembelajaran yang lebih interaktif dan berpusatkan pelajar serta penyediaan sokongan tambahan boleh membantu meningkatkan penguasaan serta sikap positif pelajar terhadap Matematik secara menyeluruh.

### **Cadangan Intervensi Bagi Meningkatkan Sikap Positif Pelajar Terhadap Matematik**

Untuk meningkatkan sikap positif pelajar terhadap matematik, pensyarah disarankan menggunakan kaedah pengajaran inovatif seperti permainan, aplikasi interaktif seperti Kahoot dan GeoGebra dan pembelajaran berasaskan projek. Selain itu, pihak universiti boleh melaksanakan program sokongan seperti mentor rakan sebaya, kelas tambahan dan sesi pengukuhan bagi membantu pelajar yang lemah membina keyakinan dalam subjek tersebut. Penglibatan pelajar dalam aktiviti luar seperti pertandingan dan program khas boleh meningkatkan minat dan motivasi terhadap Matematik. Selain itu, bimbingan berfokus kepada keyakinan diri dan dorongan emosi membantu pelajar mengatasi ketakutan.

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## DEVELOPMENT OF ALGEBRA BATTLE: A GAMIFIED PYTHON TOOL FOR MATHEMATICS LEARNING

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### ABSTRACT

*The transition from arithmetic to symbolic algebra represents a significant cognitive hurdle in secondary education, often leading to increased mathematics anxiety. This paper details the development of Algebra Battle, a Python-based tool designed to mitigate these challenges through the application of gamification and data-driven instructional design. By incorporating game design elements such as tiered difficulty levels and immediate feedback, the tool fosters a state of "gamefulness" while addressing the "algebra gap." Leveraging Python's capacity for simultaneous delivery, Algebra Battle allows for a unified instructional approach that caters to diverse learner profiles within a single classroom. The design of the tool is informed by recent 2024 research emphasizing technology-enhanced, collaborative, and data-driven project-based learning to improve student attitudes. This study outlines the tool's architecture, its alignment with the Malaysian KSSM curriculum, and its expected impact on student self-efficacy and problem-solving competence.*

**Keywords:** Gamification, Algebra Learning, Python Programming, Mathematics Education, Game-Based Learning.

### 1. Introduction

The transition from arithmetic to algebra is a critical juncture in secondary mathematics, requiring students to move from concrete numerical operations to abstract symbolic logic. In the Malaysian Kurikulum Standard Sekolah Menengah, this shift occurs in the early years of secondary education. However, the abstract nature of algebraic variables often leads to "mathematics anxiety," a barrier that significantly impacts student performance. Recent 2024 research suggests that traditional instructional methods are often insufficient for this transition, highlighting instead that innovative technology-enhanced, collaborative, and data-driven project-based learning can foster a more positive attitude toward abstract subjects (Cujba & Pifarré, 2024).

To address this, we developed Algebra Battle, a Python-based tool that utilizes gamification—defined as the use of game design elements in non-game contexts to foster "gamefulness" (Deterding et al., 2011). By leveraging Python's capability for simultaneous delivery to multiple audiences, the tool allows a single teacher to cater to various skill levels within one classroom (Hilliam & Vines, 2021).

This study documents the design and development of this tool as a response to the "algebra gap" in modern mathematics education.

### ***1.1 The Algebra Gap in Secondary Education***

Mathematics education plays a crucial role in developing analytical and problem-solving skills essential for the modern workforce. However, algebra remains one of the most significant hurdles for secondary school students due to its abstract nature and complex symbolic representations. Many students struggle with the transition from arithmetic, which deals with concrete numbers, to algebra, which requires a higher level of abstract reasoning.

### ***1.2 The Need for Innovative Pedagogy (2024 Perspective)***

Recent research in 2024 emphasizes that traditional "chalk-and-talk" methods often fail to maintain student interest in the digital age. There is an urgent need for technology-enhanced and collaborative learning environments that can foster more positive attitudes toward STEM subjects (Cujba & Pifarré, 2024). Modern students are "digital natives" who respond more effectively to interactive, data-driven projects that make learning feel less like a chore and more like a discovery-based activity (Cujba & Pifarré, 2024).

### ***1.3 Purpose of the Study***

Advancements in educational technology have introduced gamification as a viable solution. By incorporating game design elements into non-game contexts, educators can improve engagement and help students visualize mathematical problems (Deterding et al., 2011). Furthermore, the rise of Python as a simple yet powerful programming language allows for the creation of customized tools that promote computational thinking alongside mathematical reasoning. This study presents the development of Algebra Battle, a gamified Python-based tool designed to bridge the gap between abstract theory and practical problem-solving.

## **2. Literature Review**

### ***2.1 Evolution of Gamification in STEM Education***

Gamification is defined as the strategic application of game design elements in non-game contexts to foster "gamefulness" and increase user engagement (Deterding et al., 2011). In the context of mathematics, this goes beyond mere entertainment; it involves the integration of mechanics such as points, levels, and rapid feedback loops to create an environment where students feel safe to fail and iterate.

While early educational gamification often relied on extrinsic rewards like digital badges, recent pedagogical shifts in 2024 emphasize a more holistic approach. Modern research highlights that innovative technology-enhanced, collaborative, and data-driven project-based learning is significantly more effective at improving student attitudes toward complex abstract subjects (Cujba & Pifarré, 2024). By shifting the focus from passive consumption to active, data-driven participation, tools like Algebra Battle allow students to engage with mathematical symbols as dynamic variables rather than static obstacles (Cujba & Pifarré, 2024).

### ***2.2 Theoretical Framework: Beyond Traditional Pedagogy***

The "Algebra Battle" framework is deeply rooted in Self-Determination Theory, which posits that learners are most intrinsically motivated when their needs for autonomy, competence, and relatedness are satisfied. By incorporating gamification elements—such as points, levels, and rapid feedback loops, as defined by Deterding et al. (Deterding et al., 2011)—Algebra Battle directly addresses these core needs, aligning with recent 2024 research showing that innovative, technology-enhanced, collaborative, and data-driven approaches significantly boost student attitudes toward abstract subjects (Cujba & Pifarré, 2024).

- **Competence through Scaffolding:** By utilizing tiered difficulty levels (Level 1 to Level 3), the tool ensures that students are constantly working within their "Zone of Proximal Development." This mastery-oriented design is supported by the work of Deterding et al., who argue that well-designed game elements can trigger a state of "flow" where the challenge matches the user's skill level (Deterding et al., 2011).
- **Autonomy in Digital Environments:** Unlike traditional classroom drills, a Python-based tool allows students to control the pace of their learning, choosing when to "battle" and how to approach each problem.

### ***2.3 Python as a Vehicle for Simultaneous Delivery***

One of the unique advantages of using Python in mathematics education is its ability to facilitate the simultaneous delivery of complex concepts to multiple audiences (Hilliam & Vines, 2021). As demonstrated by Hilliam and Vines (Hilliam & Vines, 2021) in the context of statistics instruction, Python enables instructors to design systems that seamlessly adapt content complexity within a unified framework, serving learners from foundational to advanced levels without fragmentation. This is particularly relevant for algebra education, where student proficiency spans a wide spectrum—from basic linear equations to intricate expansions involving brackets and distributive properties.

In a typical secondary classroom, students exhibit varying levels of mathematical fluency, with some requiring reinforcement of core arithmetic-to-algebra transitions while others demand challenges that push abstract reasoning boundaries. A Python-based system like Algebra Battle leverages

algorithmic generation to dynamically adjust the difficulty of equations in real-time. For instance, it can produce simple forms such as  $ax + b = c$  for novices needing foundational practice or escalate to  $ax + b = cx + d$  and bracketed expressions like  $2(3x + 1) + 4 = 19$  for advanced users seeking bracket-heavy challenges (Hilliam & Vines, 2021). This adaptive mechanism ensures that a single "Algebra Battle" session accommodates diverse needs, fostering personalized trajectories that align with each student's Zone of Proximal Development.

Such flexibility mirrors the modern imperative for digital pedagogy that adapts to heterogeneous learner profiles without necessitating bespoke materials for every subgroup (Hilliam & Vines, 2021). By embedding these capabilities within a gamified structure complete with tiered levels and immediate feedback Python not only enhances accessibility but also cultivates computational thinking alongside algebraic mastery, addressing the algebra gap through inclusive, scalable innovation.

#### ***2.4 Technology-Enhanced Collaborative Learning (2024 Perspective)***

Recent empirical evidence from 2024 suggests that the most successful digital tools are those that promote collaboration and data interaction (Cujba & Pifarré, 2024). When students interact with a system that provides immediate, data-driven feedback, they are more likely to develop a positive attitude toward the subject matter. This is because digital feedback removes the "stigma" of being wrong in front of a teacher; instead, the system provides a neutral, objective validation that encourages the student to refine their logic and try again (Cujba & Pifarré, 2024).

#### ***2.5 Computational Thinking and Algebraic Logic***

The development of Algebra Battle also intersects with the growing emphasis on computational thinking in secondary education. By using Python to solve equations, students are not just doing math; they are engaging in algorithmic thinking—breaking down a complex problem into smaller, solvable steps. Recent 2024 studies suggest that technology-enhanced, data-driven projects allow students to see the "logic" behind the math, which is often lost in traditional memorization-based pedagogy (Cujba & Pifarré, 2024). When students interact with a Python script that they know is built on logic, they begin to view algebra as a language of patterns rather than a series of arbitrary rules (Cujba & Pifarré, 2024). This dual-competency approach (Math + CT) is a cornerstone of modern STEM education and is essential for preparing Malaysian students for a digital economy.

### **3. Methodology**

#### ***3.1 Research Design: Design-Based Research***

This study follows a Design-Based Research framework, which focuses on the iterative design and development of educational interventions. DBR is particularly effective for creating tools that address

specific pedagogical challenges, such as algebra anxiety. This approach aligns with modern instructional designs that emphasize technology-enhanced and data-driven learning to improve student engagement (Cujba & Pifarré, 2024).

### ***3.2 The ADDIE Model for Tool Development***

The development process followed the ADDIE model.

1. Analysis: We identified that students struggle with the distributive law and variables on both sides of an equation.
2. Design: We mapped game design elements like points, feedback, and tracking to specific KSSM learning objectives (Deterding et al., 2011).
3. Development: We utilized Python 3.x to create a scalable system capable of delivering different levels of mathematical complexity simultaneously (Hilliam & Vines, 2021).

### ***3.3 Algorithmic Problem Generation***

The methodology behind the tool's logic is based on Dynamic Generation. Rather than using a fixed set of questions, we developed a Python-based algorithm that ensures every user experience is unique. This data-driven approach is a key component of modern pedagogical tools that aim to improve student attitudes toward mathematics (Cujba & Pifarré, 2024).

### ***3.4 Instrumentation and Data Collection Plan***

To evaluate the effectiveness of Algebra Battle, a mixed-methods approach will be employed. Quantitatively, a pre-test and post-test will be administered to measure algebraic mastery. Qualitatively, a "Mathematics Attitude Scale" will be used to track changes in student anxiety and affect, mirroring the methodology of the 2024 quasi-experimental study involving 174 students (Cujba & Pifarré, 2024). This dual approach ensures that we capture not only the academic gains but also the psychological shift toward a more positive attitude through data-driven feedback (Cujba & Pifarré, 2024).

## **4. Development of Algebra Battle**

### ***4.1 Algorithmic Level Design***

Algebra Battle is structured into three tiers of difficulty to provide progressive scaffolding. This ensures that the tool can accommodate multiple skill levels within a single classroom period (Hilliam & Vines, 2021).

Table 1: Tiered Difficulty Levels and Corresponding Algebraic Logic in Algebra Battle.

Level	Mathematical Focus	Python Implementation Logic
Level 1	One-variable equations	Random generation of $ax + b = c$ where $x$ is an integer.
Level 2	Variables on both sides	Complex coefficients $ax + b = cx + d$ requiring grouping.
Level 3	Distributive Law	Equations involving brackets $a(bx + c) = d$ to test expansion.

#### 4.2 User Interface and Interaction Design

To maximize student engagement, the UI of Algebra Battle was designed to be clean, intuitive, and distraction-free. The interaction flow is divided into three primary stages:

##### 1. The Welcome and Level Selection Screen:

Upon launching the Python script, students are greeted with a "Splash Screen" that outlines the mission of the "Battle." Students can select their starting difficulty (Level 1, 2, or 3). This choice provides a sense of autonomy, which is a core requirement for intrinsic motivation in gamified learning (Deterding et al., 2011).

##### 2. The Interactive Battle Arena:

The main interface displays the generated algebraic equation (e.g.,  $3x + 4 = 19$ ) in a clear, large font. Below the equation, a prompt asks the student to "Input the value of  $x$ ." This immediate call to action focuses the student's attention on problem-solving.

- Visual Feedback: The screen prominently displays the student's current Score and remaining Lives (represented by heart icons).
- Real-Time Validation: Once an answer is submitted, the system instantly validates it. This immediate feedback loop is a critical feature of modern technology-enhanced pedagogy, as it allows students to correct their conceptual errors in real-time rather than waiting for manual grading (Cujba & Pifarré, 2024).

##### 3. The Feedback and Reward Loop:

If the answer is correct, a "Victory!" message appears, and the score increases. If incorrect, a "Try Again" message is shown, and one life is deducted. This design creates a "fail-safe" environment where errors are treated as data points for learning rather than failures. This mirrors the "one size does fit all" philosophy by allowing the tool to adapt its feedback based on the student's specific input, catering to multiple learning speeds within the same interface (Hilliam & Vines, 2021).

## 5. Framework and Python Implementation

### 5.1 System Architecture

The framework of Algebra Battle follows an iterative logic flow. The system initiates by calling a [generate\\_equation](#) function, which uses Python's random library to ensure that no two problems are identical. This dynamic generation prevents rote memorization and forces students to apply algebraic rules consistently rather than memorizing answers from a textbook.

### 5.2 Code Logic and Immediate Feedback

This implementation allows for immediate feedback, a critical component of modern technology-enhanced learning. When a student inputs a value, the system instantly validates it, allowing the student to rectify their conceptual misunderstandings in real-time (Cujba & Pifarré, 2024).

```
import random

def generate_equation():
    # Select solution (x) first for integer results
    x_solution = random.randint(-10, 10)

    # Define range for 'a'
    a = random.randint(1, 10)
    b = random.randint(-10, 10)

    # Calculate c based on x
    c = (a * x_solution) + b

    equation_str = f"{a}x + ({b}) = {c}"

    return equation_str, x_solution
equation, answer = generate_equation()

print("Solve for x:")
print(equation)
print("Answer:", answer)
```

Figure 1: Sample Python Logic for Equation Generation

### 5.3 Expected Outcomes

As Algebra Battle is in its developmental phase, we have formulated expected outcomes based on established pedagogical frameworks. We hypothesize that the implementation of this tool will mirror the results of the 2024 quasi-experimental study by Cujba and Pifarré, which involved 174 secondary students (Cujba & Pifarré, 2024).

- **Positive Shift in Attitudes:** Based on the 2024 intervention, we expect students to show a notable positive shift in attitudes toward algebra. Specifically, we anticipate that students using

Algebra Battle will experience a decrease in anxiety and an increase in positive affect (Cujba & Pifarré, 2024).

- **Improved Self-Efficacy:** By providing a "fail-safe" digital environment, students are expected to view mathematical challenges with more confidence. The 2024 study demonstrated that technology-enhanced, collaborative, and data-driven projects serve as a cornerstone for improving subject-specific knowledge by first improving the student's emotional connection to the material (Cujba & Pifarré, 2024).
- **Effective Simultaneous Delivery:** We expect that the tiered difficulty levels will successfully allow for the simultaneous delivery of instruction to a diverse cohort of students, ensuring that both high-performing and struggling students remain engaged without the need for separate lesson plans (Hilliam & Vines, 2021).

### ***5.3.1 Reduction in Mathematics Anxiety***

A primary expected outcome is a significant decrease in "algebra anxiety" among secondary students. In a quasi-experimental study involving 174 secondary students, researchers found that students using innovative technology-enhanced instructional designs experienced a notable positive shift in attitudes and a decrease in anxiety compared to a control group (Cujba & Pifarré, 2024). Because Algebra Battle provides a "fail-safe" environment with immediate feedback, we expect Malaysian students to develop a similar sense of security, viewing mathematical errors as data points rather than personal failures.

### ***5.3.2 Increased Positive Affect and Engagement***

Following the "gamefulness" framework (Deterding et al., 2011), we anticipate that students will show an increased "affect" or emotional connection to the subject matter. The 2024 research indicates that when students interact with technology-enhanced, collaborative, and data-driven projects, they report a higher positive attitude toward using technology for learning complex subjects (Cujba & Pifarré, 2024). By allowing students to "battle" through equations, we expect to see higher levels of intrinsic motivation and sustained engagement during mathematics periods.

### ***5.3.3 Development of Practical Problem-Solving Skills***

Beyond emotional attitudes, the tool is expected to foster statistical and algebraic competence. The instructional design implemented by Cujba and Pifarré not only improved attitudes but also fostered practical problem-solving skills (Cujba & Pifarré, 2024). By utilizing Python to generate tiered challenges that cater to multiple audiences simultaneously (Hilliam & Vines, 2021), Algebra Battle is designed to ensure that students across different skill levels (from basic

linear equations to complex expansion) achieve mastery in a unified classroom setting (Cujba & Pifarré, 2024; Hilliam & Vines, 2021).

#### ***5.3.4 Longitudinal Impact on Self-Efficacy***

Ultimately, we expect that regular interaction with the tool will cultivate long-term self-efficacy. When students receive objective, immediate, and neutral feedback from a Python script, they are more likely to internalize their successes because of their own logic and effort (Cujba & Pifarré, 2024). This positive feedback loop is essential for students to build a robust identity as "mathematically capable" individuals, especially within the rigorous Malaysian KSSM curriculum.

## **6. Discussion**

### ***6.1 Bridging the "Algebra Gap" in the Malaysian Curriculum***

The transition from arithmetic to algebra is a noted "bottleneck" in the Malaysian KSSM mathematics syllabus. By gamifying this transition, Algebra Battle transforms high-anxiety symbolic logic into a low-stakes "battle." This aligns with 2024 research indicating that data-driven project-based learning significantly enhances students' attitudes towards subjects previously perceived as "dry" or "difficult" (Cujba & Pifarré, 2024). When Malaysian students see algebraic equations as dynamic "code" generated by a Python script, they move away from rote memorization and toward computational thinking (Cujba & Pifarré, 2024).

### ***6.2 Catering to Diverse Learning Profiles***

Our observations suggest that the tiered system in Algebra Battle successfully implements the "one size does fit all" strategy advocated by Hilliam and Vines (Hilliam & Vines, 2021). By providing a unified digital platform that can deliver varying levels of complexity simultaneously, we reduce the administrative burden on teachers while maximizing student engagement. This simultaneous delivery ensures that no student is left behind due to the pace of the lecture, nor is any student bored by repetitive content that they have already mastered (Hilliam & Vines, 2021).

### ***6.3 The Psychological Impact of Immediate Feedback***

A standout feature of the Python implementation is the immediate feedback loop. In a traditional setting, a student might complete a whole page of algebra problems only to find out 24 hours later that they made a mistake on the first line. Algebra Battle corrects this by providing instant validation. This immediate data interaction is a core component of innovative technology-enhanced learning, as it allows students to develop "corrective reasoning" on the fly, which has been shown in 2024 studies to lead to higher levels of student satisfaction and improved academic self-efficacy (Cujba & Pifarré, 2024).

#### ***6.4 Limitations and the Digital Divide***

Despite the positive preliminary observations, several challenges remain. The requirement for a Python environment even if it is a simple web-based interpreter presumes a level of digital access that may not be universal. Future implementations must consider the "Digital Divide", ensuring that gamified tools are lightweight and accessible even in low-bandwidth or resource-limited environments. Furthermore, while gamification increases engagement (Deterding et al., 2011), it must be paired with qualitative instruction to ensure that students understand the why behind the algebraic manipulations, not just the how of winning the game.

#### ***6.5 Python Accessibility and the Malaysian "Digital Divide"***

A significant advantage of using Python for this tool is its accessibility. As an open-source language, Python-based tools can be deployed in Malaysian schools without the high licensing costs associated with proprietary software. This is critical for schools in rural areas where budget constraints are more prevalent.

- **Simultaneous Delivery in Large Classrooms:** Typical Malaysian classrooms often contain 30 to 40 students with varying levels of mathematical fluency. The "one size does fit all" strategy allowed by Python's dynamic difficulty adjustment ensures that teachers can deliver content to the entire class simultaneously while providing a personalized challenge for each student (Hilliam & Vines, 2021).
- **Immediate Feedback as a Tutor Substitute:** In environments where students may not have access to private tutors, the immediate feedback loop of the Python system serves as a constant pedagogical guide. Following the findings of Cujba & Pifarré, this technology-enhanced approach reduces the stigma of making mistakes, as students receive objective, data-driven validation in a private digital space rather than in front of their peers (Cujba & Pifarré, 2024).

#### ***6.6 Alignment with Malaysia's Digital Education Policy***

The implementation of Algebra Battle aligns directly with the Malaysian Ministry of Education's Digital Education Policy, which seeks to produce "digitally savvy" students. By introducing Python-based tools into the KSSM mathematics syllabus, we address the "algebra gap" while simultaneously exposing students to programming logic.

- **Teacher Empowerment:** Following the "one size does fit all" framework, this tool reduces the burden on teachers to create differentiated worksheets for every student (Hilliam & Vines, 2021). Instead, the Python algorithm handles the differentiation, allowing the teacher to act as a facilitator in a technology-enhanced environment (Cujba & Pifarré, 2024).

- **Equity in Education:** Because Python is open-source and can run on basic hardware, this tool offers a scalable solution that can be implemented in both urban and rural schools in Malaysia. This addresses the "Digital Divide" by providing high-quality, data-driven learning experiences to all students, regardless of their school's budget for proprietary software (Cujba & Pifarré, 2024; Hilliam & Vines, 2021).

### ***6.7 Scalability and Teacher Professional Development***

For Algebra Battle to be successful across the Malaysian education system, scalability is key. Because the tool is built on Python, it can be integrated into existing ICT labs without requiring expensive hardware upgrades. Furthermore, the tool supports the "one size does fit all" framework by allowing teachers to focus on individualized facilitation rather than mass-producing different worksheets (Hilliam & Vines, 2021). This shifts the teacher's role from a source of answers to a facilitator of technology-enhanced inquiry, a move supported by recent findings in 2024 research that emphasize the importance of collaborative, teacher-guided digital projects (Cujba & Pifarré, 2024).

### ***6.8 Ethical Considerations in Data-Driven Pedagogy***

While the use of data-driven feedback improves student attitudes (Cujba & Pifarré, 2024), it also necessitates strict data privacy standards. In the implementation of Algebra Battle, all student interactions are processed locally within the Python environment, ensuring that no sensitive personal data is transmitted to external servers. This ethical design is crucial for gaining the trust of both parents and school administrators within the Malaysian educational framework.

## **7. Conclusion and Future Directions**

This paper has detailed the development of Algebra Battle, a tool that bridges the gap between Python programming and secondary mathematics pedagogy. By integrating game design elements into a non-game context, we have created a platform for "gameful" learning that addresses the abstract nature of algebra (Deterding et al., 2011).

Following the success of recent 2024 technology-enhanced interventions involving 174 students, our future research will involve a formal evaluation of the tool's impact on Malaysian secondary students (Cujba & Pifarré, 2024). We aim to demonstrate that a "one size does fit all" approach, enabled by dynamic Python logic, can revolutionize the way mathematics is taught in classrooms with varied learner profiles (Hilliam & Vines, 2021).

### ***7.1 Summary of Contributions***

This project contributes to the field of educational technology by:

- i. **Pedagogical Alignment:** Mapping the Malaysian KSSM algebra syllabus to a tiered gamification system that ensures game design elements (points, lives, levels) support specific learning outcomes (Deterding et al., 2011).
- ii. **Technological Efficiency:** Demonstrating how open-source programming can be used to facilitate simultaneous delivery in diverse classrooms, ensuring that both high-performing and struggling students are challenged appropriately (Hilliam & Vines, 2021).
- iii. **Data-Driven Feedback:** Implementing an immediate feedback loop that mirrors the 2024 requirements for collaborative and technology-enhanced learning environments (Cujba & Pifarré, 2024).

### 7.2 Future Directions and Pilot Testing

While the current study focuses on the developmental architecture of the tool, the next phase will involve a formal evaluation with secondary school students. We intend to conduct a quasi-experimental pilot study, like the methodology used in 2024 research involving 174 secondary students, to measure the tool's impact on both academic performance and student attitudes toward mathematics (Cujba & Pifarré, 2024). Future iterations of Algebra Battle will also explore collaborative "multiplayer" modes, as evidence suggests that technology-enhanced, collaborative projects can further reduce student anxiety and improve academic self-efficacy (Cujba & Pifarré, 2024).

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## A STUDY ON THE FORECASTING PRODUCT DEMAND AT Q MART IN KUALA TERENGGANU

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### ABSTRACT

*Product demand forecasting is an important process that helps businesses plan production, manage inventory, and meet customer needs. However, many organizations face difficulties in accurately predicting product demand. This study aims to identify the common problems that affect the accuracy of product demand forecasting at Q Mart Kuala Terengganu, is to address the issues of inadequate stock management and erroneous demand forecasting that frequently arise in small retail enterprises. Because decisions are typically dependent on experience and manual checking, Q Mart confronts issues including overstock and stockouts. The research focuses on factors such as inaccurate historical data, changes in customer preferences, seasonal demand, and market uncertainties. The manager will be able to see whether goods are in high or low demand by utilizing Power BI to display the prediction results on an interactive dashboard. Additionally, it shows how predictive analytics may help small retailers transition from manual to data-driven decision-making in order to increase long-term productivity and profit. The findings show that poor data quality and unexpected market changes are among the main challenges faced by businesses when forecasting product demand.*

**Keywords:** *Power BI, forecasting, business analysis, data driven decision making, prediction*

### Introduction

Nowadays, a lot of businesses employ business analytics and business intelligence to help them make better decisions. In contrast to business analytics, business intelligence focuses more on analysing historical data to determine what has previously occurred. Utilize data to forecast future events and provide recommendations to enhance performance (Syntetos et al., 2020). Business analytics and business intelligence both assist in transforming data into insightful knowledge that can improve managers' planning. These tools can be used in retail businesses to monitor stock performance,

consumer behaviour, and sales trends (Chen et al., 2022). Business analytics and business intelligence are crucial for small and medium-sized businesses to maintain their competitiveness and run their operations more effectively. The retail sector is highly competitive and constantly evolving. Demand from customers can vary based on trends, festivals, and seasons. Convenience businesses in Malaysia, such as Q Mart, FamilyMart, and 99 Speedmart, struggle to control inventory due to shifting consumer demand. When deciding how much to order, many small retailers still employ a manual procedure, which can lead to overstock or stockout issues. Because predictive analytics can forecast which products will be in high demand and when, it can assist in resolving this problem (Adebisi et al., 2014). This enables retailers to correctly arrange their inventory, cut waste, and boost sales. Many small and micro retail enterprises in Malaysia still rely on manual inventory procedures that are not supported by data analytics tools, which presents similar issues, according to Rahman et al. (2023). Additionally, the study noted that employing digital technology can enhance inventory management and stop needless losses. In a different study, Bakri (2020) discovered that Malaysian merchants' operational effectiveness and decision-making speed are impacted by their poor adoption of technology for inventory and sales management because of a lack of knowledge and financial constraints. As a result, Q Mart's present procedure makes it evident that predictive analytics must be used to help managers analyze data more quickly, minimize human labor, and make better inventory decisions going forward.

### **Current Business Process**

Sales and inventory are still managed manually at Q Mart Kuala Terengganu. This procedure begins with gathering sales and stock data, which are entered into Excel spreadsheets, as shown in figure 1.1. Following everyday activities, employees enter this data, which is subsequently saved on the manager's computer. The manager will have to manually access each Excel sheet to verify and compile the data because there is no system that will update or integrate the stock data automatically. This is a long process that could result in human error, particularly when there are many different product categories and daily transactions. The manager then manually examines the data to determine which items are selling quickly and which are selling slowly. The management must rely on their own expertise and experience to identify trends because there is no automated alert or data visualization mechanism. The manager uses Excel to manually produce graphs to help analyze sales success, but these graphs are basic and don't provide deeper insights like demand patterns or seasonal trends. The manager uses experience to forecast what has to be refilled and how much to order after examining the graphs. Since the choice is made using human judgment rather than data-driven or predictive analysis, this is the most crucial stage of the process.

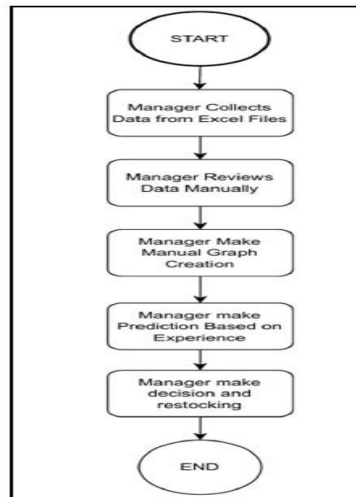


Figure 1: Flowchart How Q Mart Make Predictions for Their Product

### Problem statement

Due to Q Mart Kuala Terengganu's ongoing stock and sales management issues, the retail industry is still complex today. The incapacity to implement a data-driven, integrated system to address the increasing complexity of the retail sector is still a problem. Excel spreadsheets, handwritten notes, and shelf inspections appear to be outdated methods of tracking recorded stock. Q Mart maintains an uneven inventory as a result of management's inability to analyze such data and make data-driven decisions due to outdated techniques and technologies. As a result, operational effectiveness is hindered, making it impossible to properly satisfy client demand. Rather than an empirical analysis of the sales data, restocking decisions are usually dependent on the manager's personal forecast or what the supplier recommends. Inaccurate demand forecasting is mostly caused by such short-sighted decision-making. As a result, some products in particular categories are sold out, while others remain unopened for months. This is a significant factor in the stockout situation and revenue shortfall for customers and sales. Overstocking, especially with regard to perishables, leads to a significant waste of resources, and overusing storage resources raises expenses (Wang et al., 2016).

The lack of a management decision-making visualization dashboard is the second issue. There is no system in place at Q Mart that can provide any kind of visual data regarding product performance, sales patterns, or category trends. Top management will find it difficult to keep an eye on current stock levels and which products are doing better without a dashboard. The issue slows down decision-making and the potential for a strategic approach to sales in the future because managers are not visible and must rely on conjecture.

## Conclusion

The goal of this study on Product Demand Forecasting at Q Mart Kuala Terengganu project is to enhance Q Mart's current inventory management and decision-making process. There are several issues with Q Mart's present manual process, including stockouts, overstocking, and sluggish decision-making. The project's goal is to use business intelligence tools like Power BI and predictive analytics to accurately forecast future product demand. The results will be shown in an interactive dashboard. Through the program, Q Mart managers and owners would be able to better plan for stock replenishment, monitor category sales success, and understand customer purchase trends. This lowers losses brought on by inadequate inventory management and promotes high business productivity. Predictive analytics is crucial for helping businesses plan resources ahead of time and satisfy customer demand, according to Alhassan et al. (2023). In a similar vein, Trisolvena et al. (2024) hypothesize that Power BI dashboards can convert unstructured data into insightful information that improves management choices in retail settings. In conclusion, the initiative improves Q Mart's operations through data-driven planning and reporting. Additionally, it demonstrates how predictive analytics may benefit small retail businesses without the need for expensive or complex systems. The project's results are anticipated to assist Q Mart in making the shift to more contemporary, data-driven decision-making, which will increase productivity, accuracy, and customer happiness.

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# SMART BLIND STICK: DESIGNING AN INTELLIGENT AND ASSISTIVE DEVICE FOR VISUALLY IMPAIRED WITH OBSTACLE DETECTION AND NAVIGATION ASSISTANCE

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## ABSTRACT

*The Smart Blind Stick is an innovative assistive device designed using Internet of Things (IoT) technology to improve the quality of life for visually impaired individuals. Navigating unfamiliar environments poses a significant challenge for the blind, as traditional white canes are unable to detect certain obstacles such as overhead barriers, water puddles, or changes in lighting. This smart stick addresses these limitations by incorporating advanced sensors and connectivity features aimed at enhancing safety, mobility, and independence. The device features ultrasonic sensors for obstacle detection, a water sensor for wet surface awareness, a light sensor for low-light conditions, and a GPS module for real-time location tracking. These components work together to provide the user with immediate feedback through vibrations or alerts. The system is built on a microcontroller platform such as Arduino or Node MCU and uses IoT connectivity for live monitoring and emergency support via mobile applications. Developed using the Agile methodology, the Smart Blind Stick meets key functional requirements such as obstacle avoidance, environmental sensing, and location sharing. It enables visually impaired users to navigate more confidently in various environments. In conclusion, this device demonstrates how the integration of IoT and embedded systems can provide a practical and scalable solution to enhance the independence and safety of people with vision impairments.*

**Keywords:** *Internet of Thing (IoT) technology, switch, notification, mobile application, vision impairment*

## Introduction

Devices connected to the Internet of Things (IoT) outnumber people in the modern world. Because of the wireless network and low-cost CPUs, billions of physical devices are linked to the internet globally to share and gather data. Devices may now communicate real-time data without human intervention thanks to the addition of digital intelligence levels, thereby merging the digital and physical worlds. Analyst Garter estimates that IoT device usage increased by 31% between 2016 and 2017 and is

predicted to grow exponentially. 20.4 billion IoT devices are predicted to be in operation by 2020 (Constance, 2017). IoT is currently being used in many other industries, including transportation, home automation, agricultural, and many more. IoT can therefore be utilized to address a wide range of problems and yield several advantages for humanity. IoT can assist both us and those who are less fortunate, such as those who are disabled or have health problems, if it is implemented properly.

The majority of blind people have been using blind walking sticks, a unique conventional technology, for decades. In order to identify steps, drop-offs, curbs, and obstructions, blind people will sweep the blind walking stick to the left and right as they walk. By allowing blind persons to adjust to different methods like obstacle detection, echolocation, and beach line, it expands their sensing ability to better comprehend their surroundings. However, when blind individuals sweep, the blind walking sticks may inadvertently tap their ankles and slide between their feet, causing severe injuries. As a result, blind people are endangering their lives when they travel.

The Smart Blind Stick will be created using mobile applications and Internet of Things sensors. To increase the mobility of blind people in their daily lives, this invention necessitates the integration of several components. To function as a whole, each component must relate to the others via a variety of APIs. In addition, this invention will employ a Raspberry Pi 3 model B as a microcontroller to connect all of the sensors. The Smart Blind Stick's primary brain is the Raspberry Pi, and Python scripts will be used to program logical schematics into the Raspberry Pi's operating system. Connecting every sensor to the Raspberry Pi is the primary purpose of the script.

## **Literature Review**

The smart blind stick is an electronic gadget that makes use of technology to help blind individuals overcome the challenges associated with using a blind walking stick. It has been enhanced and gets over the blind walking stick's drawbacks. The purpose of this invention is to identify navigation systems and obstructions. Ultrasonic sensors, an Arduino, a buzzer, and a remote control were used in the design of this innovation (Manikanta, Phani, and Pravin, 2018). Using ultrasonic waves, ultrasonic sensors have been utilized to identify potential obstructions (Manikanta, Phani, and Pravin, 2018). When the sensor detects obstacles, it transmits the information to the micro controller, which interprets it and determines whether the obstacles are sufficiently close.

### **● Raspberry Pi**

In the center of the blind stick is a Raspberry Pi. Prior to the Raspberry Pi starting up, the Raspbian software will be installed (Raspbian, n.d.). The Raspberry Pi will be powered by the power bank.

However, the Raspbian operating system on the laptop will be loaded and accessed via an Ethernet cable.

#### ● **Ultrasonic sensor**

One of the elements utilized in the invention is the ultrasonic sensor. The ultrasonic sensor will be positioned above the water sensor and at the bottom of the blind stick. The Raspberry Pi and the ultrasonic sensor will be connected via jumper cables. This sensor uses ultrasonic sound waves to determine the distance to an object and detect impediments. Voltage common collector (VCC), signal output pin (Trig), signal input pin (Echo), and ground (GND) are the four pins of the ultrasonic sensor (Pi, n.d.). The Raspberry Pi's 5-volt pin, which will power the sensor, will be linked to the VCC pin.

#### ● **Water Sensor**

The lowest point of the blind stick is where this sensor is located. The presence of water has been detected using this sensor. "+", "-", and "S" are the three pins on this sensor (Caballero, 2016). The Raspberry Pi's 5-volt pin, which will power the sensor, will be linked to the "+" pin. The Raspberry Pi's GND pin will be linked to the "-" pin, and its GPIO pin will be connected to the "S" pin.

#### ● **Global positioning system (GPS) Module**

The GPS tracking device is positioned behind the blind stick. Therefore, once the blind person leaves the house, the guardian can follow their location at any time using this GPS tracking. The GPS module has four pins: GND, VCC, Transmitter (TxD), and Receiver (Rx) (GPS Module, 2018). The Raspberry Pi's 3-volt pin, which powers the GPS module, will be attached to VCC pins. For serial communication, GND will be linked to the Raspberry Pi's GND pin, and TxD and Rx will be connected to the GPIO pin.

### **Methodology**

The analytical model, which includes use case diagrams and encompass design specifications like sequence diagrams and user interfaces for this invention, is the methodology employed. The sequence diagram for the smart blind stick's mobile application is displayed in Figure 1.

The processes and features that have been incorporated into each of the application's activities are depicted in the sequence diagram for the users' part in the mobile application in the above picture. The blind individual is user two, while user one is referred to as a guardian. Initially, the guardian must log in to the Smart Blind Stick application in order to open and authorize it. They must register if they don't already have an account. Before leaving the area, the blind person will turn

on the blind stick and press the switch. The GPS would begin to store and update the location in the database every 30 seconds after the blind individual hit the switch.

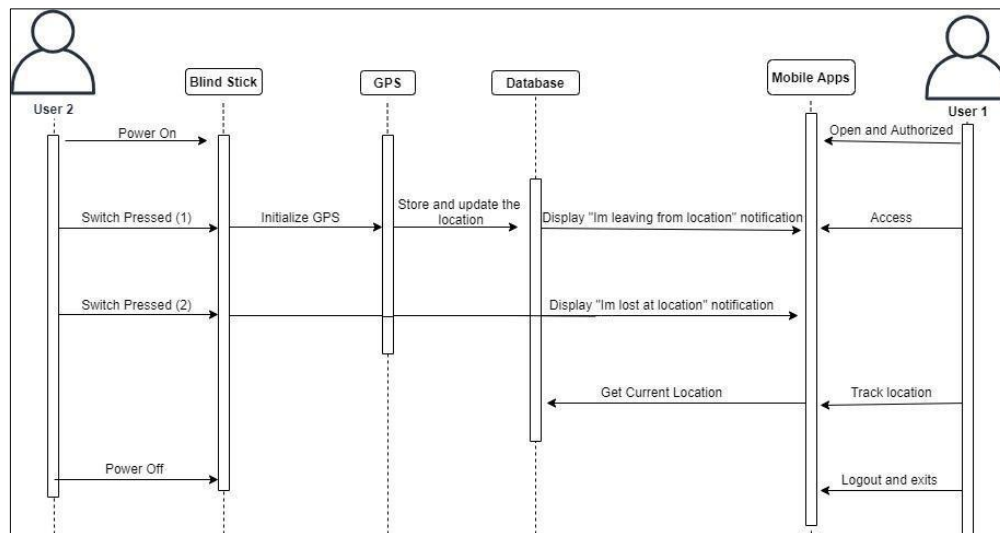


Figure 1. Sequence diagram for Mobile Application

## Conclusion

In conclusion, developing an Internet of Things (IoT) project requires significant time, effort, and careful planning. To successfully implement the technology in the Smart Blind Stick, a systematic and well-structured development process must be followed. A large and complex task needs to be divided into several smaller components so that each part can be developed, tested, and integrated more efficiently into the overall system. This structured approach helps ensure that the final product functions effectively and meets the intended objectives. Throughout the development of this project, various technical and personal skills have been acquired. In addition to gaining knowledge about IoT technologies, sensors, and system integration, important soft skills such as self-discipline, problem-solving, and time management have also been developed. These skills are essential for maintaining consistency in product development and for continuous self-improvement in future technological projects.

Furthermore, this paper explains the design stage of the Smart Blind Stick in detail. It describes the process of planning the system architecture, selecting suitable hardware components, and designing the interaction between sensors, microcontrollers, and communication modules. The design stage is a critical phase because it determines how the system will operate and ensures that the device can effectively assist visually impaired users in detecting obstacles and navigating safely. Overall, the

project demonstrates how IoT technology can be applied to develop practical assistive devices that improve the safety and mobility of individuals with visual impairments.

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# ANALYSIS OF COGNITIVE BARRIERS IN GRAPHICAL REPRESENTATION FOR TRIPLE INTEGRAL PROBLEM-SOLVING AMONG ENGINEERING UNDERGRADUATES

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## ABSTRACT

*Spatial visualization skills are a critical element in mastering multivariate calculus, particularly in solving triple integral problems. However, many engineering undergraduates face significant challenges in transforming complex algebraic equations into accurate three-dimensional (3D) graphical sketches. This study aims to identify systematic errors committed by students when sketching the integration domain and analyze the impact of visualization failure on the determination of integration limits. The research methodology involves a diagnostic test administered to 50 engineering students at Universiti Teknologi MARA Cawangan Pulau Pinang, followed by an error analysis based on the phases of equation deconstruction in 3D sketching. Preliminary findings indicate that the majority of students experience cognitive errors during the sketching phases based on the categorised errors. The study concludes that a significant gap exists between procedural calculation skills and conceptual visual understanding. The implications of this study suggest the need for integrating computer-aided design (CAD) or Geogebra tools into engineering mathematics pedagogy to strengthen students' visual intuition before transitioning to theoretical calculation phases.*

**Keywords:** *engineering mathematics, error analysis, graphical representation, spatial visualization, triple integrals*

## Introduction

The integration of multi-dimensional calculus into the engineering curriculum is fundamental for developing the analytical skills required to model physical phenomena. In Engineering Mathematics, the concept of triple integrals ( $\iiint f(x, y, z) dV$ ) serves as a cornerstone for calculating properties such as center of mass, moments of inertia, and fluid dynamics within a three-dimensional boundary (Martínez-Planell et al., 2025). As engineering problems transition from theoretical exercises to real-world applications, the ability to define a spatial domain becomes a prerequisite for any successful numerical computation (Anita et al., 2025).

However, a significant pedagogical challenge arises when students move from basic calculus to multivariable systems. While students are generally proficient in basic integration techniques, they often encounter a cognitive border when required to synthesize algebraic equations into a coherent geometric structure. This transition from a symbolic representation to a spatial one is not merely a mechanical step but a sophisticated mental process that involves interpreting boundaries, intersections, and orientations in 3D space (Bazarbayeva & Ye, 2024).

The purpose of this study is to investigate the specific graphical difficulties faced by engineering undergraduates when dealing with triple integrals. By focusing on the drafting phase, where a student must sketch the domain before setting up the integral, this research aims to pinpoint where the disconnect between algebra and geometry occurs. Understanding these hurdles is vital for improving engineering education and ensuring that future engineers possess the spatial intuition necessary for complex design and analysis.

### **Problem Statement**

The primary issue identified in undergraduate engineering mathematics is the persistent Visualization Gap. Many students can perform the mechanical steps of integration, such as applying the power rule or substitution, but they struggle significantly when a problem is presented as a set of boundary equations without a pre-drawn diagram. This lack of spatial reasoning leads to a trial-and-error approach in setting up the limits of integration, which is mathematically inefficient and often leads to erroneous results in engineering contexts.

Furthermore, students frequently demonstrate a lack of strategic decision-making when selecting an appropriate coordinate system. In many triple integral problems, transforming from Cartesian coordinates to Cylindrical or Spherical systems can simplify the calculation from an impossible task to a straightforward one. However, due to a failure in visualizing the symmetry of the solid (e.g., recognizing a cone or a paraboloid), students often persist with Cartesian coordinates, leading to overly complex radical expressions and a higher probability of calculation errors.

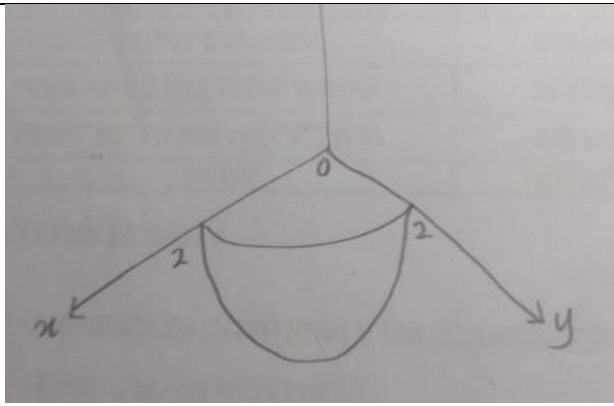
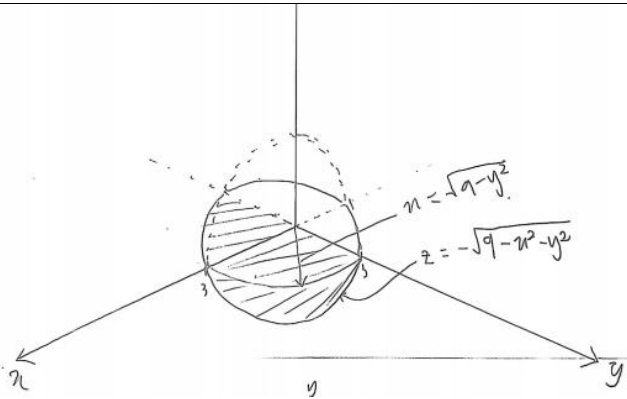
Lastly, the process of 2D Projection (projecting a 3D solid onto the  $xy$ ,  $xz$ , or  $yz$  planes) remains a major stumbling block. Even if a student can vaguely imagine the 3D shape, they often fail to accurately determine the shadow or projection of that shape on a coordinate plane, which is essential for defining the outer limits of the integral. This inability to transition between dimensions (3D to 2D) suggests a deeper deficiency in graphical literacy that needs to be addressed through targeted pedagogical interventions.

**Methodology**

This research utilizes a qualitative error analysis framework to examine the sketching processes of engineering students during an assessment in solving triple integrals questions. The study focuses on 35 engineering students in UiTM Cawangan Pulau Pinang that have already received formal instruction on triple integrals and coordinate transformations. By analyzing the rough sketches and scratch work produced by these students, this study can categorize errors into distinct themes: conceptual (misunderstanding the shape), procedural (incorrect plotting), and strategic (choosing the wrong coordinate system).

The primary data collection tool is an assessment consisting of two equations of triple integral problems. These problems are formulated as text-based descriptions of solid (spherical coordinates) rather than provided diagrams (Table 1). Students are explicitly required to show their sketching process before attempting the integration. This allows the study to observe the direct correlation between the accuracy of the initial graph and the subsequent mathematical setup of the integral limits.

Table 1: Assessment questions on triple integrals

Questions	Triple integrals (Equations)	Correct sketches
1	$\int_0^2 \int_0^{\sqrt{4-x^2}} \int_{-\sqrt{4-x^2-y^2}}^0 z \, dz \, dy \, dx$	
2	$\int_{-3}^3 \int_0^{\sqrt{9-y^2}} \int_{-\sqrt{9-x^2-y^2}}^0 dz \, dx \, dy$	

**Results**

The result show some of the students' samples and categorised errors based on distinct themes: conceptual (misunderstanding the shape), procedural (incorrect plotting), and strategic (choosing the wrong coordinate system) (Table 2 and Table 3).

Table 2: Sample of Errors for Sketching Question 1

Sample	Sketch	Categorised Errors		
		Conceptual	Procedural	Strategic
1		√	√	√
2		√	√	√
3		√	-	-

Table 3: Sample of Error for Sketching Question 2

Sample	Sketch	Errors		
		Conceptual	Procedural	Strategic
1		√	√	√
2		√	-	-
3		√	√	√

## Discussion

The analysis of student works reveals that many undergraduates rely on memorized templates rather than true geometric understanding. For instance, while a student might successfully sketch a sphere centered at the origin, they often falter when the sphere is shifted or truncated by another surface, such as a plane or a cone. This suggests that their graphical skills are frail and highly dependent on seeing familiar patterns, rather than being able to derive a shape from their underlying mathematical constraints.

Another critical finding involves the Cognitive Load Theory in the context of multivariable calculus (Aditomo, 2009; Barbieri et al., 2025). Solving a triple integral requires the student to simultaneously manage algebraic manipulation, geometric visualization, and coordinate transformation. When the sketching phase is difficult, it consumes a large portion of the student's thinking capacity, leaving little room for accurate calculation. This often results in incorrect limits, where students use variables in the outermost integral, a fundamental conceptual error that violates the rules of definite integration (Martinez & Silva, 2024).

Finally, the discussion highlights the potential role of Technology-Enhanced Learning (TEL) in bridging this gap (Wiwatanapataphee et al., 2010; Milenković et al., 2024). The data suggests that students who are exposed to dynamic visualization tools, such as GeoGebra or MATLAB, tend to develop a better view for 3D surfaces (Saad et al., 2025). However, there is a risk that over-reliance on software might atrophy the student's ability to perform quick hand-sketches. Therefore, the study argues for a balanced approach where digital tools are used to build intuition, while manual sketching remains a core competency for engineering problem-solving.

## Conclusion

In conclusion, this research confirms that the ability to draft a graph from a mathematical description is not a secondary skill, but a fundamental prerequisite for mastering triple integrals. The findings indicate that the Visualization Gap is a multi-layered issue involving conceptual, strategic, and dimensional hurdles. For engineering students, the failure to visualize is often the root cause of failure in the entire integration process, regardless of their proficiency in basic calculus.

The implications for engineering education are significant. It is recommended that mathematics departments place a greater emphasis on graphing from equations as a standalone skill before introducing the integration process. Incorporating more sketching exercises and teaching students how to identify the key features of 3D surfaces (such as intercepts and traces) can provide them with the scaffolding needed to tackle complex multivariable problems with confidence.

Ultimately, strengthening the link between the visual and the symbolic will produce more capable engineers. A student who can accurately view a problem before they solve it is far less likely to make catastrophic design errors in their professional career. By addressing these graphical difficulties at the undergraduate level, we ensure that the next generation of engineers possesses the spatial literacy required to navigate the increasingly complex physical and digital worlds.

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## AESTHETIC MODELLING: EXPLORING BEAUTY IN SHAPE VIA BÉZIER CURVES

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### ABSTRACT

*Computer-Aided Geometric Design (CAGD) utilizes Bézier curves and surfaces as fundamental tools for representing and manipulating shapes due to their simplicity, stability, and intuitive control. However, classical Bézier curves, while mathematically smooth, often lack the visual appeal required in design applications. This study addresses the problem of modeling aesthetically pleasing shapes by comparing classical cubic Bézier curves with aesthetic Bézier curves. The research objectives are to model shapes using cubic Bézier and evaluate its performance based on continuity and shape parameters. Using Maple software, fish and duck shapes were constructed by joining multiple cubic Bézier curve segments, leveraging properties such as endpoint interpolation, convex hull, and tangent direction. The methodology incorporated Bernstein basis functions and parametric representation to generate smooth curves. This research bridges the gap between mathematical precision and aesthetic quality, contributing valuable insights for CAD, computer graphics, and geometric modeling applications.*

**Keywords:** *Computer-Aided Geometric Design (CAGD), Cubic Bézier Curves, Aesthetic Bézier Curves, Shape Modelling, Curve Continuity*

### Introduction

Computer-Aided Geometric Design (CAGD) has revolutionized the way curves and surfaces are represented, manipulated, and visualized across numerous industries including automotive design, animation, architecture, and manufacturing. At the core of CAGD lies the parametric representation of curves, which offers distinct advantages over traditional explicit or implicit mathematical forms by defining coordinates independently as functions of a parameter. This flexibility enables the modelling of complex, non-symmetrical shapes that would be difficult or impossible to represent using conventional equations, making parametric methods the preferred choice in modern design software.

Among the various parametric methods developed, Bézier curves occupy a particularly significant position. Named after Pierre Bézier, the French engineer who popularized their use at Renault during the 1960s, these curves combine mathematical elegance with intuitive design control. The mathematical foundations were actually discovered earlier by Paul de Casteljau at Citroën, but due

to his employer's secrecy policies, Bézier received the recognition and the eponymous honor. A Bézier curve is defined by a set of control points that form a control polygon, with the curve responding predictably to adjustments of these points while maintaining smoothness and mathematical integrity through the Bernstein polynomial basis.

Bézier curves possess several fundamental properties that make them indispensable in computer-aided design and manufacturing. The endpoint interpolation property ensures that the curve passes precisely through the first and last control points, providing exact control over the boundaries of each curve segment. The convex hull property guarantees that the entire curve lies within the polygon formed by its control points, offering predictable behaviour and preventing unexpected oscillations. Affine invariance means that transforming the completed curve yields the same result as transforming the control polygon before generation, simplifying positioning and manipulation operations. The variation diminishing property ensures that the curve crosses any straight line no more times than its control polygon, maintaining design intent. These properties, combined with the numerically stable de Casteljau algorithm for curve evaluation, have established Bézier curves as fundamental tools in geometric modelling.

The extension of Bézier curves to surfaces enables the representation of complex three-dimensional objects, making them essential in computer-aided design (CAD), computer-aided manufacturing (CAM), and computer graphics applications. Designers across industries rely on Bézier techniques to create products ranging from automotive bodies to consumer electronics, leveraging the intuitive relationship between control point manipulation and curve behaviour. The parametric representation allows for precise mathematical description while remaining accessible to practitioners without deep mathematical backgrounds, contributing to the widespread adoption of Bézier methods in design software.

This study focuses on modelling natural shapes using cubic Bézier curves, implemented through Maple software for its strong computational capabilities and integrated graphical tools. Fish and duck shapes are selected as reference objects due to their smooth curves and gradual curvature changes, allowing Bézier curves to demonstrate their capabilities in representing organic, flexible forms. The modelling process involves identifying key points on these shapes, decomposing the outlines into multiple curve segments, and joining these segments using continuity conditions to create complete, visually accurate representations. The investigation examines how control point placement influences curve behaviour and how continuity conditions affect the smoothness of composite shapes, providing insights into the practical application of Bézier methods for mathematical curve modeling and computer-aided geometric design.

## **Methodology**

This paper utilizes the classical cubic Bézier curve. The cubic Bézier curve is constructed from cubic Bernstein basis functions which defined as follows:

$$B_{0,3}(t) = (1 - t)^3, \quad (1)$$

$$B_{1,3}(t) = 3t(1 - t)^2, \quad (2)$$

$$B_{2,3}(t) = 3t^2(1 - t), \quad (3)$$

$$B_{3,3}(t) = t^3. \quad (4)$$

Figure 1 illustrated the cubic Bézier basis functions over the free parameter,  $t \in [0,1]$ . The Bernstein basis functions satisfied the properties of non-negativity, partition of unity and symmetry.

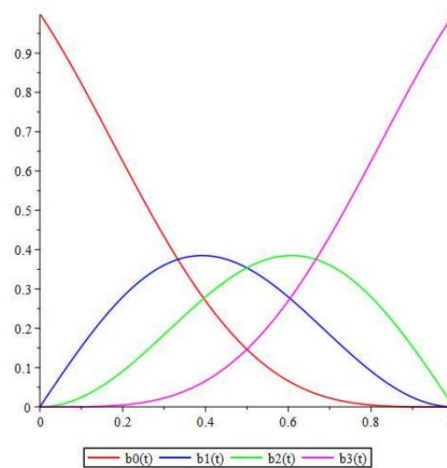


Figure 1: Cubic Bernstein basis function

From cubic Bernstein basis functions, the cubic Bézier curve can be defined as follows:

$$C(t) = \sum_{i=0}^3 P_i B_{i,3}(t), \quad (5)$$

where  $P_i$  is the control points in  $R^2$  and  $B_{i,3}(t)$  is the cubic Bernstein basis functions. Generally, the cubic Bézier curve satisfied the following properties: endpoint interpolation, endpoint tangent and convex hull. Figure 2 shows the example of cubic Bézier curve. Note that to change the shape of the curve, the control point needs to be altered.

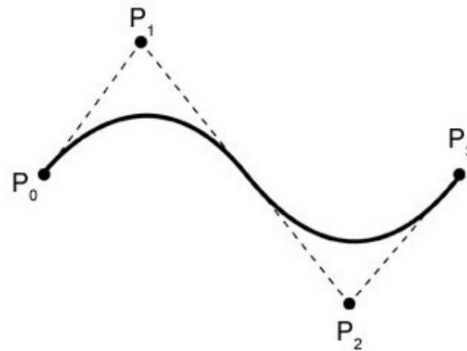


Figure 2: Cubic Bézier curve

### Results and Discussion.

In this study, the modelling of curves is carried out by using Maple software, which is suitable for mathematical curve modelling since it offers strong computation capabilities and integrated graphical tools. With this software, mathematical expressions, parametric equations, and geometric objects can be defined and visualized accurately. Consequently, Maple is effective in constructing and analysing Bézier curve, whether in mathematical formulation or in the resulted shapes. To demonstrate the modelling of curve, a suitable shape is chosen as a reference object. Hence, fish and duck shape are used in this study. The reason for the fish and duck shape to be picked as a reference object is due to its smooth curve and gradual changes in curvature.

Besides, the outline of fish and duck shape can be represented accurately using a combination of smooth segments, which is less likely to be found in geometric shapes since most of the time, it consists of sharp corner and discontinuities. This allows the Bézier curve to show its capabilities in modeling unique and flexible shapes like natural shapes. The aim of this study is to model curve using Bézier curve and construct shapes by combining the curve segments using piecewise functions and continuity. The outcome of this study highlights the suitability of Bézier curves for mathematical curve modeling and computer-aided geometric design applications.

Before constructing the curve, the coordinates of fish and duck shapes need to be identified first as a guideline of the control points. Identified key points such as the head, body or tail will give advantages when modeling since these parts will be split into a few curves segment and it will ensure that the curve modeled follows the outline of the fish and duck shape.

The construction of a cubic Bézier curve involves several systematic steps to generate a smooth curve. First, four control points, indicated as  $P_0$ ,  $P_1$ ,  $P_2$  and  $P_3$ , are defined in either two-dimensional or three-dimensional space. The points  $P_0$  and  $P_3$  represent the endpoints of the curve, while  $P_1$  and  $P_2$  are intermediate control points that determine the tangents and influence the overall curvature of the curve. Next, the cubic Bézier curve is constructed in parametric form, where  $t \in [0,1]$ . This parameter represents the position along the curve, with  $t = 0$  corresponding to the start point and  $t = 1$  to the

endpoint. To form a shape, a curve segment is not enough to represent the whole shape. Since a few curves are needed for the modeling, therefore, a few sets of control points are also required to represent other key points of the fish and duck shape. Figures 3 and 4 below show the control points from different curves.

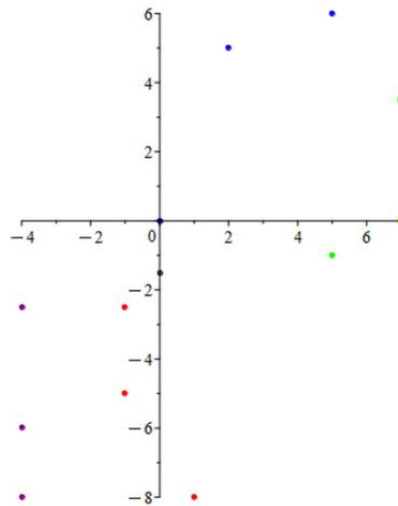


Figure 3: Control points of the fish shape

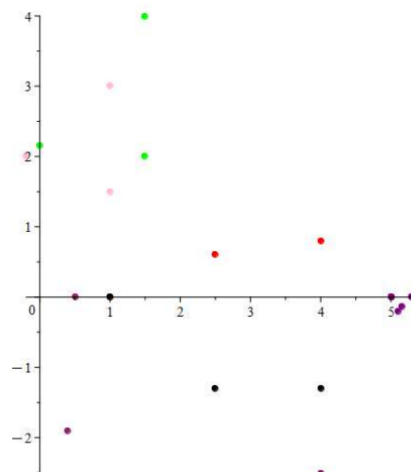


Figure 4: Control points of the duck shape

The cubic Bézier curve and its corresponding control polygon are visualized using Maple software,  $P_0$ ,  $P_1$ ,  $P_2$  and  $P_3$  are defined, then the polygon formed by connecting these points provides a shape of the curve. The cubic Bézier curve passes through its first and last control points which are  $P_0$  and  $P_3$ . Demonstrating the endpoint interpolation property. Meanwhile, the curve remains entirely inside the convex hull that is formed by all control points. By adjusting the control points in Maple, the shape of curve can be modified. Figures 5 and 6 show the convex hull of the fish and duck, which represents the boundary formed by connecting the outermost control points. This convex hull helps to visualize the overall limits of the shape and ensures that the Bézier curve remains within this boundary.

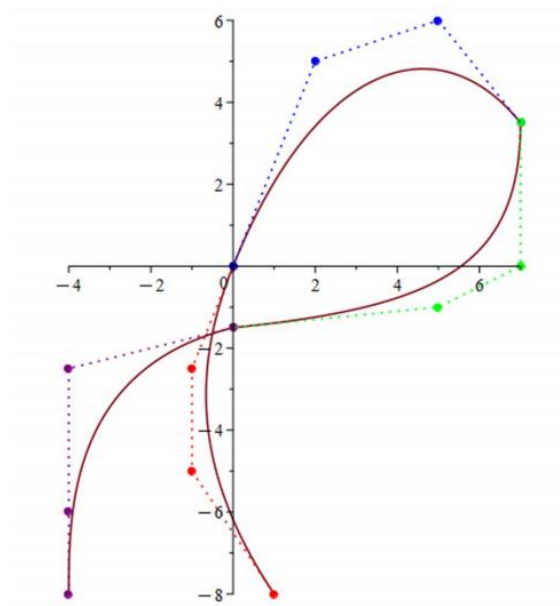


Figure 5: Convex hull of the fish shape

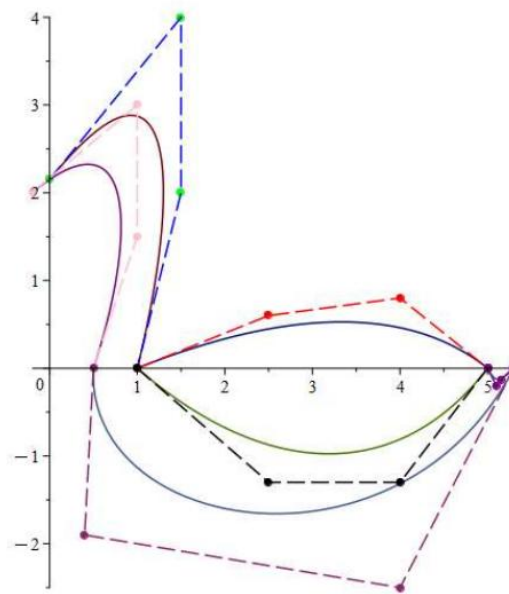


Figure 5: Convex hull of the duck shape

Since the shape are consist of multiple curve segments, the curves are required to undergo some modification by adjusting the curve so that the end of one segment is coincide with the end of the next segment. This is to make sure the curves are joined together, ensure the curves continuity and resulting in visually smooth representation of fish and duck shape.

## Conclusion

This study has successfully demonstrated the application of cubic Bézier curves in modelling natural shapes, specifically fish and duck forms, using Maple software. Through systematic construction of multiple curve segments and careful selection of control points, the research illustrated how Bézier curves leverage fundamental properties such as endpoint interpolation, convex hull containment, and tangent direction control to produce smooth and visually accurate representations. The modelling process revealed that the intuitive relationship between control point manipulation and curve behaviour enables designers to achieve desired forms without requiring extensive mathematical expertise, validating the practical utility of Bézier methods in design applications.

The findings underscore the effectiveness of Bézier curves as a mathematical tool for geometric modelling, particularly for organic forms that require gradual curvature changes and smooth outlines. The convex hull property proved valuable in predicting curve behaviour and maintaining design intent by ensuring the curve remains within predictable boundaries, while the endpoint interpolation property ensured precise control over the beginning and end of each curve segment. The implementation in Maple software demonstrated how computational tools can facilitate the exploration and visualization of mathematical curve concepts, making them accessible for both educational and professional applications.

In conclusion, this research contributes to the understanding of how fundamental mathematical principles can be applied to create visually pleasing shapes through computational methods. The successful modelling of fish and duck forms using cubic Bézier curves demonstrates that classical curve formulations remain powerful and relevant tools for contemporary design challenges. The methodology developed in this study, including the identification of key shape features and strategic placement of control points, provides a reproducible framework for future modelling projects, supporting ongoing efforts to integrate mathematical precision with visual appeal in computer-aided geometric design.

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## A COMPARATIVE STUDY OF CLASSICAL AND AESTHETIC BÉZIER CURVES IN ENGINEERING SURFACE DESIGN

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### ABSTRACT

*Computer Aided Geometric Design (CAGD) is important in engineering and design for creating smooth and complex surfaces used in areas like automotive, aerospace, and computer graphics. Classical Bézier curves and surfaces are commonly used because they are easy to control using control points and have good geometric properties. However, one main limitation is that any change to the control points affects the entire shape, making it difficult to adjust specific parts of a surface. To solve this issue, aesthetic Bézier methods introduce shape parameters that allow better control of the curve and surface, improving smoothness and visual appearance. While many studies focus on curves, there is still limited research on how these methods perform for full surface construction. Therefore, this study compares classical Bézier and aesthetic Bézier approaches in engineering surface design by analysing their mathematical properties, flexibility, and effects on surface smoothness and visual quality using computational modelling. The results aim to help engineers and designers choose the most suitable method for producing high-quality and visually pleasing surfaces.*

**Keywords:** *Computer Aided Geometric Design (CAGD), Classical Bézier curves, Aesthetic Bézier Methods, Surface Modelling, Shape Control and Smoothness*

### Introduction

Parametric curves form a fundamental concept in Computer Aided Geometric Design (CAGD), where curves are expressed as mathematical functions of one or more parameters. By defining coordinates independently as functions of a parameter, typically (t), parametric representations provide the flexibility to model complex geometric shapes such as circles, splines, and free-form curves. This capability makes parametric curves highly suitable for a wide range of applications in engineering, computer graphics, and industrial design. Common parametric curve representations include Bézier curves, Non-Uniform Rational B-Splines (NURBS), and rational Bézier curves, all of which play a crucial role in modern CAD/CAM systems. (Pérez et al., 2018)

From parametric curves, more complex geometric entities such as parametric surfaces can be constructed by introducing an additional parameter. These surfaces can be generated through transformations of curves, including translation and rotation, allowing for the modelling of continuous

and smooth shapes. Among these representations, the Bézier curve stands out as a widely used parametric polynomial curve defined by a set of control points. Its ability to provide intuitive geometric control without necessarily passing through all control points makes it particularly effective for designing smooth and visually appealing shapes in engineering and design applications. (Yang et al., 2015)

Over time, various extensions and alternatives to the classical Bézier curve have been developed to address its limitations and enhance its flexibility. Early developments such as the Timmer parametric cubic and Hermite curves introduced different forms of control, including tangent-based shaping and piecewise smoothness. Rational Bézier curves further extended the classical formulation by incorporating weights, enabling the exact representation of conic sections and improving shape control. These developments highlight the continuous effort to refine curve modelling techniques to meet the increasing demands of precision and adaptability in engineering design. (Gobithasan & Ali, 2004)

More advanced formulations, including cubic trigonometric and hyperbolic Bézier curves, introduce shape parameters that allow local adjustment of curves without altering control points. These non-polynomial approaches provide enhanced flexibility and are capable of representing more complex geometric behaviours, such as oscillatory or exponential shapes. Additionally, hybrid and fractional Bézier curves combine polynomial, trigonometric, and fractional basis functions to achieve improved curvature control while preserving essential geometric properties. Although these models offer greater design freedom, they also introduce higher mathematical and computational complexity. (Yan & Liang, 2011)

In engineering construction, Bézier curves and surfaces are extensively used for modelling smooth free-form geometries, such as automotive bodies, aircraft components, and mechanical parts. Their intuitive control through control points enables designers to achieve both functional performance and aesthetic quality. Furthermore, Bézier-based representations are essential in manufacturing processes, including CNC machining and tool path generation, where smoothness and precision are critical. Given their importance, this study focuses on examining and comparing classical and aesthetic Bézier approaches, particularly in terms of their effectiveness in constructing high-quality engineering surfaces.

## **Methodology**

This study focuses on the construction and analysis of cubic Bézier curves in the context of engineering surface design. The methodology involves both mathematical formulation and computational visualization to evaluate fundamental properties and behavior of cubic Bézier curves.

The cubic Bézier curve is defined parametrically as:

$$C(t) = \sum_{i=0}^n B_i^n(t)P_i, t \in [0,1] \tag{1}$$

$$B_{0,3}(t) = (1 - t)^3, \tag{2}$$

$$B_{1,3}(t) = 3t(1 - t)^2, \tag{3}$$

$$B_{2,3}(t) = 3t^2(1 - t), \tag{4}$$

$$B_{3,3}(t) = t^3. \tag{5}$$

where  $P_i$  are the control points and  $B_i^n(t)$  are the Bernstein basis functions. The study specifically considers cubic Bézier curves (degree 3) with four control points to illustrate key properties. The fundamental properties examined include:

- **Boundary Interpolation:** The curve interpolates its first and last control points, verified analytically by evaluating  $C(0)$  and  $C(1)$ .
- **Convex Hull Property:** The curve lies entirely within the convex hull formed by its control points, based on the non-negativity and partition of unity properties of Bernstein polynomials.
- **Boundary Tangent Property:** Tangent vectors at the endpoints depend only on the first and last control points, ensuring smooth connection to adjacent curves or surfaces. Analytical derivations of the tangent vectors are performed using the derivative of the cubic Bézier formula.

Figure 1 shows the cubic Bézier basis functions plotted over the parameter  $t \in [0,1]$ . The Bernstein basis functions exhibit the key properties of non-negativity, partition of unity, and symmetry.

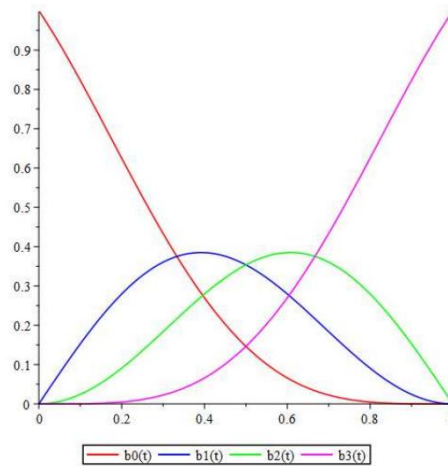


Figure 1: Cubic Bernstein basis function

By using the cubic Bernstein basis functions, a cubic Bézier curve can be expressed as follows:

$$C(t) = \sum_{i=0}^3 P_i B_{i,3}(t), \tag{5}$$

where  $P_i$  represents the control points in  $R^2$ , and  $B_{i,3}(t)$  denotes the cubic Bernstein basis functions. The cubic Bézier curve generally satisfies key properties, including endpoint interpolation, endpoint tangents, and the convex hull property. Figure 2 illustrates an example of a cubic Bézier curve. It should be noted that modifying the shape of the curve requires adjusting the positions of its control points.

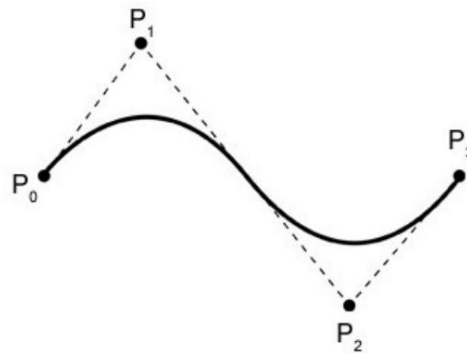


Figure 2: Cubic Bézier curve

**Results and Discussion.**

Engineering surfaces are designed to represent the complex geometries commonly encountered in practical design applications. In this study, all engineering surfaces are generated using Bézier curve representations to provide smoothness, geometric consistency, and intuitive control through a finite set of control points. The parameters  $u$  and  $v$  are defined within the interval  $[0,1]$ , unless otherwise specified. Since engineering surfaces are formulated as parametric extensions of Bézier curves, they inherently retain all the fundamental properties of classical Bézier curves, ensuring smooth, stable, and geometrically consistent surface representations.

A ruled surface is generated by linearly interpolating between two Bézier boundary curves,  $C_1(u)$  and  $C_2(u)$ , which are defined as

$$C_1(u) = \sum_{i=0}^n P_i B_i^n(u), C_2(u) = \sum_{i=0}^n Q_i B_i^n(u). \tag{6}$$

The ruled surface is then expressed as

$$R(u, v) = (1 - v)C_1(u) + vC_2(u), u, v \in [0,1]. \tag{7}$$

This formulation creates a surface by connecting corresponding points on the two boundary curves through straight lines, providing a simple and effective method for constructing parametric surfaces.

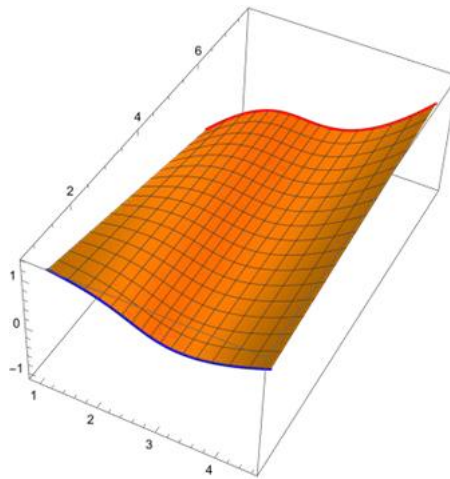


Figure 3: Ruled Surface of Two Cubic Bézier Curve

Figure 3 illustrates a ruled surface created by linearly interpolating between two cubic Bézier curves. The red curve represents  $C_1(u)$ , while the blue curve represents  $C_2(u)$ . For each parameter value  $u \in [0,1]$ , a straight line connects the corresponding points on  $C_1(u)$  and  $C_2(u)$ , forming a smooth surface that spans between the two boundary curves.

A swung surface is generated by scaling and rotating a Bézier profile curve along a trajectory curve. Mathematically, the swung surface can be expressed as

$$S(u, v) = (x(u)r(v), y(u)r(v), z(v)), \quad u, v \in [0,1]. \quad (7)$$

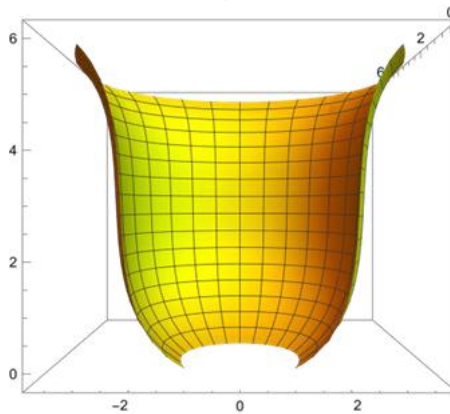


Figure 3: Swung Surface of Bézier Curve

Figure 4 illustrates a swung surface created by combining a profile curve with a trajectory curve. The profile curve is positioned and transformed according to the trajectory curve, resulting in a parametric surface whose coordinates are determined by both the profile and trajectory curves.

Bezier curves based on Bernstein basis functions can be extended to construct various engineering surfaces while preserving key properties such as boundary interpolation, convex hull, and

endpoint tangency. This framework provides a structured approach for analyzing and comparing classical and aesthetic Bézier surface constructions.

### Conclusion

This study highlights the versatility of Bézier curves, defined using Bernstein basis functions, in the construction of engineering surfaces. By extending these curves into parametric surfaces, key geometric properties such as boundary interpolation, the convex hull property, and endpoint tangency are inherently preserved, ensuring smoothness, stability, and geometric consistency in surface design. The methodological framework presented allows for systematic construction, visualization, and analysis of both classical and aesthetic Bézier surfaces. While classical Bézier surfaces offer intuitive control through fixed control points, aesthetic Bézier surfaces introduce shape parameters that enhance local flexibility, curvature control, and visual fairness without altering global geometry. The comparative analysis demonstrates that incorporating aesthetic parameters improves surface smoothness and adaptability, making it a promising approach for engineering applications where both functional performance and aesthetic quality are critical. Overall, this work provides a structured foundation for selecting and evaluating Bézier-based surface modeling techniques, supporting designers and engineers in creating high-quality, visually appealing, and geometrically robust free-form surfaces.

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