

INN FEST 2026

INTERNATIONAL INNOVATION FESTIVAL

INVENTING TOMORROW: SUSTAINABLE SOLUTIONS THROUGH INGENUITY

PROCEEDINGS

Main Organiser :



Co-Organiser :



INVENTING TOMORROW: SUSTAINABLE SOLUTIONS THROUGH INGENUITY



Chief of Editor

Ts. Hazza Roshada Binti Ramli

Editor

Dr. Joanna W Doinsing

Siti Norisikin Binti Abas

Shuheda Binti Yacob

Ashwellther Eric Asmat

Najibah Binti Md Junoh

PUBLISHED BY

POLITEKNIK SANDAKAN SABAH

E-PROCEEDING OF INNOFEST

© Politeknik Sandakan Sabah (PSS)
Edu Hub, Jalan Sungai Batang, Batu 10,
90000, Sandakan,
Sabah
No. Tel: 089-228351
No. Fax: 089-228325
<https://pss.mypolycc.edu.my>

All right reserved. The author is responsible for ensuring that his work does not violate any copyright. Editors and publishers are not liable for any copyright infringement by the author. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of Politeknik Sandakan Sabah (PSS), Sabah, Malaysia.

Published in Malaysia by:

Politeknik Sandakan Sabah (PSS)
Edu Hub, Jalan Sungai Batang, Batu 10,
90000, Sandakan,
Sabah

Terbitan 2026

e-ISBN : 978-629-7803-10-4

Perpustakaan Negara Malaysia

Data-Pengkatalogan-dalam Penerbitan

ORGANIZING COMMITTEE OF POLITEKNIK SANDAKAN SABAH

Patron

Dr. Shamsuri Bin Abdullah

Head of Director

Department of Polytechnic and Community College Education, Malaysia
(JPPKK)

Advisors

Dr. Shahiza Binti Ahmad Zainuddin

Director of Research and Innovation Centre,

Department of Polytechnic and Community College Education, JPPKK

Mohd Sahran @ Awang Bin Mohidin

Director of Politeknik Sandakan Sabah

Irwndih Bin Mat Jaili

Deputy Director (Academic) of Politeknik Sandakan Sabah

Chief of Editor

Ts. Hazza Roshada Binti Ramli

Editor

Dr. Joanna W Doinsing

Siti Norisikin Binti Abas

Shuheda Binti Yacob

Ashwellther Eric Asmat

Najibah Binti Md Junoh



ORGANIZING COMMITTEE OF POLITEKNIK NEGERI NUNUKAN

Patron

Arkas Viddy

Chairman

Andy Syarifuddin

Dr. Rofiqoh

Scientific Publication Committee

Jemri

Muhammad Syarif

Hamka Munir

Samsidar

Lisa Binti Harun

Siti Hajar

Novianti Arif

INTRODUCTION

The International Innovation Festival 2026 (InnoFest 2026) program will be held for the second time under the theme “Inventing Tomorrow: Sustainable Solutions Through Ingenuity”. Organized through a collaboration between Politeknik Sandakan Sabah, the Department of Polytechnic and Community College Education (Ministry of Higher Education) and Politeknik Negeri Nunukan, the program serves as a platform for researchers from Malaysia, Indonesia, and other countries to present their findings across various fields. It also provides discussion space for researchers to exchange ideas and inspiration in conducting studies.

OBJECTIVES

- ❖ To provide a platform for researchers from around the world to share the findings of their research.
- ❖ To support the achievements of Polytechnic KPIs regarding staff involvement in internationally published papers.
- ❖ To promote the Department of Polytechnic and Community College Education (Ministry of Higher Education) and Politeknik Sandakan Sabah on an international level.

FOREWORD

It is with great pride and enthusiasm that we present the e-Proceedings of the International Innovation Festival 2026 (InnoFest 2026) at Politeknik Sandakan Sabah. This marks the second edition of a festival born from a simple yet powerful conviction: that innovation thrives when it is shared, celebrated, and given room to grow.

Under the theme “**Inventing Tomorrow: Sustainable Solutions Through Ingenuity,**” InnoFest 2026 brought together innovators, researchers, educators, and students from Malaysia and beyond to showcase creative solutions to real-world challenges. Spanning four diverse categories: Agrotechnology, Aquaculture, Fisheries, Green Technology & Food Technology; Teaching & Learning; Engineering; and Non-Engineering disciplines including Social Science, Commerce, and Hospitality - participants demonstrated that meaningful innovation knows no single discipline. It emerges wherever curiosity meets purpose.

This compilation represents the culmination of months of dedication, experimentation, and refinement by our participants. Each paper featured within these pages underwent a rigorous review process, and we extend our heartfelt congratulations to every author whose work is published here.

As you explore the pages that follow, we invite you to see not just finished projects, but the spirit of inquiry, resilience, and collaboration that shaped them. It is our sincere hope that these e-Proceedings will serve as both a record of achievement and a source of inspiration - sparking new ideas, partnerships, and solutions for the challenges of tomorrow.

Organizing Committee

International Innovation Festival 2026 (InnoFest 2026)
Politeknik Sandakan Sabah

LIST OF REVIEWERS

REVIEWER	INSTITUTE
Dr. Muhammad Fattah Bin Fazel	KPJ Healthcare University
Ts. Dr. Noorashikin Binti Md Noor	Universiti Kebangsaan Malaysia
Dr. Siti Norliyana Binti Harun	Universiti Kebangsaan Malaysia
Dr. Nor Shariffa Binti Yussof	Universiti Sains Malaysia
Assoc. Prof. Ts. Dr. Akmal Hadi Bin Ma'radzi	Universiti Malaysia Perlis
Dr. Ida Norfaslia Binti Nasidi	Universiti Teknologi Malaysia
Ts. Dr. Nubailah Binti Abd Hamid	Politeknik Sultan Azlan Shah
Dr. Nurul Izzah Binti Abdul Samad	Universiti Sains Malaysia
Dr. Nurkaliza Binti Khalid	Universiti Islam Selangor
Dr. Nurhani Binti Selamat	Ministry of Education, Malaysia

**AGROTECHNOLOGY/AQUACULTURE/
GREEN TECHNOLOGY/FOOD TECHNOLOGY**

PAPER ID	TITLE OF MANUSCRIPT	PAGE
004	From Waste to Worth: Transforming Shrimp Shells Into Eco-Friendly Bioplastic <i>Asmahani Asmara, Hazza Roshada Ramli, Norsyafiqah' Suhaimi, Ts. Azhar Ambo</i>	1-8
001	Enhancing Oil Palm Empty Fruit Bunch Compost Using Swiftlet Guano and Effective Microorganisms for Improved Lettuce Cultivation <i>Cristmax Anak Arru, Margaret Chan Kit Yok, Nur Maizatul Idayu Othman</i>	9-25
014	SaliniTech <i>Mohd Fauzan Mamat Zawawi, Hazza Roshada Ramli, Mohd Hafizzie Hajini</i>	26-37
016	Effects of Aquatic Plants (<i>Hydrilla</i> Sp. and <i>Azolla</i> Sp.) on Dissolved Nutrient Concentrations in Fighting Fish (<i>Betta Splendens</i>) Culture <i>Muhammad Azizul Hasnain, Nikmael Nikson, Natasah Lv Alexius</i>	38-48
017	Rootify Filter: Application of Biochar Derived from Hydroponic Root Waste for Agricultural Wastewater Treatment <i>Syafina Fasya Saiful Anuar, Mohamad Munzir Mohammad Hafizan, Nur Nazuin Marwan, Nur Faradiya Natasyha Mohd Tarmizi, Nurelyana Najihah Ahmad Zamri</i>	49-55

TEACHING & LEARNING

PAPER ID	TITLE OF MANUSCRIPT	PAGE
009	Designing Play for Change: Evaluating A Social-Issue Card Game for Bullying Prevention Through Experiential Learning Among Selayang Community College Students <i>Ummu Hani Yusof</i>	56-65
011	AI Literacy Readiness Framework for TVET Educators: A Study at Politeknik Muadzam Shah <i>Safiani Osman, Asyran Zarizi Abdullah, Muhammad Fikri Abdul Rahman</i>	66-81
012	Compact Desk Solutions for Work-From-Home: A User-Centred Approach to Flexibility and Comfort <i>Raja Intan Suhaylah Raja Abdul Rahman, Ronaldi Saleh Umar, Roziha Che Haron</i>	82-95
019	Promoting Respect and Tolerance Through Educational Role-Play Game: The Case of “Kotak Harmoni” <i>Marwa Abd Malek, Najwa Abd Malek, Joanne Mercilynne Juanico</i>	96-106
020	The Effectiveness of The <i>Jejak Natura</i> Module in Enhancing Students’ Interest and Understanding of Flora and Fauna Through Inquiry-Based Learning <i>Marwa Abd Malek, Siti Nurasyura Hasnan</i>	107-115
023	Matchaberry: The Tale of Zuzu - A Gen-AI Surrealist Disruptor for Transformative Health Literacy and Cognitive Engagement Among Adolescents <i>Rabiatul Adawiyah Jamaluddin, Siti Nur Zulaikha Ahmad Budiman, Anis Kauthar Ahmad Taufiq, Nur Ardina Balqis Mohd Azif Syazwan</i>	116-125
026	The Effectiveness of Project B.O.S.S. (Bot-Operated Speaking Simulator) Innovation in Enhancing TVET Students’ Interview Readiness and Communicative Competence <i>Ramlah binti Awaluddin, Mohamad Fazril Ahmad Fauzi, Alson Alden John</i>	126-133

ENGINEERING (CIVIL/ELECTRICAL/MECHANICAL/ICT)

PAPER ID	TITLE OF MANUSCRIPT	PAGE
003	Palm Ash and Lime in Sustainable Peat Soil Improvement <i>Azrina Madihi, Siti Rozana Romali, Mimi Malisa Dolhan</i>	134-142
018	Hyperbolic Cavity Subsurface Detection Using SVM And BEMD <i>Laila Najwa Azizan, Hasimah Ali, Tengku Sarah Tengku Amran</i>	143-151
022	Application of The Addie Model in Developing BESQ: An Interactive Website for Science Learning Based on Quranic Wisdom <i>Hafizah Abdullah Ali, Noor Ain Mohd Faudzi, Shakiroh Yaakob</i>	152-158

FROM WASTE TO WORTH: TRANSFORMING SHRIMP SHELLS INTO ECO-FRIENDLY BIOPLASTIC

Asmahani Binti Asmara¹, Hazza Roshada Ramli¹, Norsyafiqah Binti Suhaimi²
Azhar Bin Ambo³

¹Department of Agrotechnology and Bio-Industry, Politeknik Sandakan Sabah

²Department of Mathematics, Science & Computer, Politeknik Sandakan Sabah

³Unit of Lifelong Learning, Tawau Community College

¹Corresponding author's email: asmahani@pss.edu.my

ABSTRACT

In recent years, shrimp aquaculture has expanded rapidly, resulting in the generation of substantial quantities of shrimp shell waste, often disposed of through environmentally harmful methods such as landfilling and incineration. To overcome this waste management issue, this study explores the conversion of shrimp shell waste into biodegradable biofilm as a sustainable alternative to petroleum-based plastics. The primary objective was to extract chitosan from shrimp shells obtained from Asia Aquaculture Sdn. Bhd. Semporna Farm, Sabah, and to evaluate the properties of chitosan-based bioplastic films, with particular emphasis on moisture content and tensile strength. The shrimp shells were subjected to a series of processes including cleaning, drying, grinding, deproteinization, demineralization, and deacetylation to produce chitosan. The extracted chitosan was then used to fabricate bioplastic films with varying concentrations (0%, 2%, and 4%), using glycerol as a plasticizer. Mechanical and moisture analyses were conducted at Universiti Kebangsaan Malaysia. The resulting films were transparent, flexible, and smooth, exhibiting tensile strengths ranging from 1.11 to 2.42 MPa and elongation at break values of up to 104.3%. However, the films demonstrated relatively high moisture content (16–25%), suggesting that water absorption contributed to increased flexibility but reduced mechanical strength. Despite their relatively low mechanical performance, the films show considerable potential for flexible applications, particularly in biodegradable food packaging. Further optimization of chitosan concentration, plasticizer content, and processing conditions is recommended to enhance mechanical properties and improve water resistance. Overall, the findings highlight the potential of transforming shrimp shell waste into an environmentally friendly, value-added bioplastic material.

Keywords: Bioplastic, Shrimp shell waste

1. Introduction

The increase of human population and activities increases the volume of waste. The rapid increase in plastic consumption worldwide has become a major environmental concern due to its detrimental effects on ecosystems.

Synthetic plastic is hard to degrade. Conventional petroleum-based plastics are widely used in food packaging, agriculture, healthcare and consumer products because of their durability, low cost and versatility. However, their resistance to degradation has

led to severe environmental pollution, particularly in marine ecosystems, where plastic waste destroys habitats and threatens aquatic life.

Simultaneously, the expansion of the shrimp farming industry has led to a substantial amount of shell waste. It leads to environmental pollution in terms of odor nuisance and aesthetic degradation of the environment. By transforming waste materials into biodegradable alternatives, this approach addresses two critical challenges simultaneously which are, reducing environmental pollution caused by plastic waste and minimizing seafood processing waste disposal issues.

This study aims to explore the development of eco-friendly bioplastics derived from shrimp shell waste as a sustainable alternative to conventional plastics. The findings of this study are expected to contribute to waste management strategies, sustainable material innovation, and the advancement of biodegradable packaging technologies in support of a greener future.

2. Literature review

The increasing demand for plastic materials and the environmental problems linked to their disposal have accelerated efforts to identify more sustainable substitutes. Traditional plastics produced from petroleum resources are resistant to degradation and play a major role in environmental contamination worldwide. As a result, growing attention has been directed toward renewable, bio-based materials as environmentally friendly alternatives. According to Ali et al. (2024), among the promising raw materials is shrimp shell waste, which is widely available and rich in valuable biopolymers, particularly chitin and chitosan.

As a by-product generated in large quantities by the shrimp farming and processing industry, shrimp shells are commonly disposed of through landfilling or incineration, practices that may contribute to environmental degradation. Nevertheless, these residues contain considerable amounts of chitin, recognized as the second most abundant natural biopolymer after cellulose (Chik et al., 2023).

Bioplastic production using shrimp shell waste involves several stages, beginning with the isolation of chitin and subsequently converting it into chitosan through a deacetylation process. Owing to its biodegradable, biocompatible, and non-toxic nature, chitosan has attracted considerable scientific attention. Its strong film-forming capability makes it a suitable candidate for bioplastic development. Furthermore, the antimicrobial characteristics and high moisture absorption capacity of chitosan expand its potential applications, especially in packaging materials and biomedical products (Ke et al., 2021).

The assessment of mechanical properties plays a crucial role in determining whether bioplastics are appropriate for real-world applications. Parameters such as tensile strength indicate the material's ability to resist applied forces, Young's modulus represents stiffness, and elongation at break measures flexibility (Clarizio & Tatara, 2012).

Chitosan-based bioplastics have demonstrated potential across multiple industries, particularly in food packaging, agriculture, and biomedical applications. In food packaging, their antimicrobial properties can help extend product shelf life by inhibiting microbial growth (Chandarana et al., 2025). In agriculture, biodegradable films may be utilized for mulching or controlled-release fertilizers. Biomedical applications include wound dressings, drug delivery systems, and tissue engineering due to chitosan's biocompatibility and non-toxic nature.

3. Methodology

3.1 Sample Collection and Preparation

The sampling of shrimp shell waste was carried out at Asia Aquaculture Sdn. Bhd., located at Semporna Farm. The shell was already separated from its body in the processing plant before being collected. After being brought into the laboratory, the shells were washed with deionised water to remove impurities and dried at 70°C for 24 hours. The sample was then blended with a blender to create shrimp shell powder.

3.2 Extraction of Chitosan from Shrimp Shells

Chitosan is extracted from shrimp shells through three main stages, namely deproteinization, demineralization, and deacetylation.

3.2.1 Demineralization

The demineralization process was carried out by soaking the shrimp shell powder in hydrochloric acid (HCl) solution to remove calcium carbonate and other inorganic minerals. The mixture was stirred and allowed to react for a specified period, followed by repeated washing with distilled water until a neutral pH was obtained.

3.2.2 Deproteinization

Subsequently, deproteinization was conducted by treating the demineralized material with sodium hydroxide (NaOH) solution at 70°C for 2 hours to eliminate proteins and organic residues. The treated material was then washed repeatedly with distilled water until neutral pH was achieved and dried to obtain chitin.

3.2.3 Deacetylation

To convert chitin into chitosan, the dried chitin was treated with 50% NaOH solution at 100°C for 3 hours. This process removed acetyl groups from chitin, producing chitosan with improved solubility and film-forming properties. The extracted chitosan was thoroughly rinsed with distilled water until neutral pH was reached and dried before further use in bioplastic film production.

3.3 Film Preparation

Once chitosan is obtained, it is dissolved in 1% acetic acid solution under continuous stirring. Tapioca starch was added and heated at 70°C while stirring for 30 minutes to ensure complete mixing. Glycerol was added as a plasticizer improve flexibility. Air bubbles were removed by allowing the solution to stand for several minutes.

The prepared bioplastic film, the solution was poured evenly onto silicone plates using a casting method. The films were dried in an oven at 40°C for 24 hours until completely dry. After drying, the bioplastic films were carefully peeled off and stored in an airtight container for further analysis.

Three variations of shrimp shell-based bioplastic films were prepared to evaluate the effect of chitosan concentration on the physical and mechanical properties of the produced bioplastic. The formulations consisted of 0%, 2%, and 4% chitosan content, which were labelled as Sample A, Sample B, and Sample C, respectively. Sample A served as the control formulation without chitosan addition (0%), while Samples B and C contained increasing chitosan concentrations of 2% and 4%. Each formulation underwent the same preparation process, including mixing, casting, drying, and film formation, to ensure consistency in experimental conditions. The produced films were then tested to tensile and moisture content analyses to evaluate their mechanical performance and physical characteristics.

The concentrations of 0%, 2%, and 4% chitosan were selected to evaluate the influence of increasing chitosan content on the mechanical and physical properties of the bioplastic films. Sample A (0%) served as the control to determine the contribution of the starch-glycerol matrix without chitosan. Samples B and C (2% and 4%) were selected based on preliminary studies and previous literature, which indicate that low to moderate chitosan concentrations improve film formation while excessive amounts may reduce flexibility due to increased intermolecular interactions.

3.4 Moisture Content and Tensile Strength

The produced shrimp shell bioplastic films were subjected to mechanical and moisture characterization to evaluate their physical properties. The samples were submitted to the Polymer Research Center (PORCE), Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM), for tensile strength and moisture content analyses.

Tensile testing was conducted using a Testometric Universal Testing Machine (M350-10CT) according to ASTM D882 standard to determine tensile strength, Young's modulus, and elongation at break. Film specimens were cut into dimensions of 100 mm × 20 mm, with a gauge length of 50 mm and tested at a speed of 5 mm/min. Five specimens were analysed for each sample.

Moisture content analysis was performed using an AND MX-50 Moisture Analyzer according to ASTM E104 standard. The bioplastic films were cut into 3 mm × 3 mm pieces with an approximate sample weight of 5.0 g, and the analysis was conducted in triplicate to ensure statistical reliability.

4. Discussion of Analysis and Findings

4.1 Bioplastic film



Figure 1.1: Shrimp shell-derived bioplastic film

Based on the visual observation shown in the image, the shrimp shell-derived bioplastic film demonstrated good film formation, transparency, and flexibility, indicating successful conversion of shrimp shell biomass into a functional biodegradable material. The film appears semi-transparent with a light yellowish or translucent appearance, suggesting a relatively uniform polymer matrix and adequate dispersion of biopolymer components during the casting process.

The bioplastic film also exhibited high flexibility and elasticity, as observed from its ability to bend and fold without visible tearing or cracking while being held. This characteristic indicates that the produced film possesses sufficient ductility and mechanical adaptability, which are important properties for biodegradable packaging materials. The film's flexibility suggests that the polymer chains were adequately plasticized, likely due to the incorporation of a plasticizing agent which is glycerol, which enhances mobility between polymer chains and reduces brittleness.

4.2 Tensile Strength Analysis

The mechanical and moisture properties of shrimp shell-based bioplastic films were evaluated to determine their suitability as eco-friendly biodegradable materials. Tensile strength, Young's modulus, elongation at break, and moisture content were analysed for three different samples (A, B, and C). The results are summarised in Table 1.1.

Property	Sample A	Sample B	Sample C
Tensile Strength (N/mm ²)	1.71 ± 0.92	2.42 ± 0.35	1.11 ± 0.16
Young's Modulus (N/mm ²)	35.81 ± 47.23	27.72 ± 9.70	1.83 ± 0.96
Elongation at Break (%)	64.10 ± 24.59	31.13 ± 3.30	104.32 ± 4.34

Table 1.1: Tensile strength analysis

The results showed notable differences in the mechanical performance of the shrimp shell bioplastic samples. Sample B recorded the highest tensile strength (2.42 MPa), suggesting that the addition of 2% chitosan enhanced intermolecular hydrogen bonding between starch and chitosan molecules. This resulted in a denser polymer

network capable of resisting greater applied stress. This suggests that Sample B possesses stronger intermolecular interactions or improved structural integrity, making it potentially more suitable for applications requiring durable bioplastic materials. In addition, Sample B exhibited a relatively high Young's modulus (27.72 ± 9.70 N/mm²), demonstrating greater stiffness and resistance to deformation. However, its elongation at break was comparatively lower ($31.13 \pm 3.30\%$), suggesting lower flexibility than the other samples.

Although Sample C exhibited the highest elongation at break (104.32%), its tensile strength decreased considerably. This indicates that increasing chitosan concentration beyond the optimum level may reduce structural uniformity, producing a more flexible but mechanically weaker film. This characteristic implies that Sample C can undergo greater deformation before rupture, making it potentially suitable for flexible packaging applications. However, the sample exhibited the lowest tensile strength (1.11 ± 0.16 N/mm²) and Young's modulus (1.83 ± 0.96 N/mm²), suggesting reduced rigidity and mechanical strength. This trade-off between flexibility and strength is commonly observed in biodegradable polymer systems.

Meanwhile, Sample A exhibited intermediate tensile strength (1.71 ± 0.92 N/mm²) and elongation at break ($64.10 \pm 24.59\%$). Nevertheless, the high standard deviation observed in both Young's modulus and moisture content indicates inconsistency in material properties, possibly due to uneven mixing, non-uniform drying, or variations during processing. Such inconsistency may affect reproducibility and performance reliability in practical applications.

The tensile strength obtained in this study (1.11–2.42 MPa) was lower than values reported by Duraisamy and Vinod (2022), who observed higher tensile strength in chitosan films prepared using optimized plasticizer ratios. The difference may be attributed to variations in chitosan purity, starch composition, glycerol concentration, and processing conditions.

4.3 Moisture Content

Property	Sample A	Sample B	Sample C
Moisture Content (%)	25.15 ± 24.76	21.97 ± 1.78	16.02 ± 1.46

Table 1.2: Moisture content analysis

In terms of moisture content as shown in Table 1.2, Sample A showed the highest moisture absorption ($25.15 \pm 24.76\%$), followed by Sample B ($21.97 \pm 1.78\%$) and Sample C ($16.02 \pm 1.46\%$). Lower moisture content in Sample C may indicate better water resistance and improved storage stability, whereas higher moisture content in

Sample A may negatively affect the durability and mechanical stability of the bioplastic. Excessive moisture absorption may also accelerate degradation and reduce shelf-life performance. The moisture content (16–25%) observed in this study agrees with previous findings that chitosan-based films possess hydrophilic characteristics because of abundant hydroxyl and amino groups (Ke et al., 2021).

Overall, the findings suggest that Sample B demonstrated the most balanced mechanical performance with superior strength and stiffness, while Sample C provided greater flexibility. Therefore, depending on the intended application, Sample B may be more suitable for rigid biodegradable packaging, whereas Sample C may be preferable for flexible bioplastic applications. These findings confirm the potential of shrimp shell waste as a sustainable raw material for producing environmentally friendly bioplastics.

5. Conclusion and future research

This study highlights the potential of shrimp shell waste as a sustainable raw material to produce eco-friendly bioplastics, demonstrating an innovative approach to transforming industrial waste into value-added products. The increasing environmental concerns associated with conventional petroleum-based plastics have accelerated the need for biodegradable alternatives, and shrimp shell-derived bioplastics present a promising solution to this challenge. Due to the presence of chitin and its derived chitosan, shrimp shells possess favourable properties that support the formation of biodegradable films with potential applications in sustainable packaging and related industries. Future studies should focus on improving the water resistance and mechanical performance of the developed bioplastic through optimization of chitosan and plasticizer concentrations. Additional investigations on biodegradability, antimicrobial activity, thermal stability, and shelf-life performance should also be conducted. Furthermore, comparisons with commercially available biodegradable packaging materials would provide valuable insight into the practical applicability and commercialization potential of shrimp shell-derived bioplastics.

Acknowledgment

The authors gratefully acknowledge the support provided by Politeknik Sandakan Sabah for facilitating this research. Appreciation is also extended to the Polymer Research Center (PORCE), Faculty of Science and Technology, Universiti Kebangsaan Malaysia (UKM), for assistance in the mechanical and moisture characterisation of the bioplastic samples. Acknowledgement is also extended to all industrial collaborators and stakeholders who contributed ideas, effort, and commitment toward the successful implementation of this project. Finally, sincere appreciation is extended to everyone who was directly or indirectly involved in providing suggestions and assistance in completing this report. It is hoped that this research will serve as a valuable source of knowledge and a useful reference for future researchers.

References

- Ali, G., Sharma, M., Salama, E. S., Ling, Z., & Li, X. (2024). Applications of Chitin and Chitosan as Natural Biopolymer: Potential Sources, Pretreatments, and Degradation Pathways. *Biomass Conversion and Biorefinery*, 14(4), 4567-4581.
- Chandarana, C., Bonde, S., Sonwane, S., & Prajapati, B. (2025). Chitosan-based c packaging: Leading Sustainable Advancements in the Food Industry. *Polymer Bulletin*, 82(11), 5431-5462.
- Chik, C. E. N. C. E., Kamaruzzan, A. S., Rahim, A. I. A., Lananan, F., Endut, A., Aslamyah, S., & Kanan, N. A. (2023). Extraction and Characterization of *Litopenaeus Vannamei*'s Shell as Potential Sources of Chitosan Biopolymers. *Journal of Renewable Materials*, 11(3).
- Clarizio, S. C., & Tatara, R. A. (2012). Tensile Strength, Elongation, Hardness, and Tensile and Flexural Moduli of PLA filled with Glycerol-Plasticized DDGS. *Journal of Polymers and the Environment*, 20(3), 638-646.
- Duraisamy, P., & Vinod, A. R. (2022). Extraction, Characterization, Antimicrobial Activity of Chitosan Extracted From Crab Shell and Preparation of Chitosan-Based Bioplastic Film For Food Packaging. *Journal of Advanced Scientific Research*, 13(01), 263-268.
- Duraisamy, P., & Vinod, A. R. (2022). Extraction, Characterization, Antimicrobial Activity of Chitosan Extracted from Crab Shell and Preparation of Chitosan-based Bioplastic Film for Food Packaging. *Journal of Advanced Scientific Research*, 13(01), 263-268.
- Ke, C. L., Deng, F. S., Chuang, C. Y., & Lin, C. H. (2021). Antimicrobial Actions and Applications of Chitosan. *Polymers*, 13(6), 904.
- Setiawan, J. V., Adhitama, R., Goeltom, M. T., Askitosari, T. D., Yang, D. C., & Sukweenadhi, J. (2022, September). The Potential of Rice Bran Waste (*Oryza sativa* L.) and Shrimp Shell Waste as Chitin Nanowhisker With Glycerol Plasticizer in the Production of Bioplastic. In *IOP Conference Series: Earth and Environmental science* (Vol. 1083, No. 1, p. 012045). IOP Publishing.
- Uğurlu, E. (2025). Utilizing Mussel and Shrimp Shell Waste For Chitin and Chitosan Extraction: A Pathway to Eco-Friendly Bioplastics. *Biomass Conversion and Biorefinery*, 15(18), 25391-25405.

ENHANCING OIL PALM EMPTY FRUIT BUNCH COMPOST USING SWIFTLET GUANO AND EFFECTIVE MICROORGANISMS FOR IMPROVED LETTUCE CULTIVATION

Cristmax Anak Arru¹, Margaret Chan Kit Yok², Nur Maizatul Idayu Binti Othman³

¹Department of Plantation Management, International College of Advanced Technology
Sarawak (i-CATS) Miri, Sarawak

²Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA (UiTM) Campus
Samarahan, Sarawak

³Faculty of Plantation and Agrotechnology, Universiti Teknologi MARA (UiTM) Campus
Jasin, Melaka

¹Corresponding author's email: cristmax@icats.edu.my; ²drmchan@uitm.edu.my

ABSTRACT

The large amount of oil palm empty fruit bunch (EFB) waste generated by the palm oil industry presents both an environmental challenge and an opportunity for sustainable agriculture. Although EFB compost is commonly used as an organic soil amendment, its relatively low nutrient availability limits its effectiveness for vegetable production. This study examined an organic fertilizer by enriching EFB compost with swiftlet guano and effective microorganisms (EM) to enhance nutrient quality and plant growth response. The experiment evaluated four compost formulations: T1 (EFB compost), T2 (EFB + swiftlet guano), T3 (EFB + EM), and T4 (EFB + swiftlet guano + EM). Compost maturity was determined by temperature and pH over a one-month composting period. Nutrient quality was assessed based on nitrogen (N), phosphorus (P), and potassium (K) contents. The effectiveness of the compost was further tested by the growth response of lettuce (*Lactuca sativa*) using a Randomized Complete Block Design with three replications. Growth parameters measured included plant height, leaf number, root length and plant weight. Results showed that the addition of organic enhancers improved compost quality and influenced the composting process. Enriched treatments recorded higher N, P, and K levels compared with untreated EFB compost. Lettuce grown using EM-enriched compost produced the highest plant height (26.91 cm) and plant weight (27.07 g), indicating better vegetative growth and productivity. The findings highlight the important role of beneficial microorganisms in improving nutrient availability and compost effectiveness. This study demonstrates a sustainable and practical approach for converting oil palm waste into a higher-value organic fertilizer. The innovation supports waste recycling, improves soil fertility, and promotes environmentally friendly vegetable production, particularly for small-scale and organic farming systems.

Keywords: Oil Palm Waste, Effective Microorganisms, Swiftlet Guano, Lettuce (*Lactuca sativa*)

1. Introduction

This study evaluates the enhancement of oil palm empty fruit bunch (EFB) compost using swiftlet guano and effective microorganisms (EM) as an organic fertilizer for lettuce (*Lactuca sativa*). It addresses the limitations of conventional EFB compost, promotes sustainable waste management, and assesses compost quality, nutrient composition, and plant growth performance within a circular agriculture framework.

1.1 Background of Study

Organic agriculture promotes sustainable soil management by enhancing biodiversity, biological cycles, and soil health while reducing reliance on external inputs. Excessive inorganic fertilizer use has contributed to soil degradation and pollution. Therefore, this study explores the enrichment of oil palm EFB compost with swiftlet guano and Effective Microorganisms (EM) to improve nutrient availability and support lettuce cultivation.

1.2 Problem Statement

Increasing food demand and environmental concerns from intensive fertilizer use highlight the need for sustainable soil management. Although EFB compost improves soil properties, its low nitrogen content limits use for high-demand crops. This study investigates the enrichment of EFB compost with swiftlet guano and EM to enhance nutrient quality and lettuce growth performance.

1.3 Contribution of the Study

This study supports sustainable agriculture by developing an enriched EFB compost fertilizer using swiftlet guano and EM. It evaluates compost quality, nutrient improvement, and effects on lettuce growth while promoting the beneficial use of oil palm residues and swiftlet waste. The findings provide potential guidance for sustainable fertilizer alternatives and environmentally responsible waste management.

1.4 Research Objective

The main objective of this study is to investigate the enrichment of oil palm EFB compost using swiftlet guano and EM for lettuce cultivation. Specifically, the study aims to determine the duration required for compost to reach maturity based on temperature and pH observations, to evaluate the quality of the compost through its nitrogen (N), phosphorus (P), and potassium (K) contents, and to assess the growth response of lettuce as an indicator of the effectiveness of the enriched compost.

1.5 Research Questions

This study is guided by several research questions: How long would the EFB compost enriched with swiftlet guano and EM take to reach maturity based on temperature and pH changes? What would be the effects of adding swiftlet guano and EM on N, P and K contents of the compost? How would the enriched compost influence the growth performance of lettuce in terms of plant height, leaf number, plant weight, and root development? These questions were intended to determine whether the proposed enrichment approach could produce a more effective and sustainable organic fertilizer.

2. Literature review

2.1 Introduction

This literature review examines the empirical and theoretical foundations for enhancing oil palm EFB compost with swiftlet guano and EM for lettuce cultivation. It highlights the importance of sustainable vegetable production, where Malaysia's lettuce self-sufficiency ratio reached 114.0% in 2020, although imports remained significant (Department of Statistics Malaysia, 2021; Global Sourcing Hub of Food and Agriculture, 2021). The review evaluates previous findings on fertilizer impacts, EFB compost, swiftlet guano, EM, and lettuce as an indicator crop. These studies provide the basis for developing hypotheses on the potential of enriched EFB compost as a sustainable organic fertilizer.

2.2 Impact of Chemical and Organic Fertilizers on Soil Properties

Continuous use of chemical fertilizers can increase crop yields in the short term but may harm soil health over time. Studies show that excessive fertilizer use causes soil degradation, pollution, nutrient imbalance, reduced soil organic matter, lower microbial diversity, and soil acidification (Kumar & Kumar, 2019; Sharma et al., 2014; Ge et al., 2018). In contrast, combining organic amendments such as farmyard manure with balanced fertilization improves soil fertility, organic matter, microbial activity, and biodiversity while maintaining productivity (Bhatt et al., 2019; Chandini et al., 2019; Sun et al., 2023). These findings support integrated nutrient management for sustainable soil health and long-term agricultural productivity.

2.3 Empty Fruit Bunch (EFB) Compost

Empty fruit bunch (EFB) is a major by-product of the oil palm industry and can be converted into compost for sustainable waste management. EFB contains essential nutrients and improves soil aeration, water retention, pH, and nutrient recycling (Abdullah & Sulaim, 2013; Allah & Hanafi, 2014). Composting increases its stability and effectiveness as a soil amendment, enhancing soil quality, crop growth, and yield (Tahir et al., 2021; Adu et al., 2022). However, EFB releases nutrients slowly and may not meet the immediate nutrient demand of high-value crops. Enriching EFB compost with nutrient-rich additives and beneficial microbes can improve its fertilizer value and agronomic performance.

2.4 Guano as an Organic Fertilizer

Guano is a nutrient-rich organic fertilizer that can restore soil fertility and improve crop production. Swiftlet guano contains high levels of organic matter, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and other essential nutrients, making it a valuable agricultural input (Azizon Abdullah, 2017; Azizon et al., 2017). Studies show that guano enhances crop growth, yield, and nutrient uptake in crops such as potato, sweet corn, and shallot (Harahap et al., 2003; Tampus & Escasinas, 2019; Suprijono et al., 2024). Although nutrient composition varies by location, incorporating swiftlet guano into EFB compost provides a safe and effective way to enrich compost and improve soil fertility.

2.5 Effective Microorganisms (EM)

Effective Microorganisms (EM) are beneficial microbes that improve composting and sustainable agriculture. EM contains photosynthetic bacteria, lactic acid bacteria, yeasts, actinomycetes, and fungi that accelerate organic matter decomposition and nutrient mineralization (Higa & Parr, 1994). Studies show that EM shortens EFB composting time, enhances compost maturity, and increases nutrient content such as magnesium (Mg), potassium (K), calcium (Ca), and boron (Bo) (Lim et al., 2015; Zahari et al., 2023). EM also promotes beneficial microbial activity, improves soil quality, and supports plant growth when combined with organic materials rather than used alone. Overall, EM enhances EFB compost quality and its effectiveness as an organic fertilizer

2.6 Lettuce (*Lactuca sativa* L.) as an Indicator Crop

Lettuce is a suitable indicator crop for evaluating compost quality because it grows quickly, has high nitrogen (N) demand, and responds rapidly to changes in soil fertility. Its shallow root system requires nutrient-rich topsoil, making it sensitive to fertilizer management (Kouassi et al., 2019). Lettuce grows best in slightly acidic to neutral soils (pH 6.0–6.8) and is affected by poor nutrient availability or phytotoxicity (Chen et al., 2021). Studies show that organic fertilizers improve lettuce growth, nutrient uptake, and soil quality (Hossain & Ryu, 2017; García-Rández et al., 2025). Therefore, lettuce is an ideal crop to evaluate the effectiveness of EFB compost enriched with swiftlet guano and Effective Microorganisms (EM).

2.7 Hypothesis Development

Based on previous findings, this study hypothesized that enriching EFB compost with swiftlet guano and EM would improve compost quality and lettuce growth compared with untreated EFB compost. EM addition was expected to accelerate compost maturity through enhanced microbial activity, while swiftlet guano was expected to increase N, P, and K content due to its nutrient richness. Furthermore, the combined use of swiftlet guano and EM was predicted to enhance lettuce growth by improving nutrient availability and compost effectiveness. Overall, the study proposed that integrating EFB compost with organic nutrients and microbial inoculants could produce a more sustainable and effective fertilizer for lettuce production.

3. Methodology

3.1 Preparation of EFB Compost Treatments

The EFB used in this study was collected at an early decomposition stage from the Selangau plantation pile in Sarawak. Composting was conducted in shaded compost pits with three replications as shown in Table 1. The compost piles were turned every three days to release trapped carbon dioxide (CO₂) and improve aeration. Data collection was carried out from 1 November to December 2021.

Treatment 1 (T1)	Only EFB (10kg) compost for the controlled treatment
Treatment 2 (T2)	The EFB (10 kg) compost mixed with 7 kg swiftlet guano
Treatment 3 (T3)	The EFB (10 kg) compost mixed with 500 ml of EM
Treatment 4 (T4)	The EFB (10 kg) compost mixed with 7 kg swiftlet guano and 500 ml of EM

Table 1: Treatments of EFB compost with and without swiftlet guano and effective microorganism.

3.1.1 Determining the compost maturity.

Compost temperature and pH were monitored throughout the study. Temperature was measured using a thermometer at five locations within each compost pile every two days for 14 readings. pH analysis was conducted weekly using 10 g samples collected from five locations, diluted with distilled water, and measured using a pH meter (HANA Instruments HI98103 Checker).

3.1.2 Determination of Nitrogen(N), Phosphorus(P) and Potassium(K) Contents of the EFB Compost Treatment

The N, P, and K contents of EFB and swiftlet guano were analysed before composting by SP Lab Sarawak Plantation Sdn. Bhd. After composting, samples were collected, mixed with topsoil, and used as planting media. Post-harvest samples were also analysed using an Auto Analyzer to determine nutrient changes before and after cultivation.

3.2 Field Experiments on Growth Response of Lettuce

The planting medium comprised soil and EFB compost at a 1:2 ratio (Lew et al., 2020). A Randomized Complete Block Design with four treatments and three replications (36 polybags) was used. Lettuce growth was monitored over nine weeks by measuring plant height, leaf number, root length, and fresh weight after harvest.

3.3 Determination of N, P and K Contents Absorb by Plant using Foliar Sampling

The analysis of N, P and K contents absorbed by plants from the four treatments were tested by using foliar sampling method. It was carried out by SP Lab Sarawak Plantation Sdn Bhd.

3.4 Data analysis

Both descriptive and inferential statistics were generated using the International Business Machine Statistical Packages and Software Services (IBM SPSS). The analysis of variance (ANOVA) was conducted to test the significance, and the significant differences were determined using Duncan Multiple Range Test at $\alpha = 0.05$ level

4. Discussion of analysis and findings

4.1 Compost maturity

The maturity of EFB compost was indicated by temperature and pH.

4.1.1 Temperature of Compost

Figure 1 shows the mean compost temperature from 1 November to 1 December 2021. Treatment 1 showed a slight decrease from 32.2°C to 30.4°C. Treatment 2 fluctuated the most, declining from 34.2°C to 26.4°C before increasing to 32.8°C and ending at 30.0°C. Treatment 3 recorded the lowest temperature, decreasing from 32.0°C to 29.6°C. Treatment 4 decreased from 34.0°C to 29.8°C. Overall, all treatments showed gradual temperature reduction during composting. Treatment 3 was significantly different from Treatment 4 but not significantly different from Treatment 1 and 2, while Treatment 4 was also not significantly difference from Treatment 1 and Treatment 2.

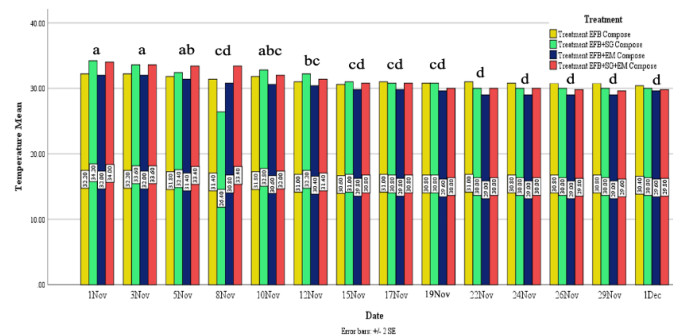


Figure 1: Mean compost temperature of four treatments: T1-EBF, T2-EBF+Swiftlet Guano (SG), T3-EBF+Effective Microorganism and T4-EBF+ Swiftlet Guano+ Effective Microorganism; ANOVA indicated significant differences in the temperature throughout the duration with $p < 0.000$. Common letters indicated no significant differences based on Duncan Multiple Range Test at $\alpha = 0.05$

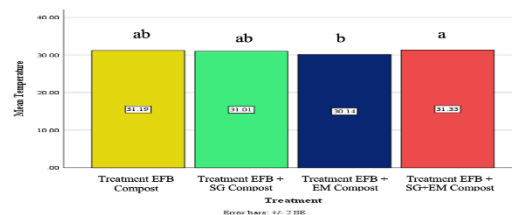


Figure 2: Overall mean of compost temperature of four treatments: T1-EBF, T2-EBF+Swiftlet Guano (SG), T3-EBF+Effective Microorganism and T4-EBF+ Swiftlet Guano+ Effective Microorganism; ANOVA indicated significant differences in the temperature as $p = .012$. Common letters indicated no significant differences based on Duncan Multiple Range Test at $\alpha = 0.05$

4.1.2 pH of Compost

Figure 3 shows the mean pH changes among treatments. Treatment 1 maintained a stable pH range of 6.20–6.98, while other treatments recorded lower values. Treatment 2 remained consistent at pH 5.36–5.50. Treatments 3 and 4 showed fluctuations, with Treatment 4 decreasing to 4.54 before increasing. However, ANOVA showed no significant differences among weeks ($p = 0.308$).

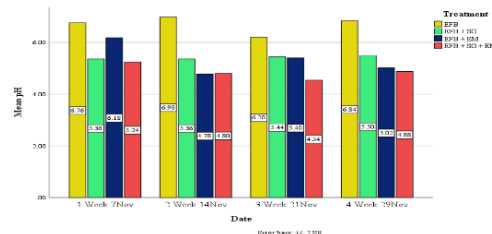


Figure 3: The mean potential hydrogen (pH) from four treatments: T1- EFB, T2- EFB+Swiftlet Guano (SG), T3- EFB+Effective Microorganism and T4- EFB+ Swiftlet Guano+ Effective Microorganism; ANOVA indicated no significant differences as $p = .308$

Figure 4-shows the overall pH of four treatments of EFB compost. The highest pH was observed in Treatment 1 at 6.70, followed by Treatment 2 at 5.42 and Treatment 3 at 5.35. Treatment 4 was observed to have a pH of 4.86.

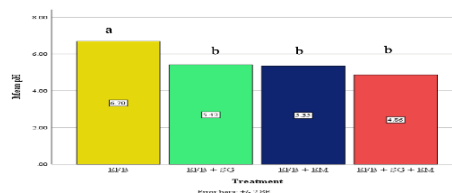


Figure 4: Overall pH of compost with standard error ± 2 SE of four treatments: T1- EFB, T2- EFB+Swiftlet Guano (SG), T3- EFB+Effective Microorganism and T4- EFB+ Swiftlet Guano+ Effective Microorganism; ANOVA indicated significant differences in the temperature as $p < .000$. Common letters indicated no significant differences based on Duncan Multiple Range Test at $\alpha = 0.05$

4.2 Quality of the Soil Media + EFB compost enriched with SG and EM

4.2.1 Nitrogen, Phosphorus and Potassium Content of Compost

Table 1 presents the N, P, and K contents of EFB compost, raw swiftlet guano, and topsoil. Swiftlet guano recorded the highest N (9.72%) and P (2.45%) contents, followed by EFB compost (N: 2.70%, P: 0.94%). However, EFB compost showed the highest K content (1.64%), compared with swiftlet guano (1.25%) and topsoil (0.34%). These results indicate swiftlet guano as a valuable N and P source, while EFB contributes higher potassium.

Sample	Percent Dry Matter		
	N (105°C, oven dry)	P (% 105°C, oven dry)	K (% 105°C, oven dry)
EFB Compost	2.70%	0.94%	1.64%
Swiftlet Guano	9.72%	2.45%	1.25%
Topsoil	0.06%	0.07%	0.34%

Table 1: Nitrogen, phosphorus and potassium contents in EFB, Swiftlet Guano and topsoil before treatment determined at SP Lab Sarawak Plantation Sdn Bhd

Table 2 shows N, P, and K changes before and after cultivation. Treatment 2 recorded the highest initial N (4.45%), P (1.26%), and K (1.68%). After harvest, Treatment 1 increased N (52%), P (49%), and K (0.5%), while Treatments 2, 3, and 4 decreased due to nutrient uptake by lettuce. Treatment 2 remained highest after cultivation.

Sample	Percent Dry Matter (% 105°C, oven dry)					
	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Before	After	Before	After	Before	After
Treatment 1 (EFB+Topsoil)	0.62	1.29	0.42	0.82	0.69	0.73
Treatment 2 (EFB+SG+Topsoil)	4.45	2.23	1.26	0.51	1.68	0.90
Treatment 3 (EFB+EM+Topsoil)	2.64	0.92	0.80	0.56	1.60	0.60
Treatment 4 (EFB+SG+EM+Topsoil)	4.15	2.00	1.17	0.61	1.48	0.69

Table 2: Nitrogen, phosphorus and potassium content before and after field experiment

4.3 Growth Response of The Lettuce as an Indicator of Quality of the EFB Compost Enriched with Swiftlet Guano and EM

4.3.1 Mean Plant Height

Figure 5 shows the growth pattern based on mean plant height of lettuce over a duration of nine weeks. The plant height mean from Treatment 1 was 5.33cm at Week 1 progressing to 29.67cm at harvest. Treatment 2 was 4.69cm at Week 1 and 22.00cm at harvest. Treatment 3 progressed from 5.22cm to 49.44cm at the harvest while the plant height in Treatment 4 was 5.44cm at Week 1 to 20.00cm at harvest. Treatment 3 showed the higher plant height mean compared to other treatments throughout the duration.

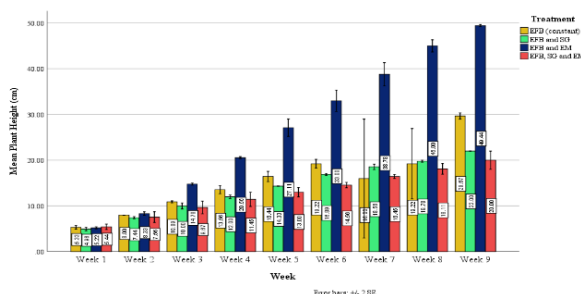


Figure 5: Growth pattern of Lettuce plants over a duration of 9 weeks from four treatment: T1-EFB, T2-EFB+Swiftlet Guano (SG), T3-EFB+Effective Microorganism and T4-EFB+ Swiftlet Guano+ Effective Microorganism

Figure 6 shows the overall plant height mean of Lettuce plants between treatments. Treatment 1, 2 and 4 obtained an overall plant height of 15.37 cm, 14.00 cm and 12.91 cm respectively which were significantly lower than Treatment 3 with 26.91cm. There was significant difference as ANOVA indicated a p value < .00.

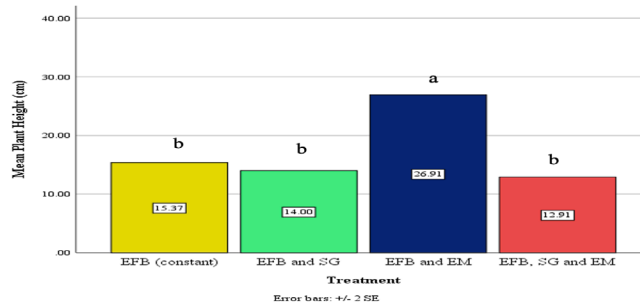


Figure 6: The overall mean plant height of Lettuce plants with +/-2SE from Treatment 1, Treatment 2, Treatment 3, and Treatment 4; ANOVA indicated significant differences in the temperature as $p < .000$. Common letters indicated no significant differences based on Duncan Multiple Range Test at $\alpha = 0.05$

4.3.2 Mean Number of Leaves

Figure 7 shows the mean weekly number of leaves of Lettuce plants. The growth pattern was expected indicating increase of leave number over time with the best response from Treatment 3 followed by Treatment 1. The difference at harvest for Treatment 1 was 12 leaves (11.89) and Treatment 3 was 12 leaves (12.11) while for Treatment 2 was 8 leaves (8.44) and Treatment 4 was 8 leaves (8.11). This clearly shows that Treatment 1 and 3 had 33.33% more leaves than Treatment 2 and 4.

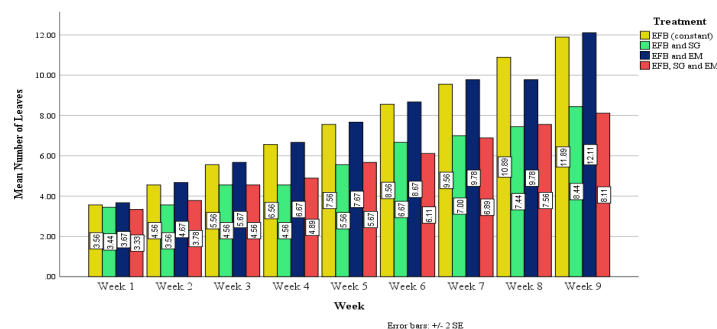


Figure 7: Mean number of leaves of Lettuce over a duration of 9 weeks from four treatment: T1-EFB, T2-EFB+Swiftlet Guano (SG), T3-EFB+Effective Microorganism and T4-EFb+ Swiftlet Guano+ Effective Microorganism

Figure 8 shows the overall mean number of lettuces leaves between treatments. Treatment 2 and Treatment 4 obtained an overall number of 5.69 leaves and 5.66 leaves which were less than Treatment 1 and Treatment 3 with both recorded with 7.63 leaves. There were significant differences as ANOVA indicated a p value < .00 at $\alpha=0.005$.

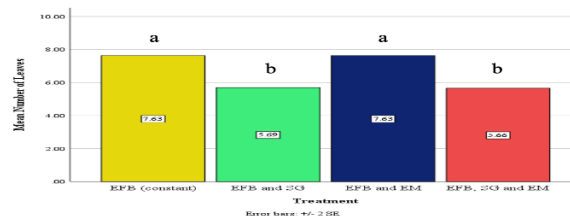


Figure 8: The mean number of leaves of Lettuce plants from Treatment 1, Treatment 2, Treatment 3, and Treatment 4; ANOVA indicated significant differences in the temperature as $p < .000$. Common letters indicated no significant differences based on Duncan Multiple Range

4.3.3 Mean Length of Root

Figure 9 shows the mean root length of Lettuce plants. The mean root length for Treatment 1 was 9.70 cm, Treatment 2 was 5.90 cm, Treatment 3 was 9.06 cm, and Treatment 4 was 6.44 cm. The Lettuce roots from Treatment 1 and 3 was significant longer than Treatment 2 and Treatment 4 as ANOVA obtained a $p < .000$. All the treatments were significantly difference from each other.

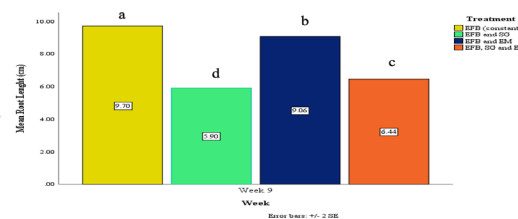


Figure 9: Mean root length of Lettuce at harvest from four treatments: T1-EFB, T2-EFB+Swiftlet Guano (SG), T3-EFB+Effective Microorganism and T4-EFb+ Swiftlet Guano+ Effective Microorganism; ANOVA indicated significant differences in the temperature as $p < .000$. Common letters indicated no significant differences based on Duncan Multiple Range Test at $\alpha = 0.05$

4.3.4 Mean Plant Weight

Figure 10 shows the mean weight of harvested Lettuce plants. The mean weight for Treatment 1 is 22.10g while for Treatment 2, Treatment 3 and Treatment 4 were 15.88g, 27.08g, and 17.14g respectively. The Lettuce plants from Treatment 3 were 32.94% heavier than other treatments.

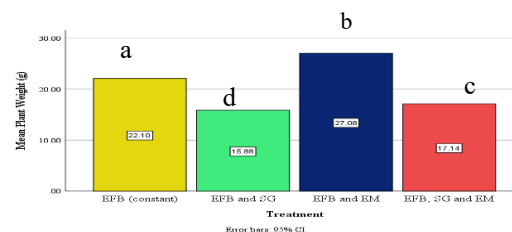


Figure 10: Mean plant weight of Lettuce from four treatments: T1-EFB, T2-EFB+Swiftlet Guano (SG), T3-EFB+Effective Microorganism and T4-EFb+ Swiftlet Guano+ Effective Microorganism; ANOVA indicated significant differences in

the temperature as $p < .000$. Common letters indicated no significant differences based on Duncan Multiple Range Test at $\alpha = 0.05$

4.3.5 Foliar Nutrient Content

Table 4 shows the percent of nutrient content absorbed by plant determined by foliar analysis. Plant in Treatment 1 showed that NPK was 3.42%:0.418%:11.82%. Treatment 2 was 3.61% N, 0.418% P and 11.59% K. For Treatment 3 was 3.77%N, 0.516%P and 8.83%K. While Treatment 4 NPK content was 3.46%N, 0.418%P and 10.32%K. Treatment # show high in N and P which were 3.77% and 0.516% respectively but lower in K which was 8.33% that other treatments.

Sample	Percent of Dry Matter (%)		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Treatment 1	3.43%	0.418%	11.82%
Treatment 2	3.61%	0.418%	11.59%
Treatment 3	3.77%	0.516%	8.83%
Treatment 4	3.46%	0.418%	10.32%

Table 4: The nitrogen, phosphorus and potassium nutrient content absorbed by plants using foliar analysis

4.4 Discussion

Thi et al. (2022) reported that composting consists of four stages: mesophilic (20–40°C), thermophilic (40–70°C), cooling (40–45°C), and maturation, where temperature returns to ambient levels. The EFB compost temperature of 31.19°C indicated that it had reached the maturation stage before adding swiftlet guano and EM. The addition of EM accelerated compost maturity, resulting in a lower temperature of 30.14°C, likely due to enhanced microbial activity and faster organic matter decomposition (Feng et al., 2026). However, compost containing swiftlet guano showed slightly higher temperatures, suggesting a slower maturation process.

The initial EFB compost pH of 6.70 was within the suitable range for mature compost (Trisakti et al., 2018). However, adding EM and swiftlet guano reduced pH to acidic levels, likely due to microbial activity and ammonium release from swiftlet guano. The acidic condition negatively affected lettuce growth, particularly in treatments containing swiftlet guano.

Among all treatments, EFB compost with EM produced the best lettuce growth, with higher plant height, leaf number, biomass, and root development. EM improved nutrient availability and supported plant growth, while swiftlet guano application may require proper rate adjustment to prevent excessive acidity. Overall, EM-enriched EFB compost showed strong potential as a sustainable organic fertilizer for improving lettuce production and reducing dependence on chemical fertilizers.

5. Conclusion and future research

Compost temperature varied significantly among treatments and composting periods, while pH differences showed that additives affected the composting process. Swiftlet guano increased nitrogen and phosphorus content, whereas EFB compost contributed to higher potassium levels. However, the treatment with EM alone produced the best lettuce growth performance, showing the highest plant height, leaf number, root

development, and plant weight. Treatments containing swiftlet guano, particularly when combined with EM, showed lower performance. Future studies should evaluate different application rates of swiftlet guano and EM, include pH adjustment methods, and assess more compost maturity indicators across different crops and planting cycles to determine the long-term benefits of enriched EFB compost.

Acknowledgment

The authors are grateful to Universiti Teknologi MARA (UiTM) Sarawak Samarahan Campus for the continuous assistance in providing research facilities. Our appreciation also goes to the staff of Farm Unit, UiTM Samarahan for their invaluable assistance and cooperation during this research

References

- Abdullah, N., & Sulaim, F. (2013). The Oil Palm Wastes in Malaysia. Biomass Now - Sustainable Growth and Use, December. <https://doi.org/10.5772/55302>
- Adugna, G. (2016). A review on impact of compost on soil properties, water use and crop productivity. *Agricultural Science Research Journal*, 4(3), 93–104.
- Agegehu, G., Srivastava, A. and Bird, M. . (2017). The role of biochar and biochar-compost in improving soil quality and crop performance: a review. *Soil Ecology*, 119, 156–170.
- Agriculture, G. S. H. of F. &. (2021). Import of Fresh Lettuce To Malaysia. <https://www.tridge.com/intelligences/lettuce/MY/import>
- Ahn, H.K., Richard, T.L. & Choi, H. L. (2007). Mass and thermal balance during composting of a poultry manure-wood shavings mixtures at different aeration rates. *Process Biochemistry*, 42, 215–223.
- Amrizal, A. (2012). Pengaruh Pemberian Pupuk Guano dan Tithonia (*Tithonia diversifolia*) Terhadap Pertumbuhan dan Hasil Jagung Manis (*Zea mays saccharata* Strurt.). Padang: Faculty of Agriculture, Andalas University.
- Azizon Abdullah. (2017). Nutrient Composition of Swiftlets (*Aerodramus Fuciphagus*) Guano from The East Coast Economic Region (ECER) of Malaysia And Its Potential As An Organic Fertilizer. Nutrient Composition of Swiftlets (*Aerodramus Fuciphagus*) Guano from The East Coast Economic Region (ECER) of Malaysia And Its Potential As An Organic.
- Bee-Hui Yeo, Teck-Kim Tang, Shew-Fung Wong, Chin-Ping Tan, Yong Wang Lai, L.-Z. C. & O.-M. (2021). Potential Residual Contaminants in Edible Bird's Nest. *Front. Pharmacology*. <https://doi.org/10.3389/fphar.2021.631136>
- Buckler, L. (2018). The Hidden Dangers of Chemical Fertilizers. Occupational Health and Safety. <https://ohsonline.com/Articles/2017/12/07/The-Hidden-Dangers-of-Chemical-Fertilizers.aspx?Page=1>

- Chan, G. K. L. (2013). The Quality Assurance of Edible Bird's Nest : Removal of Nitrite Contamination and Identification of an Indicative Chemical Marker. <https://lbezone.ust.hk/bib/b1213319>
- Chan, G. K. L., Wu, K. Q., Fung, A.H.Y., Poon, K.K.M., Wang, C.Y.W., Gridneva, E., & Al, E. (2018). Searching for Active Ingredients in Edible Bird's Nest. *Journal of Complementary Medicine & Alternative Healthcare*. 2(555683).
- Chan, G. K. L., Zhu, K. Y., Chou, D. J. Y., Guo, A. J. Y., Dong, T. T. X., & Tsim, K. W. K. (2013). Surveillance of Nitrite Level in Cubilose: Evaluation of Removal Method and Proposed Origin of Contamination. *Food Control*, 34, 637–644. <https://doi.org/10.1016/j.foodcont.2013.06.010>
- Chan, M.K.Y., Ariffin, T.M. & Rosli, N. (2019). Effect of Amended Soil with Oil Palm Fruit Bunch Compost on the pH of Soil and the Growth of Choy Sam (*Brassica chinensis* Var *parachinensis*). *Journal of Engineering and applied Sciences* 14(3): 6057-6061. DOI:10.36478/jeasci.2019.6057.6061.
- Chandini, Kumar, R., Kumar., R & Prakesh, O. (2019). The Impact of Chemical Fertilizers on our Environment and Ecosystem. *Research Trends in Environmental Sciences*, 2.
- Chen, Z., Shah Jahan, M., Mao, P., Wang, M., Liu, X., & Guo, S. (2021). Functional Growth, Photosynthesis and Nutritional Property Analyses of Lettuce Grown Under Different Temperature and Light Intensity. *Journal of Horticultural Science and Biotechnology*, 96(1), 53–61.
- Chrispaul Muthaura, David M. Musyimi, J. A. O.& S. V. O. (2010). Effective Microorganisms and Their Influence on Growth and Yield of Pigweed (*Amaranthus dubians*). *ARPJ Journal of Agricultural and Biological Science*, 5.
- Cornell Composting (1996). *Monitoring Compost pH*. Cornell Waste Management Institute, Cornell University, N.Y. USA.
- Daiss, N., Lobo, G., Socorro, A. R., Bruckner, U., Heller, J. & Gonzales, M. (2008). The effect of three organic pre-harvest treatments on Swiss chard (*Beta vulgaris* L. var. *cycla* L.) quality. *European Food Research and Technology*, 226, 345–353.
- Feng, Y., Zahi, Y., Ao, J., Qian, K., Wang, Y., Ma, M., Sun, P., Li, Y., Zhang, B., Li, X. & Yu, H. (2026). Effects of Effective Microorganism (EM) Inoculation on Co-Composting of *Auricularia heimuer* Residue with Chicken Manure and Subsequent Maize Growth. *Microorganisms* 14(1): 106. doi: 10.3390/microorganisms14010106
- Gamage, A., Gangahagedara, R., Gamage, J., Jayasinghe, J., Kodikara, N., Suraweera, P. & Merah, O. (2023). *Farming System* 1 100005. <https://doi.org/10.1016/j.farsys.2023.100005>

- Ge, S., Zhu, Z. & Jiang, Y. (2018). Long-term impact of fertilization on soil pH and fertility in an apple production system. *Journal of Soil Science and Plant Nutrition*. <https://doi.org/http://dx.doi.org/10.4067/S0718-95162018005001002>
- Guo LY, Wu GL, Li Y, Li CH, Liu WJ, Meng J, Liu HT, & Yu XF, J. G. (2016). Effects Of Cattle Manure Compost Combined with Chemical Fertilizer on Topsoil Organic Matter, Bulk Density and Earthworm Activity in a Wheat-Maize Rotation System in Eastern China. *Soil and Tillage Research*, 156, 140–147.
- Harahap, D., A. Jamil & K.E., R. (2003). Pemanfaatan Pupuk Guano Alam untuk Tanaman Kentang di Dataran Medium Kabupaten Tapanuli Selatan. Balai Pengkajian Teknologi Pertanian Provinsi Sumatera Utara. Medan. www.nad.litbang.deptan.go.id.
- Higa, T. & Parr, J. F. (1994). Beneficial and Effective Microorganisms for a Sustainable Agriculture and Environment. International Nature Farming Research Center, Atami, Japan, 16.
- Horneck, D., Wysocki, D., Hopkins, B., Hart, J. & Stevens, R. (2007). Acidifying soil for crop production: Inland Pacific Northwest. University Extension Publication EM 8917-E.
- Jamil, A., L.R., Widowati, & W., H. (2014). Kesuburan Tanah Manajemen dan Inovasi untuk Mendukung Pertanian Organik. In Prosiding Seminar Nasional Pertanian Organik. Bogor.
- Komilis, D.P. & Tziouvaras, I. S. (2009). A Statistical Analysis to Assess the Maturity and Stability of Six Composts. *Waste Management*, 29, 1504–1513.
- Kouassi, C. K., Kouassi, A. K., Yao, M. K., Kouassi, G. A., & Koffi-Nevry, R. (2019). Assessment of the Risk of Microbial Contamination of an Urban Crop in the City of Daloa: Case of Lettuce (*Lactuca sativa L.*). *Journal of Food Research*, 8(3), 122. <https://doi.org/10.5539/jfr.v8n3p122>
- Kumar, R.; Kumar, R. . P. (2019). The Impact of Chemical Fertilizers on our Environment and Ecosystem. *Chief Editor*, 35, 69.
- Kumara, N.R.A., & Sumiahadi, A. (2024). Evaluation of Oil Palm Empty Fruit Bunch Compost Application on Samhong Mustard (*Brassica juncea L.*) Cultivation in Polybags. *Applied Research in Science and Technology* 4(2): 102-109. DOI: 10.33292/areste.v4i2.93
- Lew Jin Hau, Rashid Shamsuddin, Alvyana Khiew Ai May, Aqsha Saenong. Ahmad Mohamed Lazim, M. N. & A. L. (2020). Mixed Composting of Palm Oil Empty Fruit Bunch (EFB) and Palm Oil Mill Effluent (POME) with Various Organics: An Analysis on Final Macronutrient Content and Physical

- Properties. Waste and Biomass Valorization, 11(22).
<https://doi.org/10.1007/s12649-020-00993-8>
- Lim, P.N., Wu, T.T., Clarke, C., Nik Daud, N. . (2015). A potential bioconversion of empty fruit bunches into organic fertilizer using *Eudrilus eugeniae*. *International Journal of Environmental Science and Technology*, 12, 2533–2544.
- Liu H, Meng J, Bo W, Cheng D, Li Y, Guo L, Li C, Zheng Y, Liu M, Ning T, Wu G, Yu X, Feng S, Wuyun T, Li J, Li L, Zeng, Y., & Liu S. V. J. G. (2016). Biodiversity Management of Organic Farming Enhances Agricultural Sustainability. *Scientific Report*, 6. <https://doi.org/10.1038/srep23816>
- Mukhlis , Mohd. Razi Ismail , Halimi, Mohd. Saud , S.H. Habib , H. Kausar, M. A. M. and M. A. H. (2016). Efficacy Evaluation of Empty Palm Oil Fruit Bunch Compost in Improving Soil Characteristics, Plant Growth and Disease Suppression of Tomato Plants Under Tropical Acid Soil. *Journal of Environmental Biology*. 38(1): 123-129.
- Muryanto, & Lidar, S. (2020). Guano Fertiliser Applications to Improve Growth of Palm Oil Seeds (*Elaeis guineensis* Jacq) in Pre-nursery. *Jurnal Ilmiah Pertanian*, 16.
- Musadia Afa. (2016). The Effect of Natural Guano Organic Fertilizer on Growth and Yield of Spring Onion (*Allium fistulosum* L.). Kolaka University, 1, 28–31. url: <http://usnsj.com/index.php/ATJ/article/view/ATJ005>
- Pahlavi, H.N., Rafiya, L. Rashid, S., Nisar, B. and Kamili, A. N. (2021). Chemical Fertilizers and Their Impact on Soil Health. *Microbiota and Biofertilizers*, 2, 1–20.
- Paydar, M., Wong, Y. L., Wong, W. F., Hamdi, O. A., Kadir, N. A., and Looi, C. Y. (2013). Prevalence of nitrite and nitrate contents and its effect on edible bird nest's color. *J. Food Sci*. <https://doi.org/10.1111/1750-3841.12313>
- Pimental, D., Hepperly, p., Hanson, J. Douds., and Seldel, R. (2005). Enviromental, energetic and Economic Comparisons of Organic and Conventional Farming Systems. *BioScience*, 7, 573–353.
- Puranapong, N. and Siphuang, C. (2001). Utilization of manures fermented with EM (effective microorganisms) in vegetable. In: *Proceedings of the 3rd Maejo University Annual Conference*. Maejo University, Chiang Mai,Thailand, 120–126.
- Quek, M. C., Chin, N. L., Yusof, Y. A., Law, C. L., and Tan, S. W. (2018). Pattern Recognition Analysis on Nutritional Profile and Chemical Composition of Edible Bird's Nest for Its Origin and Authentication. *International Journal of Food Properties*, 21, 1680–1696.

- Quek, M. C., Chin, N. L., Yusof, Y. A., Tan, S. W., and Law, C. L. (2015). Preliminary Nitrite, Nitrate and Colour Analysis of Malaysian Edible Bird's Nest. *Information Processing in Agriculture*, 2, 1–5. <https://doi.org/10.1016/j.inpa.2014.12.002>
- Reganold JP, Glover JD, Andrews PK, H. H. (2001). Sustainability of Three Apple Production Systems. *Nature*, 926–930. <https://doi.org/10.1038/35073574>
- Richard, T.L., Hamelers, H.V.M., Veeken, A.H.M., & Silva, T. (2002). Moisture Relationships in Composting Processes. *Compost Science and Utilization*, 10, 286–302.
- Sangakkara, U. R. (2012). Effect of EM on Nitrogen and Potassium Levels in the Rhizosphere of Bush Bean. http://www.infrc.or.jp/english/KNF_Data_Base_Web/3rd_Conf%0A_S_6_7.html
- Sawant, A. (2021). Lettuce Cultivation Guide. Agriculture Guruji. <https://agricultureguruji.com/lettuce-cultivation/>
- Sediyarso, M. (1999). Fosfat Alam Sebagai Bahan Baku dan Pupuk Fosfat. Pusat Penelitian Tanah Dan Agroklimat. Bogor.
- Sekman E, Top S, V. G. and B. M. S. (2011). Pilot-scale Investigation of Aeration Rate Effect on Leachate Characteristics in Landfills. *Fresenius Environmental Bulletin*, 20, 1841–1852.
- Sharma, U., Paliyal, S. S., Sharma, S. P., & Sharma, G. D. (2014). Effects of Continuous Use of Chemical Fertilizers and Manure on Soil Fertility and Productivity of Maize–Wheat Under Rainfed Conditions of the Western Himalayas. *Communications in Soil Science and Plant Analysis*, 45(20), 2647-2659.
- Singh D.S., Chand S, Anvar, M. and P. (2003). Effect of Organic and Inorganic Amendment on Growth and Nutrient Accumulation by Isabgol (*Plantago ovata*) in sodic soil under greenhouse conditions. *Journal of Medicinal and Aromatic Plant Sciences*, 414-419.
- Subhan, A. Hidayat & N., G. (1998). Penggunaan Pupuk Nitrogen dan Pupuk Kandang Ayam pada Tanaman Cabai di Lahan Kering. *The Horticulture Journal*, 8(3), 1178–1183.
- Suwandi, G.A., S. & Y. (2015). Efektivitas Pengelolaan Pupuk Organik, Pupuk NPK dan Pupuk Hayati Terhadap Terhadap Pertumbuhan dan Hasil Bawang Merah. Balai Penelitian dan Pengembangan Pertanian. Balai Penelitian Tanaman Sayuran, Lembang. Bandung.

- Tampus, D.S. & Esacasinas, O. S. (2019). Effects of Swiftlet (*Aerodramus fuciphagus*) Manure and Methods of Crop Establishment on the Growth and Yield of Sweet Corn (*Zea mays var. Saccharata*) in Western Leyte, Philippines. *Advances in Crop Sciences and Technologies*, 7.
- Tan, S. N., Sani, D., Lim, C. W., Ideris, A., Stanslas, J., & Lim, C. T. S. (2020). Proximate Analysis and Safety Profile Of Farmed Edible Bird's Nest In Malaysia and Its Effect on Cancer Cells. *Evidence Based Complementary. Alternative Medicine*. <https://doi.org/10.1155/2020/8068797>
- Thi, T.K.H., Van, T.T. Thanh, H.L. Nguyen, N., Tran, C. Nguyen, P.T., Vo, T., Van, N.T. & Bui, X.T. (2022). Compost to Improve Sustainability Soil Cultivation and Crop Productivity. *Cases Studeis in Chemical and Environmental Engineering* 6, 100211.
- Titirmare, N.S., Ranshur, N.J., Patil A.H. and Patil, S.R. (2023). Effect of inorganic fertilisers and organic manures on physical properties of oisl – A Review. *International Journal of Plant & Soil Science* 35(19): 1015-1023.
- Tokeshi, H., Alves, M. C., Sanches, A. B. & Harada, D. Y. (2010). Effective Microorganisms for Controlling the Phytopathogenic *Fungus Sclerotinia sclerotiorum* in Lettuce. <http://emrojapan.com/emdb/content/126.html>
- Trisakti, B., Mhardela, P., Husaini, T., & Matseh, I. (2010). Production of Oil Palm Empty Fruit Bunch Compost for Ornamental Plant Cultivation.
- Trubé A., De Toni, A., Benito, P., Lavelie, P., Camacho, N. R., & Van Der Puttens, W. H. (2010). Functions, Threats and Tools for Policy Markers. *Soil Biodiversity*: <https://doi.org/https://bioemco.ccsd.cnrs.fr/bioemco-00560420>
- Tu C, Louws, F. J., Creamer, N.G., Mueller, J.P., Brownie, C., Fager, K., & Bell, M, H. S. (2006). Responses of Soil Microbial Biomass and Availability to Transition Strategies from Conventional to Organic Farming Systems. *Agriculture Ecosystem and Environment*, 205–215.

SALINITECH

Mohd Fauzan Mamat Zawawi¹, Hazza Roshada Ramli², Mohd Hafizzie Hajini²

¹Department of Agrotechnology and Bio-Industry, Politeknik Jeli Kelantan

²Department of Agrotechnology and Bio-Industry, Politeknik Sandakan Sabah

¹Corresponding author's email: fauzan@pjk.edu.my

ABSTRACT:

Artificial saltwater preparation in aquaculture hatcheries is often conducted manually, leading to inconsistent salinity levels, time inefficiency, and increased risk of human error. These limitations are more pronounced in institutions without access to natural seawater sources, restricting effective marine aquaculture operations and training. The SaliniTech system utilizes an ESP32 microcontroller. Data is transmitted in real-time to the Thingier.io cloud platform for remote monitoring via mobile devices. A peristaltic pump mechanism is employed to automatically dispense concentrated salt solution or freshwater until the target salinity is reached. Experimental results demonstrate minimal salinity deviation, confirming reliable and stable system performance. The uniqueness of this innovation lies in its "closed-loop" automation that replaces manual refractometer testing with high-precision digital sensing. Prototype test results demonstrate that the system maintains salinity within a consistent range of 29–31 ppt with minimal variation. The system's ability to maintain readings within a very narrow range demonstrates the effectiveness of the integrated sensors. Whenever salinity drops below the present value, the peristaltic pump is immediately activated to deliver a salt solution into the main tank. This performance proves that SaliniTech offers accuracy and reliability compared to manual mixing. The system has high potential for application in educational institutions as a technical teaching aid and in small-to-medium-scale aquaculture industries to optimize water quality management, reduce operational costs, and support sustainable aquaculture practices. The system supports SDG 9, SDG 12, SDG 14, and SDG 4 by promoting technological innovation, resource-efficient water management, sustainable aquaculture practices, and enhanced digital learning in technical education.

Keywords: IoT, Salinity, Aquaculture Automation

1. Introduction

Aquaculture is a significant component for food security and economic growth in the nation of Malaysia, accounting for about 30% of total fisheries production in 2022 (Obi et al., 2025). The modern aquaculture production system heavily relies on automated and digital monitoring technologies for productivity enhancement, water quality monitoring, and operational sustainability (Flores et al., 2025). Aquaculture plays a significant part in the national fish production as well as food security in Malaysia, especially in the production of marine fish, shrimp and ornamental aquatic species. Marine fisheries and aquaculture sectors contribute significantly to Malaysia's coastal economy and employment opportunities (Obi et al., 2025). Salinity is a key environmental parameter in marine aquaculture, which directly affects osmoregulation, metabolism, growth performance and survival of cultured aquatic organisms (Kültz, 2015). However, in many inland hatcheries, the preparation of artificial seawater still involves manual processes, leading to inconsistent salinity levels and operational inefficiencies. These challenges emphasize the need for the

development of automated and IoT-based salinity monitoring systems that promote sustainable and efficient practices in marine aquaculture.

1.1 Problem statement

The geographical location of Politeknik Sandakan Sabah which is far from the coast, lack of access to natural seawater sources such as the one from the sea creates significant challenges in conducting practical marine aquaculture activities. Relying on manual labor to mix and monitor water quality takes a lot of time and is very prone to human error. Furthermore, the logistics of transporting salt water are expensive to operate.

1.2 Background of the Study

Technology plays an important role in the modern aquaculture industry by enhancing efficiency, productivity, and sustainability. Managing water quality is vital especially salinity levels, it serves as a key factor in the success of marine aquaculture operations.

1.3 Contribution of the Project

The SaliniTech project helps in modern aquaculture practice by providing a smart and automated salinity management solution tailored towards hatcheries and learning institutions where natural seawater is not readily available. The invention combines the features of salinity sensor, automatic pumping systems, and cloud real-time monitoring into a smart aquaculture solution. Moreover, the adoption of IoT-enabled monitoring technology allows for real-time monitoring of water quality parameters, improves efficiency and reduces human error in the process of managing marine aquaculture. The project uses an ESP32 microcontroller, IoT platform (Thingier.io), peristaltic pump and mobile real-time monitoring. The project also encourages sustainable aquaculture practices through improved resource management and reduction of water quality variations.

1.4 Objectives

- i. To develop an automated salinity monitoring system for controlling water salinity
- ii. To reduce manual monitoring processes and minimize human error in salinity management.
- iii. To improve time efficiency in hatchery operations.
- iv. To evaluate system effectiveness in maintaining stable salinity (29-31 ppt).

2. Literature review

2.1 Importance of Salinity in Aquaculture

The salinity of water, which refers to the concentration of salt in water, is one of the most important factors in aquaculture. Salinity, expressed in parts per thousand (ppt) is an extremely important factor when considering the appropriateness of the environment for the development and survival of aquatic life, including fish, shrimps, and mollusks. Since each aquatic species has distinct salinity requirements, a thorough understanding of this parameter is vital for ensuring the success of aquaculture operations. This essay will discuss the significance of water salinity, its effects on aquatic organisms, and the methods for managing salinity within aquaculture systems (Boyd, 2015).

2.2 Smart Aquaculture and IoT Technologies

Smart fish farming faces critical challenges in achieving comprehensive automation, real-time decision-making, and adaptability to diverse environmental conditions and multi-species aquaculture. This study presents a novel Internet of Things (IoT)-driven intelligent decision-making system that dynamically monitors and optimizes water quality parameters to enhance fish survival rates across various regions and species setups. The system integrates advanced sensors connected to an ESP32 microcontroller, continuously monitoring key water parameters such as pH, temperature, and turbidity which are increasingly affected by climate-induced variability (Kanwal, 2024).

2.3 Electrical Conductivity Sensors for Salinity Monitoring

An Electrical Conductivity (EC) sensor is a crucial device in water quality monitoring, functioning to measure the capacity of water to conduct an electrical current. The operating principle of this sensor relies on the presence of dissolved ions—such as salts, minerals, and metals—in the water, which act as carriers of electrical charge. Fundamentally, a higher concentration of dissolved ions in the water results in a correspondingly higher electrical conductivity value. This value is typically expressed and exhibits a direct correlation with the salinity level of the water (Boyd & Tucker, 2014).



Figure 1.1: EC Sensor

2.4 ESP32-based Monitoring Systems

ESP32 microcontrollers have become popular in IoT applications due to their integrated Wi-Fi capability, low power consumption, and computational efficiency. They support real-time sensor integration and cloud communication platforms. The ESP32 is a system-on-chip (SoC) that has revolutionized the fields of electronics and embedded computing with its dual-core processing capabilities and integrated wireless connectivity. Manufactured by Espressif Systems, this chip was introduced in 2016 as the successor to the highly popular ESP8266 (Espressif Systems, 2022). According to a study by Smith and Johnson (2021), the ESP32 integrates a 32-bit dual-core Xtensa processor with 802.11b/g/n Wi-Fi and Bluetooth 4.2 capabilities, making it a highly efficient all-in-one solution for Internet of Things (IoT) applications. With its affordable price point and high performance, the ESP32 has become a top choice among developers, engineers, and electronics enthusiasts worldwide.

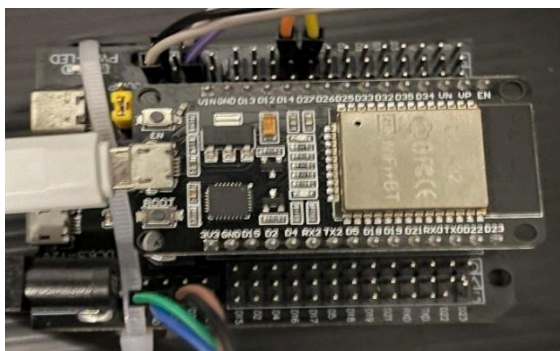


Figure 1.2: ESP32

2.5 Peristaltic Pump

A peristaltic pump, also called a hose pump, peristaltic pump or roller pump, is a positive displacement pump. The hose is permanently installed in the pump housing. The rotating rotor squeezes the tubing and pushes the liquid through the tubing due to the rotary motion. A peristaltic pump consists of a rotor with rollers (in the pump head), the pump housing and the hose. A product change is carried out very quickly, as only the hose is in contact with the liquid, PeriPump



Figure 1.3: Peristaltic Pump

2.5 Thinger.Io

Thingier.Io is an open-source Internet of Things (IoT) platform that provides a comprehensive solution for connecting, managing, monitoring, and analyzing data from interconnected devices. The platform is designed to simplify IoT application development by offering a scalable cloud-based infrastructure that enables real-time communication between devices and users through an intuitive web interface. According to Bustamante, Patricio, and Molina (2019), Thinger.io integrates cloud computing, big data, and IoT technologies, allowing developers to collect, process, and visualize large volumes of sensor data efficiently in a cost-effective environment.

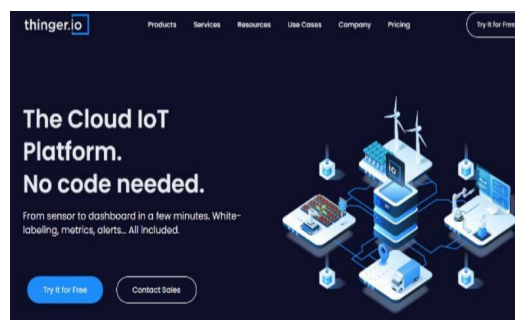


Figure 1.4: Platform Thinger.Io

3. Methodology

The SaliniTech system is an automated salinity control system designed specifically for hatchery applications. The system's primary objective is to maintain water salinity within a precise target range of 29 to 31 parts per thousand (ppt). Utilizing an integrated Internet of Things (IoT) approach, the system combines real-time sensing via EC sensors, data processing through an ESP32 microcontroller, and remote monitoring via the Thinger.io cloud platform. The operational logic is governed by a continuous feedback loop that triggers automated dosing of either salt solution or freshwater to counteract fluctuations, ensuring optimal environmental conditions for the hatchery. To evaluate the performance of SaliniTech, experimental testing was conducted over a four-week period under simulated hatchery conditions. The target salinity was fixed at 30 ppt, with an acceptable operating range between 29 and 31 ppt. Salinity measurements were recorded three times per week (Monday, Wednesday, and Saturday), resulting in a total of 12 observation sessions. Whenever the measured salinity dropped below 29 ppt, the ESP32 automatically activated the peristaltic pump to inject concentrated salt solution. Conversely, if the salinity exceeded 31 ppt, the freshwater pump was activated until the target salinity was restored. The response time of the dosing system was approximately 5–10 seconds after a salinity deviation was detected, depending on the volume of water and required dosage. To assess system effectiveness, the automated SaliniTech system was also compared with conventional manual salinity preparation using a handheld refractometer and manual salt addition. Performance indicators included salinity stability, operational consistency, labour requirement, and response time.

3.1 Technical Architecture and Components

The Salinitech system relies on four primary hardware and software components to execute its salinity management functions:

- EC Sensor: Responsible for continuous, real-time measurement of water salinity levels.
- ESP32 Microcontroller: Serves as the central processing unit, analyzing sensor data and executing the system's decision-making logic.
- Thingier.io Cloud Platform: Facilitates the transmission of data for remote, real-time monitoring of system performance.
- Automated Dosing Pumps (peristaltic pump): Two distinct pumps (Salt Solution and Freshwater) are utilized to adjust the chemical composition of the water based on microcontroller commands.



Figure 1.5: System diagram of SaliniTech

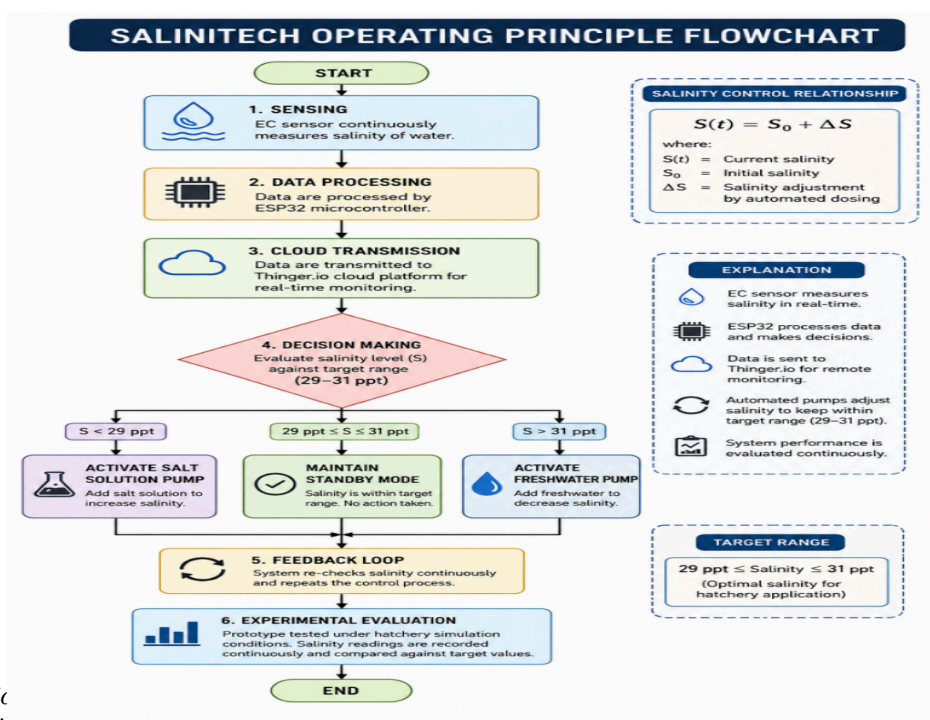


Figure 1.6: SaliniTech operating principal flowchart



Figure 1.7: SaliniTech (Product)

3.2 Testing Duration and Number of Trials

The performance evaluation of SaliniTech was carried out over a continuous four-week testing period (28 days) under simulated hatchery conditions. Salinity readings were logged three times per week (Monday, Wednesday, and Saturday), producing a total of 12 monitoring sessions across the testing period. Within each session, three consecutive readings were taken at short intervals to confirm reading stability before logging, giving a total of 36 individual sensor readings over the study. In addition to the field monitoring, 10 controlled bench trials were conducted prior to the four-week evaluation to verify the responsiveness and repeatability of the dosing mechanism under artificially induced salinity deviations, both above and below the 29–31 ppt target range. This combination of long-duration field monitoring and short-duration controlled bench trials allowed the system to be assessed for both long-term stability and short-term responsiveness.

3.3 Sensor Calibration Procedure

Prior to testing, the EC sensor was calibrated using a two-point calibration method with standard reference solutions representing the lower and upper ends of the salinity range expected in marine hatchery operations. Calibration readings were cross-checked against a handheld refractometer to confirm accuracy, and the resulting calibration curve was programmed into the ESP32 firmware to convert raw EC voltage readings into ppt values. To account for possible sensor drift caused by biofilm build-up or electrode fouling, the sensor was re-calibrated once every week throughout the four-week testing period. Calibration accuracy was verified to remain within a narrow tolerance of the refractometer reference readings throughout the study, confirming that the sensor maintained reliable measurement performance across the testing duration.

3.4 Pump Response Time Evaluation

The response time of the peristaltic dosing pumps was evaluated separately from the salinity stability trials. A total of 15 controlled activation trials were conducted for each pump (salt solution and freshwater), in which salinity was deliberately deviated outside the 29–31 ppt range and the time between deviation detection and pump activation was recorded using a digital stopwatch. Across these trials, the average response time was approximately 5–10 seconds, depending on the magnitude of the deviation and the volume of water requiring correction. No failed activation attempts were recorded during the trials, indicating consistent and reliable pump performance across repeated cycles.

3.5 Comparative Testing Protocol (Manual vs. Automated)

To benchmark SaliniTech against conventional practice, a parallel set of manual salinity preparation trials was conducted using a handheld refractometer and manual salt addition performed by a trained operator. The manual method was tested over the same four-week period, with salinity checked and adjusted at the same three-times-weekly intervals, resulting in 12 manual trials in total to allow a direct, like-for-like comparison with the automated system. For each manual trial, the time required to collect a sample, take a refractometer reading, calculate the necessary salt or freshwater dosage, and manually adjust the water was recorded, together with the resulting salinity deviation from the 30 ppt target. This comparative protocol allowed the study to quantify both the stability advantage and the labour-time savings achieved by replacing manual monitoring and dosing with the closed-loop SaliniTech system.

4. Discussion of analysis and findings

4.1 System Performance Analysis

Salinity was kept within the required operational range (29–31ppt) throughout the 4-week testing process. No significant deviations outside the target range were observed during the 12 monitoring sessions. The automated feedback mechanism successfully compensated for salinity fluctuations caused by evaporation and water replacement activities.

The cloud dashboard provided continuous real-time monitoring, allowing users to observe system performance remotely. The recorded data confirmed stable system operation with minimal salinity variation, demonstrating the effectiveness of the closed-loop control strategy. The Electrical Conductivity (EC) sensor constantly detected the salinity levels and transmitted the data in real time to the ESP32 controller. If there was any variation in the salinity levels from the pre-set threshold, then the system automatically triggered the relevant dosing pump to regulate the salinity levels. Figure 4.1 below showed the results that the system successfully maintained salinity between 29 and 31 ppt with minimal fluctuation. This demonstrates that the closed-loop control mechanism could respond effectively to salinity changes without requiring operator intervention.

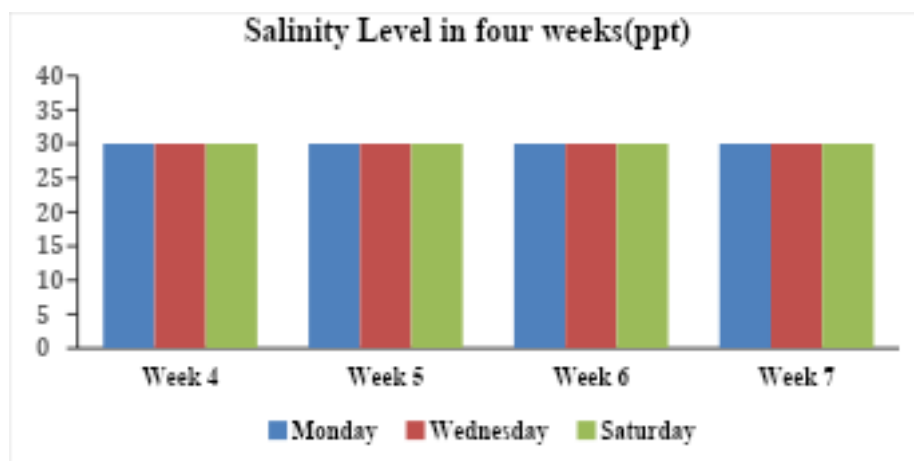


Figure 1.8: Salinity stability performance of SaliniTech during a Four-Week evaluation

Parameter	Manual Method	SaliniTech
<i>Salinity measurement</i>	Manual refractometer	EC Sensor (Real-time)
<i>Monitoring</i>	Periodic	Continuous
<i>Salt addition</i>	Manual	Automatic
<i>Human error</i>	High	Low
<i>Labour requirement</i>	High	Low
<i>Response time</i>	Depends on operator	5–10 seconds
<i>Salinity consistency</i>	Moderate	High
<i>Remote monitoring</i>	No	Yes (Thingier.io)

Table 1.1: Comparison between manual salinity preparation and SaliniTech

A comparison between the conventional manual method and the proposed SaliniTech system, in terms of monitoring approach, response time, operational efficiency, and salinity stability, is presented in Table 4.1 above. The comparison highlights the advantages of automation in reducing human intervention while improving the consistency and reliability of salinity management in aquaculture operations.

Across the 12 monitoring sessions, SaliniTech maintained salinity consistently within the 29–31 ppt target band, with only minor fluctuations attributable to evaporation and water replacement activities. By comparison, the 12 parallel manual trials showed noticeably wider variation around the 30 ppt target, reflecting the influence of operator technique, refractometer reading precision, and inconsistent dosage calculation. In terms of process time, the automated system corrected salinity deviations within 5-10 seconds of detection, whereas each manual

adjustment cycle encompassing sample collection, refractometer reading, dosage calculation, and manual salt or freshwater addition required considerably longer to complete. These findings indicate that, beyond improving salinity stability, SaliniTech offers a substantial reduction in labour time per adjustment cycle compared to conventional manual salinity preparation, reinforcing the case for automation in hatchery water quality management.

4.2 Finding of the Study

The performance evaluation of SaliniTech was conducted simultaneously with conventional manual salinity preparation methods under simulated hatchery conditions. The findings revealed that SaliniTech consistently maintained salinity levels within the desired operational range of approximately 30 ppt throughout the testing period.

The stability achieved by the system demonstrates the effectiveness of the automated control algorithm and sensor integration. Through continuous monitoring and automatic activation of the dosing mechanism, SaliniTech effectively compensated for salinity fluctuations caused by water dilution, evaporation, or operational disturbances.

Furthermore, the system significantly reduced labour dependency and minimized human errors associated with manual salt addition and periodic salinity measurements. This capability is particularly important in hatchery operations where stable environmental conditions are essential for aquatic organism health, growth, and survival. The implementation of SaliniTech generated positive impacts across technical, economic, educational, and environmental dimensions. From a technical perspective, the system improved salinity stability and reduced operational variability. Economically, the automation process reduced labour dependency and minimized operational costs associated with manual monitoring activities. From an educational standpoint, SaliniTech serves as a practical learning platform for students studying aquaculture, automation, and Internet of Things (IoT) technologies. The project also supports the implementation of Industry 4.0 concepts within Technical and Vocational Education and Training (TVET) institutions. Environmentally, the precise dosing mechanism reduced unnecessary salt usage and minimized resource wastage, contributing to more sustainable aquaculture practices. Overall, the findings demonstrate that SaliniTech is an innovative, cost-effective, and scalable solution capable of supporting the future development of smart aquaculture systems.

5. Conclusion and future research

The SaliniTech project successfully achieved its main objective of developing an automated artificial seawater preparation and monitoring system using Internet of Things (IoT) technology. The system was designed to address the limitation of natural seawater availability at inland aquaculture facilities while supporting teaching and learning activities in aquaculture education. Through the integration of an ESP32 microcontroller, Electrical Conductivity (EC) sensor, ADS1115 module, peristaltic pumps, and the Thingier.io platform, SaliniTech was able to automatically monitor and maintain salinity at the target level of 30 ppt. The experimental results demonstrated consistent performance and confirmed the effectiveness of the IoT-based automation system in maintaining stable salinity conditions.

In addition to its educational value, SaliniTech has strong potential for practical application in aquaculture hatcheries. The system can reduce labour requirements, improve operational efficiency, and support sustainable aquaculture practices. Overall, the project demonstrates that IoT technology can provide an innovative and cost-effective solution for modern aquaculture water quality management. This study was conducted under controlled testing conditions and focused primarily on salinity monitoring and control. Therefore, further testing in commercial hatchery environments is recommended to evaluate long-term system performance.

Future research should focus on integrating additional water quality parameters such as pH, dissolved oxygen, temperature, and ammonia. The development of a mobile application and advanced data analytics features could further enhance the functionality and commercialization potential of SaliniTech.

Acknowledgment

The authors would like to express their gratitude to Politeknik Sandakan Sabah and Politeknik Jeli Kelantan for providing the infrastructure, technical facilities, and conducive research atmosphere which made the research project possible. The authors would like to extend their sincere appreciation to all lecturers, technical personnel, students, and collaborators who made significant contributions in the process of developing and evaluating the SaliniTech project.

References

- Boyd, C. E. (2000). Water quality: an introduction. Springer Science & Business Media.
- Boyd, C. E., & Tucker, C. S. (2014). Handbook for aquaculture water quality. Craftmaster Printers.
- Bustamante, A. L., Patricio, M. A., & Molina, J. M. (2019). Thinger.io: An open source platform for deploying data fusion applications in IoT environments. *Sensors*, 19(5), 1044.
- Chen, X., Wang, Y., & Liu, Z. (2020). Advances in automated dosing mechanisms and fluid isolation in IoT systems. *Journal of Mechanical and Biomedical Engineering*, 14(2), 88-102.
- Espressif Systems. (2022). ESP32 series datasheet. Espressif Systems. https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf
- Flores-Iwasaki, M., Guadalupe, G. A., Pachas-Caycho, M., Chapa-Gonza, S., Mori-Zabarburú, R. C., & Guerrero-Abad, J. C. (2025). Internet of Things (IoT) Sensors for Water Quality Monitoring in Aquaculture Systems: A Systematic Review and Bibliometric Analysis. *AgriEngineering*, 7(3), 78. <https://doi.org/10.3390/agriengineering7030078>

- Kanwal, S., Abdullah, M., Kumar, S., Arshad, S., Shahroz, M., Zhang, D., & Kumar, D. (2024). An optimal internet of things-driven intelligent decision-making system for real-time fishpond water quality monitoring and species survival. *Sensors*, 24(23), 7842.
- Kültz, D. (2015). Physiological mechanisms used by fish to cope with salinity stress. *The Journal of experimental biology*, 218(12), 1907-1914.
- Obi, C., Dompheh, E. B., Manyise, T., Tan, S. H., Woo, S. P., & Rossignoli, C. M. (2025). Overview of the fishery and aquaculture sectors in Malaysia. *Frontiers in Sustainable Food Systems*, 9, 1545263.
- PeriPump. (2025). Function of a peristaltic pump. Retrieved from <https://www.peripump.eu/en/function-peristaltic-pump>

EFFECTS OF AQUATIC PLANTS (*HYDRILLA* SP. AND *AZOLLA* SP.) ON DISSOLVED NUTRIENT CONCENTRATIONS IN FIGHTING FISH (*BETTA SPLENDENS*) CULTURE

Muhammad Azizul Hasnain¹, Nikmael Nikson¹, Natasah Lv Alexius¹

¹Department of Agrotechnology and Bio-Industry, Politeknik Sandakan Sabah

¹Corresponding author's email: azizul@pss.edu.my

ABSTRACT

The effects of aquatic plants (*Hydrilla* sp. and *Azolla* sp.) on the concentration of dissolved nutrients in *Betta splendens* (fighting fish) tank culture were investigated. The study was driven by increasing concerns over nutrient accumulation in aquaculture systems, particularly ammonia, nitrite, nitrate, and phosphate, which can negatively affect overall water quality. The primary objective of this study was to compare dissolved nutrient concentrations (ammonia, nitrite, nitrate, and phosphate) in *Betta splendens* culture systems with and without aquatic plants (*Hydrilla* sp. and *Azolla* sp.). The study was carried out over a 30-day experimental period to evaluate the effectiveness of aquatic plants in reducing dissolved nutrient concentrations and to observe gradual changes in water quality and fish growth performance under different treatment conditions. Nine experimental tanks were arranged into three treatments with three replicates each: tanks containing *Azolla* sp., tanks containing *Hydrilla* sp., and control tanks without aquatic plants. The findings revealed significant differences ($P < 0.05$) in total dissolved solids (TDS) and dissolved nutrient concentrations among treatments. Tanks containing *Azolla* sp. recorded the lowest concentrations of phosphate, ammonia, and nitrite, followed by *Hydrilla* sp., while the control tanks showed the highest values. However, nitrate concentrations did not differ significantly among treatments. In conclusion, the application of aquatic plants, especially *Azolla* sp., effectively reduced dissolved nutrient concentrations and improved water quality in *Betta splendens* culture systems, demonstrating their potential as sustainable biological filters in aquaculture practices.

Keywords: Aquatic plants; Dissolved nutrients; Water quality

1. Introduction

Water quality is one of the most important factors influencing the success of aquaculture production, as it directly affects the growth, health, and survival of cultured organisms. Excessive concentrations of dissolved nutrients, particularly ammonia, nitrite, nitrate, and phosphate, can impair fish metabolism, reduce growth performance, and increase physiological stress.

In recent years, aquatic plants have gained attention as an eco-friendly and effective method for improving water quality in aquaculture systems. Through the process, aquatic plants help reduce dissolved nutrients such as ammonia, nitrate, and phosphate from aquaculture wastewater. *Hydrilla* sp. is a submerged aquatic plant known for its rapid growth and ability to absorb nutrients efficiently through its root system. Meanwhile, *Azolla* sp. is a floating aquatic fern that functions as a natural

biofilter in freshwater environments. Generally, both aquatic plants play an important role in maintaining water quality by absorbing excess nutrients required for their growth.

Although, *Azolla* sp. and *Hydrilla* sp. have been widely used in water treatment applications, studies comparing their effectiveness in reducing dissolved nutrient concentrations within the same experimental aquaculture system remain limited. Therefore, this study aimed to evaluate and compare the concentrations of ammonia, nitrite, nitrate, and phosphate in ornamental fish culture water with and without the application of aquatic plants (*Hydrilla* sp. and *Azolla* sp.), thereby assessing their potential as natural biofilters for sustainable aquaculture water management.

2. Literature review

Aquatic plants play an important role in improving water quality in aquaculture systems by reducing dissolved nutrients and organic pollutants. Excessive concentrations of ammonia, nitrite, nitrate, and phosphate can negatively affect aquatic organisms and contribute to eutrophication. Through phytoremediation, aquatic plants absorb excess nutrients directly from the water and help maintain a healthier culture environment (Ansari et al., 2020). Aquaculture wastewater generally contains high concentrations of nutrients originating from uneaten feed, fish excretion, and organic matter decomposition. These nutrients can be assimilated by aquatic plants, thereby reducing the accumulation of harmful compounds in culture systems (Bin Lu et al., 2018).

In addition to direct nutrient uptake, aquatic plants provide suitable habitats for beneficial microorganisms involved in nutrient transformation processes such as nitrification and denitrification. The root systems of aquatic plants serve as substrates for microbial colonization, promoting bacterial growth that contributes to nutrient removal and organic matter degradation (Hu et al., 2008). Nutrient reduction occurs through several mechanisms, including plant assimilation, microbial activity, nitrification, and volatilization processes (Bednarek et al., 2014). Recent studies have further highlighted the synergistic interaction between aquatic plants and microbial communities in enhancing nutrient removal efficiency from aquaculture wastewater (Nizam et al., 2020).

Aquatic plants also improve water conditions through oxygen release during photosynthesis and by trapping suspended particles within their root systems. Oxygen transported to the rhizosphere enhances microbial activity and supports the decomposition of organic compounds, contributing to better overall water quality (Stottmeister et al., 2003). Previous studies have demonstrated that aquatic plants such as *Azolla pinnata*, *Lemna minor*, and other floating macrophytes effectively reduce ammonia, nitrate, and phosphate concentrations in aquaculture wastewater while improving overall treatment performance (Amyati et al., 2020; Paolacci et al., 2021). Similarly, phytoremediation using *Azolla pinnata* resulted in significant reductions in ammonia concentration in aquaculture effluent. Other studies have also reported reductions in organic pollutants, phosphate, total dissolved solids, and water hardness

following the application of aquatic plants in contaminated water systems (Moyo et al., 2013).

Aquaculture activities can contribute to water pollution through the accumulation of dissolved nutrients and organic waste derived from uneaten feed, fish excretion, and decomposition processes. Excessive concentrations of ammonia, nitrite, nitrate, and phosphate may deteriorate water quality and negatively affect fish health and survival (Boyd et al., 2020). High ammonia levels are particularly harmful because they can damage fish gills, reduce metabolic efficiency, and increase physiological stress, while excessive nitrate and phosphate concentrations may promote eutrophication and algal blooms (FAO, 2022). Poor water quality has been identified as a major factor associated with disease outbreaks, reduced growth performance, and increased mortality in intensive aquaculture systems (Dauda et al., 2021). Furthermore, the accumulation of dissolved nutrients and organic waste can adversely affect fish health and compromise aquaculture sustainability if not properly managed (Lee et al., 2021).

Recent studies have shown that inadequate nutrient management in intensive aquaculture systems is often associated with environmental degradation and declining production performance (Dauda et al., 2021). Therefore, regular monitoring of dissolved nutrients and water quality parameters is essential to maintain a stable and sustainable culture environment. Environmentally friendly approaches such as phytoremediation using aquatic plants have gained increasing attention due to their ability to absorb excess nutrients, support beneficial microbial communities, and improve water quality naturally. The integration of aquatic macrophytes into aquaculture wastewater treatment systems has been recognized as a sustainable and cost-effective strategy for nutrient removal and environmental management (Nizam et al., 2020; Lee et al., 2021). Overall, aquatic plants have strong potential as eco-friendly biofilters for sustainable aquaculture water management.

3. Methodology

This study on the effects of aquatic plants on dissolved nutrient concentrations in ornamental fish (betta fish) culture water was conducted at a suitable aquaculture facility for 30 days. Water quality parameters and dissolved nutrient concentrations were sampled on Day 1, Day 10, Day 20, and Day 30 to evaluate the changes in nutrient concentration throughout the experimental period. A total of 40 betta fish were stocked in each experimental tank with a capacity of 80 liters of water. Two types of aquatic plants were used in this study, namely *Hydrilla* sp. and *Azolla* sp. *Hydrilla* sp. was collected from a wild habitat near a lake, whereas *Azolla* sp. was purchased from a local farmer engaged in medium scale aquaculture activities. *Hydrilla* sp. is a submerged aquatic plant commonly found in freshwater environments. In addition, treatment without aquatic plants was prepared as the control treatment. Each treatment consisted of three replicates to compare the effects of aquatic plants on dissolved nutrient concentrations and water quality.

A total of nine tanks were used in this experiment, with three replicates for each treatment. The tank positions were arranged randomly to ensure balanced data collection. Aeration systems were installed in each tank to provide sufficient oxygen throughout the study period. The biomass of aquatic plants used in each tank was 50 g wet weight. Changes in plant biomass during the experiment were used as an indicator of the efficiency of aquatic plants in absorbing dissolved nutrients from the culture water.

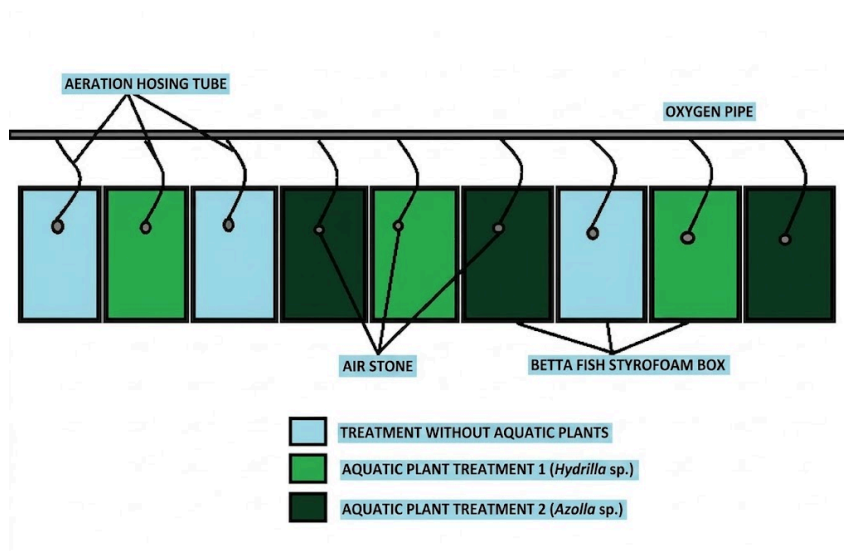


Figure 1.1: Experimental design layout

3.1 Measurement of dissolved nutrient concentration using spectrophotometer

Water samples were collected from each experimental tank and transported to the laboratory for nutrient analysis. Upon arrival, the samples were filtered using a vacuum filtration system equipped with a micro-fiber filter to remove suspended particles. The filtered samples were then transferred into conical flasks for subsequent analysis. Nutrient concentrations were determined using nutrient-specific reagents supplied in the test kits, following the manufacturer's instructions. For each analysis, an appropriate volume of the filtered sample was transferred into a test vial, followed by the addition of the designated reagents. The mixture was gently shaken to ensure complete mixing and left to react for the recommended period to allow colour development. After the colour reaction had formed, the absorbance was measured using a spectrophotometer at the appropriate wavelength for each nutrient parameter. The absorbance (Abs) values obtained were then substituted into the corresponding linear calibration equation to determine the dissolved nutrient concentration for each treatment:

$$y = a x + b$$

y = light absorbance (A)

x= dissolved nutrient concentration (mg/L)

a= slope of the linear equation

b= y-intercept

3.2 Statistical analysis

The recorded in-situ water quality data and dissolved nutrient concentrations were analysed using IBM SPSS Statistics Version 31. One-way ANOVA followed by Duncan's post hoc test was used to analyse the changes in in-situ water quality parameters among treatments. Differences in dissolved nutrient concentrations between tank media were analysed using the Kruskal - Walli's test. Significant differences among treatments were further determined using all-pairwise comparisons with the Bonferroni method. Spearman correlation analysis was performed to examine the relationship between dissolved nutrient concentrations and in-situ water quality parameters. In addition, linear regression analysis was used to determine the influence of dissolved nutrient concentrations on in-situ water quality.

4. Discussion of analysis and findings

The results showed the overall mean concentrations of dissolved nutrients, namely $\text{PO}_4\text{-P}$, $\text{NH}_3\text{-N}$, $\text{NO}_2\text{-N}$, and $\text{NO}_3\text{-N}$, in tanks containing aquatic plants (*Azolla* sp. and *Hydrilla* sp.) and in tanks without aquatic plants throughout the 30-day experiment. Based on the Kruskal-Wallis test, the concentrations of $\text{NH}_3\text{-N}$, $\text{PO}_4\text{-P}$, and $\text{NO}_2\text{-N}$ differed significantly among treatments ($P < 0.05$), while $\text{NO}_3\text{-N}$ showed no significant difference ($P > 0.05$). The highest mean phosphate ($\text{PO}_4\text{-P}$) concentration was recorded in the control tank without aquatic plants (1.63 ± 1.13 mg/L), followed by the *Hydrilla* sp. tank (0.72 ± 0.46 mg/L), while the lowest concentration was observed in the *Azolla* sp. tank (0.69 ± 0.42 mg/L). A similar trend was observed for ammonia ($\text{NH}_3\text{-N}$), where the highest concentration was recorded in the tank without aquatic plants (1.55 ± 1.16 mg/L). Lower concentrations were found in the *Azolla* sp. tank (0.71 ± 0.45 mg/L) and *Hydrilla* sp. tank (0.70 ± 0.47 mg/L). For nitrite ($\text{NO}_2\text{-N}$), the highest mean concentration was also detected in the control tank (1.91 ± 1.39 mg/L), followed by the *Hydrilla* sp. tank (0.89 ± 0.60 mg/L), while the lowest concentration was recorded in the *Azolla* sp. tank (0.78 ± 0.53 mg/L). In contrast, nitrate ($\text{NO}_3\text{-N}$) concentration showed no significant difference ($P > 0.05$) among all treatments, with mean values ranging from 0.98 ± 0.68 mg/L to 1.73 ± 1.26 mg/L. The table below presents a comparison of the dissolved nutrient concentrations among the different treatments.

Parameter	Treatment			
	n	<i>Azolla</i> sp.	<i>Hydrilla</i> sp.	Without aquatic plants
NH ₃ -N (mg/L)	36	0.71 ± 0.45 ^a	0.70 ± 0.47 ^a	1.58 ± 1.12 ^b
NO ₂ -N (mg/L)	36	0.78 ± 0.53 ^a	0.89 ± 0.60 ^a	1.91 ± 1.39 ^b
NO ₃ -N (mg/L)	36	1.02 ± 0.84 ^a	0.98 ± 0.68 ^a	1.73 ± 1.26 ^b
PO ₄ -P (mg/L)	36	0.69 ± 0.42 ^a	0.72 ± 0.46 ^a	1.63 ± 1.13 ^b

Table 1.1: Result for dissolved nutrient concentration. Values in the same column bearing different superscripts indicate significant differences ($p < 0.05$)

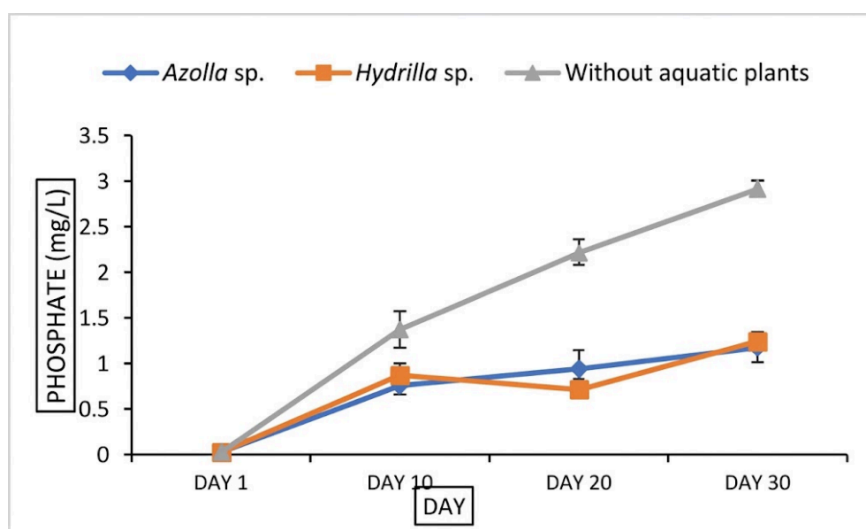


Figure 1.1: Phosphate concentration

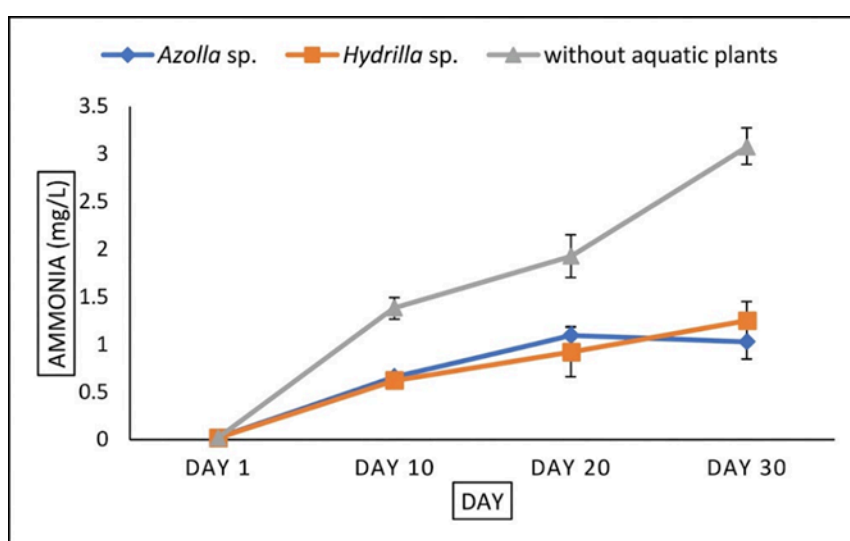


Figure 1.2: Ammonia concentration

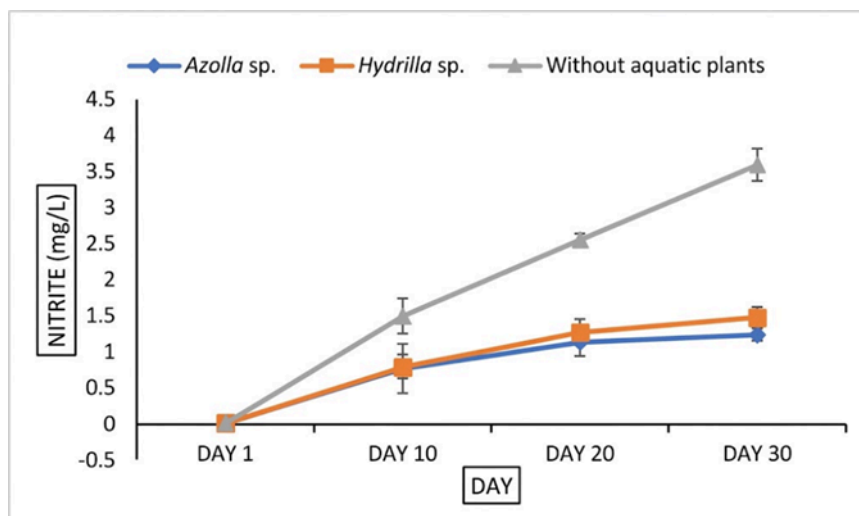


Figure 1.3: Nitrite concentration

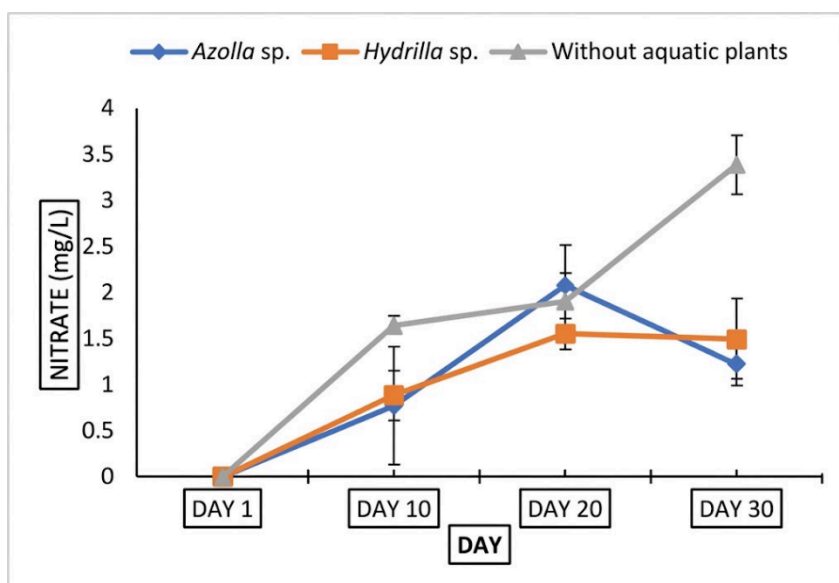


Figure 1.4: Nitrate concentration

Phosphate ($\text{PO}_4\text{-P}$) is one of the dissolved nutrients that can reduce water quality and negatively affect aquatic organisms when present at high concentrations. In this study, phosphate concentration increased more rapidly in the control tank without aquatic plants, whereas tanks containing aquatic plants (*Azolla* sp. and *Hydrilla* sp.) showed lower and more stable phosphate levels throughout the experiment. This finding suggests that aquatic plants were able to absorb and utilise phosphate for growth, indirectly improving water quality. Similar findings have been reported in recent studies where aquatic plants functioned as natural biofilters by

removing excess phosphorus from aquaculture wastewater (Nizam et al., 2020; Springer Nature, 2025).

Ammonia ($\text{NH}_3\text{-N}$) concentration gradually increased throughout the 30-day experiment due to fish feeding activities and waste excretion, which are major sources of nitrogen in aquaculture systems. However, tanks containing aquatic plants showed lower ammonia concentrations compared to the control tank without plants. This indicates that aquatic plants played an important role in nutrient uptake and helped maintain a more stable culture environment by reducing ammonia accumulation. Previous studies also reported that aquatic plants and algae can improve nitrogen removal efficiency in aquaculture systems through nutrient absorption and biological filtration processes (Ramli et al., 2020; Zhang et al., 2021).

Nitrite ($\text{NO}_2\text{-N}$) concentration also increased over time in all treatments, particularly in the control tank without aquatic plants. In contrast, tanks containing *Azolla* sp. and *Hydrilla* sp. maintained lower nitrite concentrations throughout the experiment. The presence of aquatic plants may support nitrification processes by providing surfaces for microbial growth and enhancing nutrient cycling in the culture water. High nitrite concentration is harmful to fish as it can interfere with oxygen transport and physiological functions. Therefore, the lower nitrite concentration observed in planted tanks indicates better water quality conditions for fish culture. Similar observations were highlighted in recent phytoremediation studies involving aquaculture wastewater treatment (Nizam et al., 2020; Li et al., 2025).

For nitrate ($\text{NO}_3\text{-N}$), no significant difference was observed among treatments throughout the experiment. Nevertheless, slightly lower nitrate concentrations were recorded in tanks containing aquatic plants. This may be associated with nutrient uptake by aquatic plants and microbial activities such as nitrification and denitrification occurring within the culture system. Aquatic plant roots can also act as substrates for beneficial microorganisms involved in nitrogen cycling, contributing to the reduction of dissolved nutrients in aquaculture water (Ramli et al., 2020; Li et al., 2025).

Overall, the findings of this study demonstrate that aquatic plants, particularly *Azolla* sp. and *Hydrilla* sp., were effective in reducing dissolved nutrient concentrations and improving water quality in the aquaculture system. Their application as natural biofilters may therefore provide a sustainable and environmentally friendly approach for aquaculture wastewater management.

5. Conclusion and future research

This study demonstrated that the presence of aquatic plants, namely *Hydrilla* sp. and *Azolla* sp., significantly influenced dissolved nutrient concentrations in a closed *Betta splendens* culture system over a 30-day period. Significant differences ($P < 0.05$) were observed for Phosphate ($\text{PO}_4\text{-P}$), Ammonia ($\text{NH}_3\text{-N}$), and Nitrite ($\text{NO}_2\text{-N}$) concentrations between tanks with and without aquatic plants, while Nitrate ($\text{NO}_3\text{-N}$) showed no significant difference. The variations in nitrogen compounds were associated with the nitrification process, which contributes to the reduction of nitrogen substances in the culture water.

Overall, *Hydrilla* sp. and *Azolla* sp. were effective in absorbing excess dissolved nutrients in the aquaculture system, with *Azolla* sp. showing greater nutrient absorption potential based on its higher biomass increase during the study period. The findings suggest that aquatic plants can serve as a natural, environmentally friendly, and cost-effective alternative for improving water quality in aquaculture systems.

This approach also has strong potential for future application and further research in sustainable aquaculture practices, particularly in semi-intensive and intensive freshwater culture systems. Future studies involving different aquatic plant species and aquaculture organisms are recommended to expand scientific understanding and enhance the development of eco-friendly nutrient management and aquaculture wastewater treatment systems.

Acknowledgment

All praise be to God for granting me the strength, guidance, and opportunity to successfully complete this study. First and foremost, I would like to express my deepest gratitude and sincere appreciation to my supervisor for the guidance, patience, continuous support, and valuable advice provided throughout the completion of this research. The encouragement and knowledge shared have greatly contributed to the success of this study. We would also like to extend my appreciation to all lecturers and staff members of Jabatan Agroteknologi dan Bio-industri, Politeknik Sandakan Sabah for their assistance, support, and contributions during the research process.

References

- Amyati, A., Zahidah, Supriadi, D., & Hamdani, H. (2020). The effectiveness of the use of aquatic plants (*Lemna perpusilla*, *Landoltia punctata* and *Azolla pinnata*) in the phytoremediation process of catfish aquaculture wastewater. *Asian Journal of Fisheries and Aquatic Research*, 8(4), 10–19.
- Ansari, A. A., Gill, S. S., Gill, R., Lanza, G. R., & Newman, L. (2020). *Phytoremediation: Management of environmental contaminants* (Vol. 6). Cham, Switzerland: Springer.
- Bednarek, A., Szpakowska, B., & Zalewski, M. (2014). Nutrient removal mechanisms in aquatic plant systems. *Ecological Engineering*, 73, 482–489.
- Boyd, C. E., Tucker, C. S., & Somridhivej, B. (2020). *Aquaculture pond water quality management*. New York, NY: Springer.
- Dauda, A. B., Romano, N., Chen, W. H., Natrah, I., Kamarudin, M. S., & Karim, M. (2021). Water quality management in intensive aquaculture systems

- and its impact on fish health. *Aquaculture International*, 29(4), 1509–1528.
- FAO. (2022). *The state of world fisheries and aquaculture 2022: Towards blue transformation*. Rome, Italy: Food and Agriculture Organization of the United Nations.
- Goddek, S., & Keesman, K. J. (2020). Improving nutrient and water use efficiencies in multi-loop aquaponics systems. *Aquaculture International*, 28(6), 2481–2490. <https://doi.org/10.1007/s10499-020-00600-6>
- Hu, Z., Lee, J. W., Chandran, K., Kim, S., Sharma, K., & Khanal, S. K. (2008). Effect of plant species on nitrogen recovery in aquaponics. *Bioresource Technology*, 99(16), 7488–7493.
- Lee, K. Y., Ooi, K. Y., Ooi, C. W., Foo, S. C., Chew, K. W., & Show, P. L. (2021). Environmental impacts and imperative technologies towards sustainable treatment of aquaculture wastewater: A review. *Journal of Water Process Engineering*, 40, 101908.
- Lu, H., Kuang, B., & Wang, X. (2018). Nutrient removal by different aquatic plant species: An alternative way to remediate polluted rural rivers. *Ecological Engineering*, 110, 18–26.
- Moyo, P., Chapungu, L., & Mudzengi, C. P. (2013). Effectiveness of aquatic plants in improving wastewater quality. *Physics and Chemistry of the Earth, Parts A/B/C*, 66, 38–45.
- Nizam, N. U. M., Hanafiah, M. M., Noor, I. M., & Karim, H. I. A. (2020). Efficiency of five selected aquatic plants in phytoremediation of aquaculture wastewater. *Applied Sciences*, 10(8), 2712. <https://doi.org/10.3390/app10082712>
- Paolacci, S., Stejskal, V., & Jansen, M. A. K. (2021). Estimation of the potential of *Lemna minor* for effluent remediation in integrated multi-trophic aquaculture using newly developed synthetic aquaculture wastewater. *Aquaculture International*, 29(5), 2101–2118.
- Ramli, N. M., Verreth, J. A. J., Yusoff, F. M., Nurulhuda, K., Nagao, N., & Verdegem, M. C. J. (2020). Integration of algae to improve nitrogenous waste management in recirculating aquaculture systems: A review. *Frontiers in Bioengineering and Biotechnology*, 8, 1004. <https://doi.org/10.3389/fbioe.2020.01004>
- Shahar, B., & Guttman, L. (2020). An integrated, two-step biofiltration system with *Ulva fasciata* for sequenced removal of ammonia and nitrate in mariculture effluents. *Algal Research*, 52, 102120. <https://doi.org/10.1016/j.algal.2020.102120>

Stottmeister, U., Wiessner, A., Kusch, P., Kappelmeyer, U., Kästner, M., Bederski, O., Müller, R. A., & Moormann, H. (2003). Effects of plants and microorganisms in constructed wetlands for wastewater treatment. *Biotechnology Advances*, 22(1–2), 93–117

ROOTIFY FILTER: APPLICATION OF BIOCHAR DERIVED FROM HYDROPONIC ROOT WASTE FOR AGRICULTURAL WASTEWATER TREATMENT

Syafina Fasya binti Saiful Anuar¹, Mohamad Munzir bin Mohammad Hafizan¹,
Nur Nazuin binti Marwan¹, Nur Faradiya Natasyha binti Mohd Tarmizi¹,
Nurelyana Najihah binti Ahmad Zamri¹

¹Department of Plantation and Agrotechnology, School of Science, Technology and Management, Kolej Yayasan Pahang, Kuantan, Pahang

¹Corresponding author's email: syafina@kyp.edu.my

ABSTRACT

Agricultural wastewater pollution, particularly from excessive nitrate (NO_3^-) accumulation, has become an increasing environmental concern that requires sustainable and cost-effective treatment approaches. This study introduces Rootify Filter, an eco-friendly water treatment system developed from recycled hydroponic root waste. The discarded roots were converted into biochar and utilized as a natural bio-adsorbent for wastewater remediation. The study aimed to evaluate the effectiveness of hydroponic root-derived materials in improving water quality parameters, including nitrate concentration, pH, and turbidity. A controlled experimental design consisting of four treatments was conducted, namely T1; untreated wastewater (control), T2; fresh hydroponic roots, T3; dried and crushed hydroponic roots, and T4; hydroponic root-derived biochar. All treatments were prepared using a fixed ratio of 1 L wastewater to 10 g treatment material and monitored over a period of 7–14 days. Water quality parameters were assessed at regular intervals to determine treatment efficiency. The findings demonstrated that hydroponic root-derived biochar exhibited the highest nitrate removal efficiency, achieving a 90% reduction, followed by dried and crushed roots (72%) and fresh roots (65%), while the control treatment showed only a minimal reduction of 15%. In addition, biochar treatment produced improved pH stabilization and the lowest turbidity level due to its high adsorption capacity and porous structure. These results indicate that hydroponic root-derived biochar has significant potential as a low-cost, sustainable, and chemical-free filtration material for agricultural wastewater treatment. Furthermore, the innovation supports waste-to-resource utilization and contributes to the advancement of sustainable green technology practices in agricultural systems

Keywords: Bio-adsorbent, Hydroponic root waste, Agricultural wastewater

1. Introduction

Rootify Filter is an eco-friendly water treatment solution made from recycled hydroponic root waste, promoting sustainable waste management by converting agricultural by-products into value-added materials. The roots are processed into biochar, a highly porous material that functions as a natural bio-adsorbent to remove excess nitrates (NO_3^-) and other impurities. It also helps improve pH balance and reduce turbidity in agricultural wastewater. The system is low-cost, scalable, and easy to apply, offering an efficient and chemical-free approach to enhancing overall water

quality. By leveraging the inherent porosity of biochar, this filtration technology serves as a critical biofilm niche for nitrifying bacteria, facilitating the conversion of harmful nitrogenous compounds while fostering a circular economy model in agricultural practice (Li *et al.*, 2020). Furthermore, the integration of these carbonized substrates addresses the critical challenge of high nitrate concentrations in effluents that typically lack sufficient carbon to support effective biological denitrification (Kiani *et al.*, 2020). The objectives of this research are 1) to evaluate the effectiveness of hydroponic root waste as a wastewater treatment material, 2) to incorporate waste management by converting discarded hydroponic roots into value-added filtration media, 3) to compare adsorption performance between dried roots and root-biochar, 4) to improve water quality (nitrate, pH, turbidity) and 5) to develop a low-cost, sustainable, and eco-friendly filtration method.

2. Literature review

Current research emphasizes that conventional nitrogen removal techniques, such as reverse osmosis and ion exchange, often entail prohibitive operational costs, necessitating the exploration of nature-based solutions (Castellar *et al.*, 2018). In this context, biochar derived from agricultural biomass (hydroponic vegetable roots) has emerged as a cost-effective alternative for remediating polluted water, leveraging its inherent porosity to facilitate the adsorption of contaminants (Kumar *et al.*, 2025). Furthermore, the application of such substrates in recirculating systems promotes the colonization of beneficial nitrifying microorganisms, which significantly enhances the biological transformation of nitrogenous pollutants (Ahmed *et al.*, 2026). By utilizing discarded hydroponic vegetable roots biomass, this approach simultaneously addresses the waste disposal challenge of greenhouse operations while creating a value-added, sustainable bio-absorbent for high-efficiency water remediation (Pantoja *et al.*, 2023). Recent investigations highlight that biochar derived from agricultural residues not only mitigates nutrient runoff, such as nitrates and sulfates, but also provides a stable scaffold for microbial communities that drive denitrification processes. Moreover, the synergy between biochar and microbial inoculation has been shown to achieve significant nitrate reduction in treated effluent, even while influencing ammonia dynamics through complex nitrogen cycling pathways. This cost-effective integration of biochar-based filtration addresses the limitations of high-energy treatment methods while providing a scalable framework for managing nutrient pollution in agricultural water systems.

3. Methodology

A controlled experiment was conducted to evaluate the effectiveness of hydroponic root materials in treating wastewater. There are four different treatments were prepared which are; Treatment 1 as a control, Treatment 2 (wastewater treated with fresh hydroponic roots, Treatment 3 (wastewater treated with dried and crushed hydroponic roots) and Treatment 4 (wastewater treated with hydroponic root-derived biochar).

Treatments	Details of wastewater treatments
T1	Control / Untreated wastewater
T2	Wastewater + fresh hydroponics roots
T3	Wastewater + dried hydroponic roots (crushed)
T4	Wastewater + hydroponic root-derived biochar

Table 1.1: Experimental wastewater treatments

Equal volumes of wastewater were used in all treatments to ensure consistency and comparability of results. Each treatment was prepared using a fixed wastewater to treatment material ratio of 1 L: 10 g (1% w/v). Throughout the experimental period, all samples were maintained under identical environmental condition which is room temperature incubated to minimize external influences on treatment performance. The treatments were monitored over a period of 7 to 14 days, during which key water quality parameters were assessed at regular intervals. These parameters included nitrate concentration (NO_3^-), pH, and turbidity, which were selected as indicators of nutrient removal, water acidity/alkalinity, and suspended solids, respectively. The collected data were used to evaluate and compare the effectiveness of each treatment in improving wastewater quality over time.

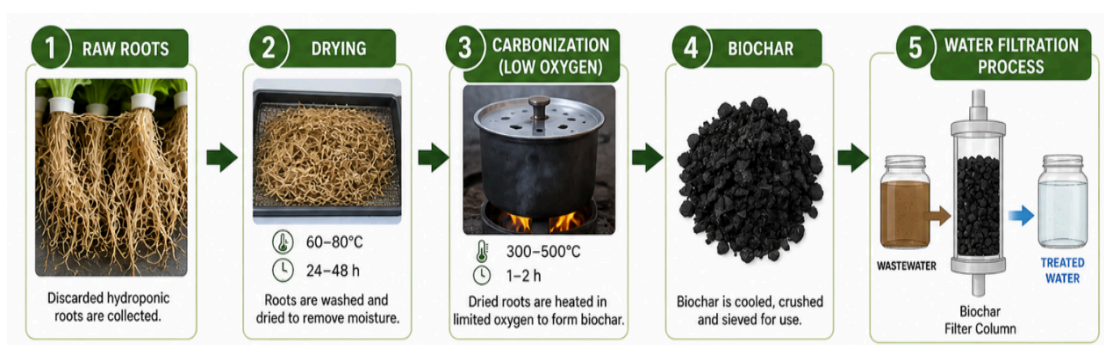


Figure 1.1: The process of biochar production from Hydroponic Root Biomass.

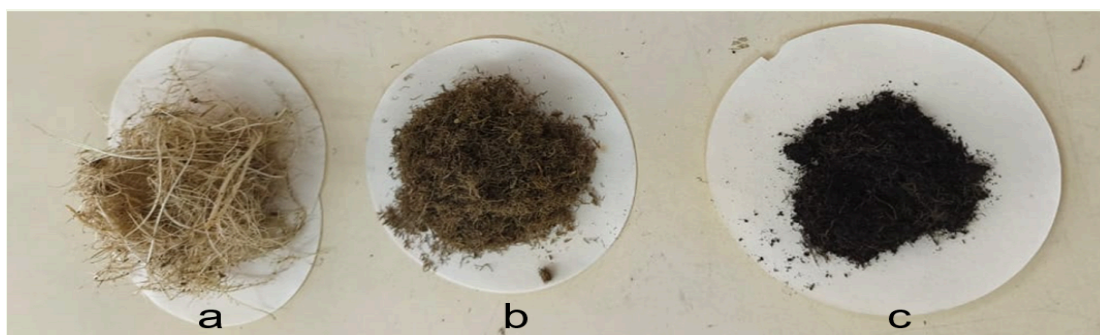


Figure 1.2: The products of hydroponic roots based; a) Fresh Hydroponic Root, b) Dried Hydroponic Roots (Crushed), c) Hydroponic Root-Derived Biochar

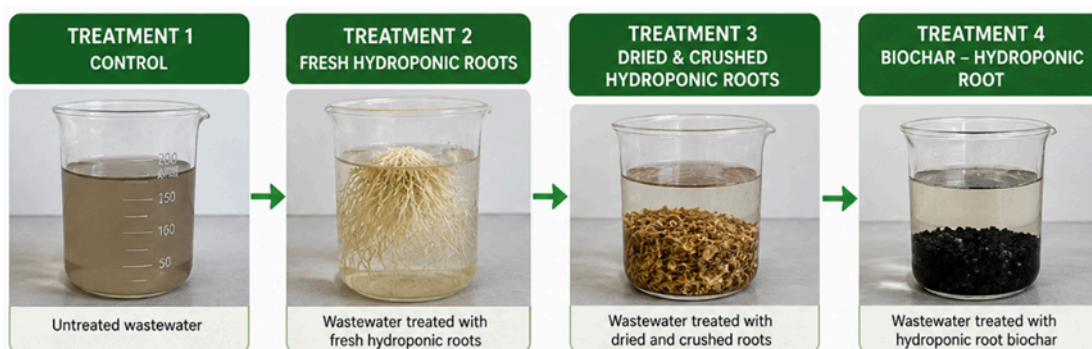


Figure 1.3: The different treatments in wastewater

4. Discussion of analysis and findings

The results obtained from the wastewater treatment experiment are presented in terms of nitrate (NO_3^-) removal, water pH, and water turbidity reduction over the 14-day monitoring period. These parameters were selected as indicators of treatment effectiveness in improving wastewater quality. Comparisons among the control, fresh root, dried and crushed root, and hydroponic root-derived biochar treatments were conducted to determine their respective performances and potential suitability for wastewater remediation applications. Each treatment was conducted with three independent replicates, and the data were analyzed using IBM SPSS Statistics. Differences among treatments were evaluated using one-way analysis of variance (ANOVA) at a significance level of $p < 0.05$.

4.1 The nitrates level in wastewater

The initial nitrate (NO_3^-) concentration in the wastewater was 40 mg/L for all treatments. Nitrate concentrations decreased across all treatments throughout the 14-day experimental period, whereas only a minimal reduction was observed in the T1 (control) treatment (15%). Among the treatments, T4 (hydroponic root-derived biochar) demonstrated the highest nitrate removal efficiency, achieving a 90% reduction, followed by T3 (dried and crushed hydroponic roots) (72%) and T2 (fresh hydroponic roots) (65%). The rapid nitrate removal observed during the first seven days may be attributed to the abundance of available adsorption sites and the high initial nitrate concentration. The subsequent decline in the removal rate is likely due to the gradual saturation of adsorption sites and the reduced availability of nitrate in the wastewater. These findings indicate that hydroponic root-derived biochar possesses superior adsorption capacity for nitrate removal, consistent with previous studies reporting the high porosity and large specific surface area of biochar, which enhance its adsorption performance.

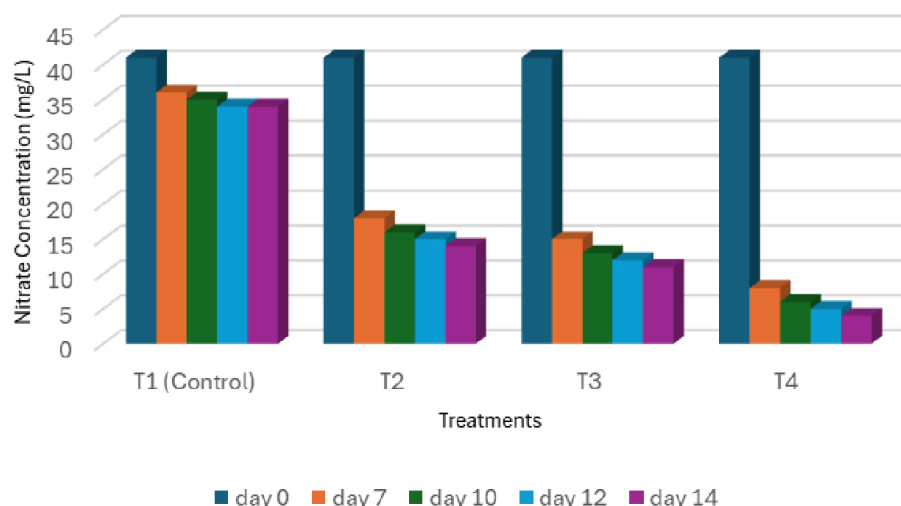


Figure 1.4: The performance of Hydroponic Root-Based treatments in reducing nitrate levels in wastewater over 14 days

4.2 The pH levels in wastewater

The initial pH of the wastewater was 6.7 for all treatments. Over the 14-day experimental period, a gradual increase in pH was observed across all treatments, indicating an improvement in water quality. The highest final pH was recorded in T4 (hydroponic root-derived biochar) (pH 8.2), followed by T3 (dried and crushed hydroponic roots) (pH 7.7) and T2 (fresh hydroponic roots) (pH 7.4), while the control treatment (T1) exhibited only a slight increase. The higher pH observed in the biochar treatment is likely due to the alkaline properties of biochar and its mineral content, which help neutralize acidic conditions and stabilize the wastewater pH. These findings demonstrate that hydroponic root-derived biochar is effective in improving the physicochemical properties of agricultural wastewater..

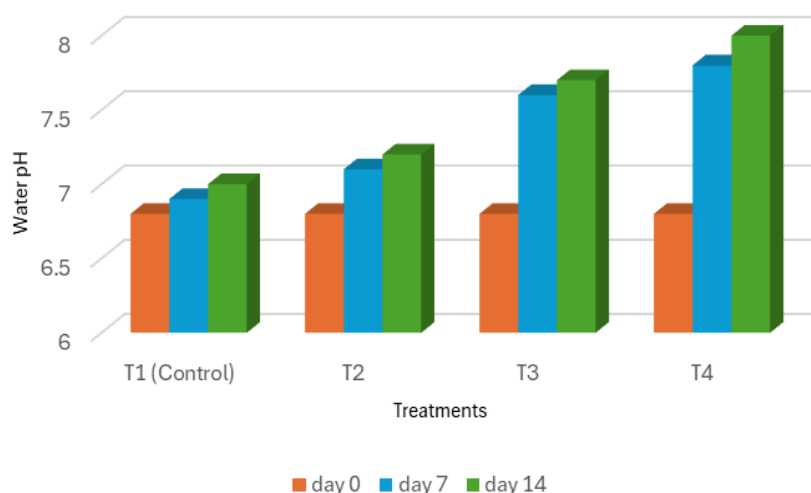


Figure 1.5: The effect of Hydroponic Root-Based treatments on wastewater pH level over 14 days

4.3 The turbidity status in wastewater

Water clarity improved in all treatments throughout the 14-day experimental period, as indicated by the increased transparency depth shown in Figure 4.3. The hydroponic root-derived biochar treatment (T4) achieved the greatest improvement, reaching a transparency depth of 15 cm, followed by the dried and crushed hydroponic roots (T3) and fresh hydroponic roots (T2), while the control treatment (T1) showed the least improvement. The superior performance of T4 is likely attributable to the highly porous structure and large surface area of biochar, which enhance its ability to adsorb suspended particles and trap fine solids within its pore network. Consequently, the biochar treatment produced clearer water and more effectively reduced suspended matter than the other treatments. These findings suggest that hydroponic root-derived biochar has considerable potential as an efficient and sustainable filtration material for improving the physical quality of agricultural wastewater.

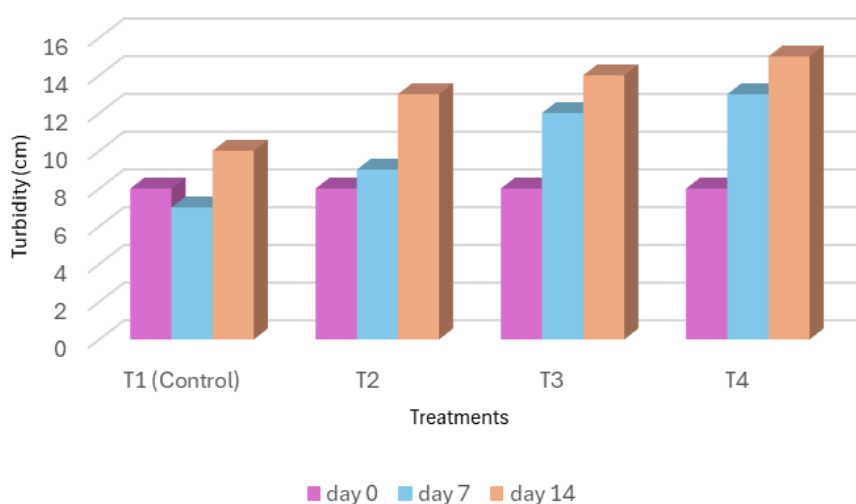


Figure 1.6: The changes in water clarity depth under different Hydroponic Root Based treatments on wastewater over 14 days

5. Conclusion

The findings of this study demonstrate that all root-based treatments (T2, T3 and T4) improved wastewater quality, as evidenced by reductions in nitrate concentration, increases in pH, and decreases in turbidity over the 14 days treatment period. Among the treatments evaluated, biochar hydroponic root (T4) exhibited the highest performance, achieving the greatest nitrate (NO_3^-) removal efficiency, the highest water pH value, and the most significant improvement in water clarity turbidity. These results suggest that converting hydroponics roots to biochar enhances their adsorption capacity and effectiveness in wastewater treatment. Therefore, biochar root shows considerable potential as a low-cost and sustainable material for wastewater remediation and water quality improvement.

Acknowledgment

The authors would like to express their sincere gratitude to all individuals who contributed to the completion of this research. Special appreciation is extended to Encik Firdaus Arshad, owner of Kebun Sayur Chengal Lempung, Kuantan, for his valuable assistance and support in term of raw materials throughout the study. The authors also acknowledge the Science Laboratory, School of Science, Technology and Management (SOSTM), Kolej Yayasan Pahang (KYP), for facilitating the experimental work. Appreciation is further extended to all students of the Diploma in Plantation Industry Management, KYP for their cooperation and involvement in this research.

References

- Ahmad, A.B., Rezgui, M., Dauelbait, M., El- Shaboury, G.A., Bourhia, M., Algophisi, U.B., Ruzieva, M., Mahmoudi, Jaouni, A., Cheffei Houari, C., & Ammar, W.B.H (2026). Impact of Biofilm Support Media on Microbial Dynamics, Rocket (*Eruca vesicaria subsp. sativa*) growth and antioxidative content in Aquaponics, *BMC Plant Biology*.
- Andaras, J., Rubin, R.L., Rodriguez- Reillo, W., Chatelain, C., Morrill, O. & Ballentine, K.A. (2025). Biochar- Enhanced Bioreactors for Agricultural Nitrogen Mitigation. *Journal of Environmental Management*, 389, 126260.
- Castellar, J.A.C., Formosa, J., Fernandez, A.I., Jove, P., Ganzalez, M.B., Morato., J. Brix., H. & Arias.C.A. (2018). Cork as Sustainable Carbon Source for Nature-Based Solutions Treating Hydroponic Wastewater-Preliminary Batch Studies. *The Science of The Total Environment*, 650, 267-276.
- Kiani, S., Kujala, K., Pulkkinen, J., Aalto, S.L., Surnakki, S., Roknkanen, A. (2020). Enhanced Nitrogen Removal of Low Carbon Wastewater in Denitrification Bioreactors by Utilizing Industrial Waster towards Circular Economy. *Journal Cleaner Production* 25(4).
- Kumar, R., Rahman, A., Lamba, J., Adhika, S., & Torbert, H.A (2025). Harnessing Biochar Nitrate Reomoval from Contaminated Soil and Water Environments. *Biochar*, 7(1) 105-113.
- Li, S., Chan, C. Y., Sharbatmaleki, M., Trejo, H., & Delegah, S. (2020). Engineered Biochar Production and Its Potential Benefits in a Closed -Loop Water -Reuse Agriculture Sustainable Water. 12(10), 2847-2847.
- Pantoja, F.L., Sukmana. H., Beszedes, S., & Laszlo, Z. (2023). Removal of Ammonium and Phosphate from Aqueous Solution by Biochar produced from Agricultural Waste. *Journal od Materials Cycles and Waste Management*. 25(4), 1921-1934

DESIGNING PLAY FOR CHANGE: EVALUATING A SOCIAL-ISSUE CARD GAME FOR BULLYING PREVENTION THROUGH EXPERIENTIAL LEARNING AMONG SELAYANG COMMUNITY COLLEGE STUDENTS

Ummu Hani Binti Yusof

¹Department of Games Art Technology, Kolej Komuniti Selayang

¹Corresponding author's email: hani@kkselayang.edu.my

ABSTRACT

Bullying remains a significant social and educational issue because it affects students' emotional safety, peer relationships, and sense of belonging within learning institutions. However, conventional anti-bullying awareness activities often rely on information delivery and may not sufficiently promote empathy, reflection, or constructive behavioural intention among students. Therefore, this study aimed to evaluate Play for Change, a student-developed social-issue card game initiative, as a game-based experiential learning approach for bullying prevention among students at Selayang Community College. A mixed-method design was employed in two phases. The first phase involved 77 students who responded to a preliminary survey on preferred game-based approaches and design elements. The second phase involved 20 students who developed social-issue card games, played games created by other groups, and completed a post-game impact evaluation questionnaire. Findings showed that students preferred interactive, role-based, and socially meaningful game designs, particularly a combined digital and tabletop format, role-playing as a victim, bully, or bystander, and rewards for positive choices. The post-game evaluation indicated a high overall perceived impact, with reflection recording the highest mean score, followed by positive response intention, understanding and awareness, belief shift, and empathy. Qualitative responses showed increased recognition of hidden bullying behaviour, social manipulation, victim protection, communication, and teamwork. Because this study relies on a small, self-reported sample, the current findings reflect students' perceived impact and behavioral intentions rather than guaranteed, actual behavioural changes. Future research should involve larger samples, multiple TVET institutions, and pre-test, post-test, and delayed post-test designs to examine sustained behavioural change.

Keywords: Game-Based Learning; Bullying Prevention; Serious Game.

1. Introduction

Bullying remains a significant challenge within Malaysian educational institutions, with the Ministry of Education reporting over 7,600 cases in 2024. These incidents threaten student health, reduce social cohesion, and disrupt learning environments at both school and tertiary levels. In response, national authorities have introduced measures such as the Anti-Bully Bill 2025, safety audits, and character-building programs, reflecting ongoing efforts to improve psychosocial safety. However, despite the implementation of these policy strategies and conventional approaches such as outreach campaigns and punitive actions, evidence for their effectiveness in fostering deeper empathy, sustained reflection, or positive behavioral change remains limited.

Mixed results from intervention programs in Malaysian schools highlight this gap (Hsbollah & Rosli, 2022; Radović et al., 2021).

Game-based and experiential learning approaches have been shown to enhance student engagement and motivation in vocational education and training (Dahalan et al., 2023; Hikmat et al., 2024). However, studies examining analog game-based interventions, such as card games, remain limited within Technical and Vocational Education and Training (TVET) contexts in Malaysia. Existing research has primarily focused on integrating games to improve language and communication skills (Rosli et al., 2022).

Given this gap, an empirical examination is needed to determine how student-developed, low-cost social-issue card games may contribute to bullying-prevention education. It is necessary to identify which game formats, mechanics, and motivational elements are most appealing to students, and to evaluate the effects of these games on students' awareness, empathy, and intentions to respond constructively.

This study addresses two research questions and objectives: first, to identify students' preferred game-based learning formats, mechanics, and motivational elements for bullying-prevention education; and second, to evaluate the impact of student-developed social-issue card games on students' perceived understanding, awareness, reflection, empathy, belief shifts, and intention to respond constructively to bullying.

2. Literature review

Game-based experiential learning has increasingly been positioned as a pedagogical approach that integrates active participation, reflection, collaboration, and applied problem-solving. Radović et al. (2021) argue that experiential learning becomes more meaningful when learning activities are authentic, reflective, and collaborative. This conceptual position is relevant to bullying prevention because students need to experience social situations, interpret consequences, and reflect on their own roles rather than only receive information through conventional awareness activities. Similarly, Dabbous et al. (2022), Hsbollah and Rosli (2022) found that game-based learning can increase motivation, knowledge acquisition, usability, and meaningful learning. However, these studies are mainly located in pharmacy, higher education, and programming contexts. Therefore, although they provide strong evidence for cognitive and motivational outcomes, they offer limited explanation of how gameplay supports socio-emotional outcomes such as empathy, belief shifts, and positive response intention in bullying-prevention learning.

The second theme concerns engagement, motivation, and learning performance. Systematic reviews indicate that gamification and game-based learning can improve student motivation, participation, academic performance, and engagement across higher education, vocational education, and applied learning contexts (Dahalan, Alias, & Shaharom, 2023; Jaramillo-Mediavilla, Basantes-Andrade, Cabezas-González, & Casillas-Martín, 2024; Khaldi, Bouzidi, & Nader, 2023). Martín-Hernández et al. (2021) further found that game-based learning promoted teamwork engagement, intrinsic motivation, teamwork competence, and innovation behavior. Nevertheless,

these findings require careful interpretation, as engagement does not necessarily indicate deep learning or behavioral change. Tavares (2022) cautions that evidence on long-term learning effects remains limited, while Videnovik, Vold, Kiønig, Bogdanova, and Trajkovik (2023) highlight methodological inconsistency in game-based learning studies. Consequently, bullying-prevention games must be evaluated beyond enjoyment, prioritizing instead reflection, empathy, awareness, and intention to act.

To conduct the evaluation, Alsaqqaf and Li (2022) proposed mapping Kolb's Experiential Learning Theory (ELT) directly to game mechanics, with 23 expert participants confirming the model's usefulness for serious game development. Hsbollah & Rosli (2022) found significant improvements in student understanding and engagement by investigating game-based learning through the lens of ELT and by using the ELT four stages in card game development has large effect on student achievement (Mahunyag et al., 2024), significant improvement in scores (Hsbollah and Rosli, (2022), improved accuracy, comprehension and motivation (Wan et al. (2025).

The third theme relates directly to prevention of bullying. Achab Moukram et al. (2023) show that gamification can support awareness of bullying, while Siddiqui and Schultze-Krumbholz (2023) argue that cyberbullying prevention requires stronger theoretical and intervention frameworks. In addition, Hikmat, Suryani, Yosep, and Jeharsae (2024) identify empathy as an important factor in reducing bullying behavior and strengthening victim-defending responses. Although Oyekoya, Urbanski, Shynkar, Baksh, and Etsaghara (2021) demonstrate the value of role-based VR simulation for perspective-taking, such interventions may be constrained by cost, limited access to technology, and implementation difficulty.

Analogue games present a practical alternative. Sousa et al. (2023) found that board, tabletop, and analogue game-based learning can support knowledge, soft skills, and psychological outcomes, while Smith and Conway (2025) showed that card games can strengthen teamwork, social interaction, and problem-solving. However, existing research remains limited on student-developed social-issue card games, especially in Malaysian TVET and community college contexts. Therefore, the proposed study addresses theoretical, contextual, and methodological gaps by evaluating Play for Change as a low-cost, experiential card-game intervention to improve students' understanding, empathy, reflection, belief shifts, and positive response intention toward bullying prevention.

3. Methodology

This study used a sequential mixed-methods design to address two objectives: (1) to identify students' preferred game-based learning formats, mechanics, and motivational elements for bullying-prevention education, and (2) to evaluate the impact of student-developed social-issue card games on students' understanding, awareness, reflection, empathy, belief shifts, and intention to respond constructively.

Two validated instruments were used. In Phase One, students completed the baseline survey to explore community college students' experiences and responses to bullying, as well as their preferred game-based learning formats, mechanics, and

motivational elements for bullying-prevention education. The initial online questionnaire involved 77 students from Selayang Community College from seven academic programs. Qualitative analysis was conducted, and the results guided the design of student-developed card games in Phase Two.

In the second phase, purposive sampling was utilized to select 20 semester 1 students from the Diploma in Games Art Technology program, chosen because their background in game development made them suitable for playtesting. Each team played the other groups' card games and answered an impact evaluation questionnaire measuring six constructs, with 18 items on a 5-point Likert scale (where higher scores indicate stronger perceived impact). The questionnaire was developed based on Kolb's Experiential Learning Theory (ELT) and was validated to ensure relevance to the learning constructs. Quantitative data were analyzed using descriptive statistics to interpret Likert-scale responses, while qualitative responses to the open-ended questions underwent thematic analysis to categorize students' reflections into recurring themes. The instrument's internal consistency was high (Cronbach's $\alpha = .977$), though the small sample size warrants caution.

The study followed institutional ethical rules. Participation was voluntary, with informed consent. Anonymity and confidentiality were maintained. Ethics approval was granted by the Selayang Community College research committee.

4. Discussion of analysis and findings

The findings were derived from two questionnaires administered in two phases. The first questionnaire was used as a preliminary needs analysis to identify students' preferred game-based approaches and design elements for bullying-prevention learning. The second questionnaire was used as a post-game impact evaluation to examine students' perceived understanding, awareness, reflection, empathy, belief shifts, and positive response intention after playing the Play for Change social-issue card games.

4.1 Findings and Discussion for Objective 1: Students' Preferred Game-Based Approaches and Design Elements

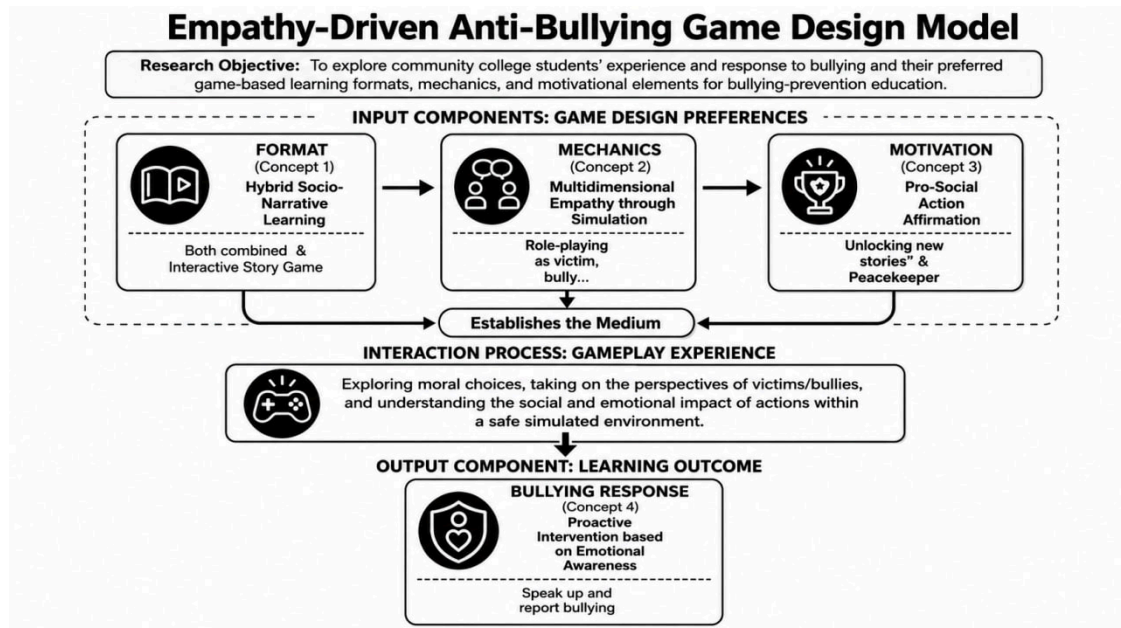


Figure 1.0 Empathy-Driven Anti Bullying Game Design Model.

The qualitative findings show four interrelated concepts emerged from the data: Hybrid Socio-Narrative Learning, Multidimensional Empathy through Simulation, Pro-Social Action Affirmation, and Proactive Intervention based on Emotional Awareness. The findings have been illustrated as explained in the Figure 1.0 to help visualize the output.

The first key finding relates to students' preference for a hybrid socio-narrative format. The preference for both digital and tabletop formats, along with suggestions such as interactive story games and bullying-situation cards, indicates that students value a learning experience that integrates digital storytelling with face-to-face discussion. This finding supports the view that experiential learning becomes more meaningful when it is authentic, reflective, and collaborative (Radović, Hummel, & Vermeulen, 2021). In addition, the hybrid format functions as the medium through which bullying scenarios can be explored in a safe and socially engaging environment. Rather than isolating students through individual screen-based interaction, the proposed model emphasises a blended format that allows narrative immersion while preserving peer communication and collective reflection.

The second finding shows that role-playing and moral choice are central to students' preferred game mechanics. The concept of Multidimensional Empathy through Simulation emerged from students' preference for taking on the roles of victim, bully, or bystander. This suggests that effective bullying-prevention gameplay should not focus only on winning but should allow students to experience different social positions and consequences. Such mechanics are theoretically significant because bullying involves relational roles, hidden motivations, peer pressure, and bystander decisions. This finding is aligned with Oyekoya et al. (2021), who highlighted the value of role-based perspective-taking in bullying-prevention simulation. However, the present study extends this discussion by showing that similar perspective-taking can be achieved through low-cost card and tabletop mechanics.

The third finding concerns motivation. Students preferred unlocking new stories, making positive choices, and receiving recognition as a Peacekeeper or Supportive Friend. This indicates that motivation in social-issue games should be linked to meaningful consequences rather than superficial reward systems. Consistent with gamification literature, rewards can increase engagement (Jaramillo-Mediavilla et al., 2024; Khaldi, Bouzidi, & Nader, 2023). However, the present finding suggests that for bullying prevention, rewards should affirm pro-social identity and ethical decision-making.

Finally, the model's output indicates that the intended learning outcome is proactive intervention based on emotional awareness. Students' emphasis on "Speak up and report bullying" and "Words and actions can hurt deeply" shows a shift from passive awareness to active response. This supports Hikmat et al. (2024), who identified empathy as important in strengthening victim-defending behaviour. Overall, the model demonstrates that when game format, mechanics, and motivation are aligned with empathy-driven design, social-issue card games can move beyond awareness raising and function as an experiential tool for encouraging reflective, responsible, and proactive anti-bullying behaviour.

4.2 Findings and Discussion for Objective 2: The impact of student-developed social-issue card games on students' perceived understanding, awareness, reflection, empathy, belief shifts, and intention to respond constructively to bullying.

In this study, the gameplay experience functioned as the concrete learning activity through which students encountered bullying-related situations, reflected on their responses, reconstructed their beliefs, and considered future constructive action. The quantitative findings indicate a generally positive perceived impact across all 18 Likert-scale items. The highest mean score was recorded for "I learned new concepts or information about the issue from the game" ($M = 4.40$, $SD = .940$), followed by "I reflected on how this issue affects people in real life" ($M = 4.35$, $SD = .745$) and "I compared my initial understanding to what I learned after playing the game" ($M = 4.30$, $SD = .865$). These results suggest that the game was particularly effective in supporting cognitive understanding and reflective learning. This aligns with the first ELT stage, Cognitive Deconstruction of Bullying Dynamics, where students encountered new bullying scenarios through gameplay and began to dismantle previous assumptions. Qualitative responses such as "a bully could be anyone, including my friends," "act innocent and act like nothing happened to hide all the truth," and "manipulate a situation" indicate that students recognised bullying as a hidden, relational, and manipulative behaviour rather than only a visible physical act.

Corresponding to Kolb's reflective observation stage, the high reflection scores suggest that students were not merely playing the game but actively interpreting its meaning. This was supported by qualitative responses such as "I tend to believe people easily by their kind acts and that makes a fool of myself," "Empathy towards victim," and "I felt the real situation." These responses indicate that the game acted as an affective mirror, allowing students to reflect on their own vulnerability to manipulation while developing empathy for victims. This supports the argument that game-based experiential learning is meaningful when it connects authentic experience with reflection and emotional interpretation.

The findings also represent abstract conceptualisation. Although belief shift recorded a slightly lower but still high score, the responses show evidence of mindset change. Statements such as “Don’t trust people too easily,” “Be more cautious of my surroundings,” and “Understand other people’s beliefs and principles” suggest that students formed new social principles after gameplay. This finding indicates that the card game contributed to belief reconstruction, although the slightly lower mean for belief-related items suggests that deeper value transformation may require repeated gameplay, guided debriefing, and stronger scenario design.

Finally, this study reflects Kolb’s active experimentation stage. The high scores for positive response intention indicate that students were willing to translate their learning into future action. Qualitative responses such as “need to help others,” “need to be brave in your action,” “Must take action for myself,” and “need to fight back” show movement from passive awareness to constructive intervention. However, the item “I felt emotionally connected to the issue while playing the game” recorded the lowest mean ($M = 3.85$, $SD = 1.040$), suggesting that emotional engagement was weaker than cognitive reflection. Therefore, future versions of Play for Change should include stronger victim-perspective cards, real-life bullying scenarios, and structured post-game reflection. Overall, the findings suggest that the student-developed card games supported a sequential socio-emotional learning process, moving students from understanding and awareness towards reflection, belief shift, and proactive anti-bullying intention.

5. Conclusion and future research

Bullying remains a significant educational and social issue because it affects students’ emotional safety, peer relationships, learning participation, and sense of belonging. In TVET and community college contexts, bullying prevention should not rely only on discipline, reporting systems, or awareness campaigns. It should also develop students’ understanding, empathy, reflection, and willingness to respond constructively. Therefore, this study evaluated Play for Change, a student-developed social-issue card game initiative, as a game-based experiential learning approach for bullying prevention among students at Selayang Community College. The study was guided by two objectives: to identify students’ preferred game-based approaches and design elements, and to evaluate the game’s impact on students’ perceived understanding, awareness, reflection, empathy, belief shifts, and intention to respond constructively to bullying.

The findings show that students preferred interactive, role-based, and socially meaningful bullying-prevention games. They favoured a combined digital and tabletop approach, role-playing as victim, bully, or bystander, reward systems based on positive choices, and messages that encourage students to speak up and report bullying. These findings address the first objective by showing that students prefer active, experiential learning formats over passive awareness activities. The post-game evaluation answered the second objective by showing a high overall perceived impact, with reflection recording the highest mean score, followed by positive response intention, understanding and awareness, belief shift, and empathy. Qualitative responses further showed that students recognised hidden bullying behaviour, social manipulation, the

importance of protecting victims, communication, teamwork, and how game mechanics supported understanding.

However, this study has limitations. The post-game evaluation involved only 20 respondents and was conducted at a single institution, which limits generalisability. More importantly, the study relied entirely on self-reported data and did not include a pre-test, delayed post-test, control group, or long-term behavioural observation. Therefore, any claims regarding actual behavioural change must be made cautiously; the findings demonstrate a strong perceived impact and an intention to respond constructively, but they cannot fully confirm sustained attitude or real-world behavioural change.

Future research should involve larger samples from multiple community colleges, polytechnics, and TVET institutions. A pre-test, post-test, and delayed post-test design should be used to measure whether the impact is sustained. Without this, Play for Change may remain validated only as a short-term engaging activity. Selayang Community College, JPPKK, counselors, student affairs units, and lecturers can support future implementation. Potential barriers include limited facilitation time, sensitivity of bullying discussions, and inconsistent facilitator skills. Future studies should therefore focus on facilitator training, stronger victim-perspective cards, real-life scenarios, guided reflection, and structured post-game debriefing.

Acknowledgement

The author thanks Selayang Community College, the participating students, and the heads of programs and lecturers for their support and contributions to this research.

References

- Achab Moukram, Y., Manzano-León, A., Rodríguez-Ferrer, J. M., Rodríguez-Moreno, J., & Aguilar-Parra, J. M. (2023). A systematic review of gamification as a playful strategy to prevent bullying. *Environment and Social Psychology*. doi:10.18063/esp.v7.i2.1566
- Alsaqqaf, A., & Li, F. W. B. (2022). Gamifying experiential learning theory. In *International Conference on Advances in Web-Based Learning*.
- Dabbous, M., Kawtharani, A., Fahs, I. M., Hallal, Z., Shouman, D., Akel, M., Sakr, F. (2022). The role of game-based learning in experiential education: Tool validation, motivation assessment, and outcomes evaluation among a sample of pharmacy students. *Education Sciences*. doi:10.3390/educsci12070434
- Dahalan, F., Alias, N., & Shaharom, M. S. (2023). Gamification and game-based learning for vocational education and training: A systematic literature review. *Education and Information Technologies*. doi:10.1007/s10639-022-11548-w

- Hikmat, R., Suryani, S., Yosep, I., & Jeharsae, R. (2024). Empathy's crucial role: Unraveling impact on students' bullying behavior: A scoping review. *Journal of Multidisciplinary Healthcare*. doi:10.2147/JMDH.S469921
- Hsbollah, H. M., & Rosli, K. (2022). Creating meaningful learning and improving students' knowledge using game-based learning in higher education. *World Journal of English Language*. doi:10.5430/wjel.v12n2p257
- Jaramillo-Mediavilla, L., Basantes-Andrade, A., Cabezas-González, M., & Casillas-Martín, S. (2024). Impact of gamification on motivation and academic performance: A systematic review. *Education Sciences*. doi:10.3390/educsci14060639
- Khalidi, A., Bouzidi, R., & Nader, F. (2023). Gamification of e-learning in higher education: A systematic literature review. *Smart Learning Environments*. doi:10.1186/s40561-023-00227-z
- Mahunyag, C. A. L., Mabayo, T. A. L. E., Eulatriz, K. V., Montero, R. D., & Walag, A. M. P. (2024). ELQUAN: A game-based learning tool to master electron configuration and quantum numbers. *Journal of Chemical Education*.
- Martín-Hernández, P., Gil-Lacruz, M., Gil-Lacruz, A., Azkue-Beteta, J. L., Lira, E. M., & Cantarero, L. (2021). Fostering university students' engagement in teamwork and innovation behaviors through game-based learning. *Sustainability*. doi:10.3390/su132413573
- Oyekoya, O., Urbanski, J., Shynkar, Y., Baksh, A., & Etsaghara, M. (2021). Exploring first-person perspectives in designing a role-playing VR simulation for bullying prevention: A focus group study. *Frontiers in Virtual Reality*. doi:10.3389/frvir.2021.672003
- Radović, S., Hummel, H. G. K., & Vermeulen, M. (2021). The challenge of designing "more" experiential learning in higher education programs in the field of teacher education: A systematic review study. *International Journal of Lifelong Education*. doi:10.1080/02601370.2021.1994664
- Rosli, S. H., Ekhwan, R., & Hassan, H. (2022). Lecturer's experience and perspective on game-based learning in technical and vocational education and training. *Politeknik & Kolej Komuniti Journal of Social Sciences and Humanities*. doi:10.37134/pmjssh.vol.1.2.2022
- Siddiqui, S., & Schultze-Krumbholz, A. (2023). Successful and emerging cyberbullying prevention programs: A narrative review of seventeen interventions applied worldwide. *Societies*. doi:10.3390/soc13090212
- Smith, R., & Conway, E. (2025). Playing with numbers: The social and behavioural impacts of using a card game to teach business metrics. *Behavioral Sciences*. doi:10.3390/bs15060761

- Sousa, C., Rye, S., Sousa, M., Torres, P. J., Perim, C., Mansuklal, S., & Ennami, F. (2023). Playing at the school table: Systematic literature review of board, tabletop, and other analog game-based learning approaches. *Frontiers in Psychology*. doi:10.3389/fpsyg.2023.1160591
- Tavares, N. (2022). The use and impact of game-based learning on the learning experience and knowledge retention of nursing undergraduate students: A systematic literature review. *Nurse Education Today*. doi:10.1016/j.nedt.2022.105484
- Videnovik, M., Vold, T., Kiønig, L., Bogdanova, A. M., & Trajkovik, V. (2023). Game-based learning in computer science education: A scoping literature review. *International Journal of STEM Education*. doi:10.1186/s40594-023-00447-2
- Wan, Y., Gao, N., & Wu, M. (2025). Enhancing English listening comprehension through interactive games: An ELT-based assessment approach. *International Journal of Education, Humanities and Social Sciences*.

AI LITERACY READINESS FRAMEWORK FOR TVET EDUCATORS: A STUDY AT POLITEKNIK MUADZAM SHAH

Safiani binti Osman¹, Asyran Zarizi bin Abdullah², Muhammad Fikri bin Abdul Rahman¹

¹Design and Visual Communication Department, Politeknik Muadzam Shah

²Information Technology and Communication Department, Politeknik Muadzam Shah

¹Corresponding author's email: safiani@pms.edu.my

ABSTRACT

Amid the advancements of the Industrial Revolution 4.0, Artificial Intelligence (AI) has become central to technological progress and global innovation. Mastery of AI literacy in education is increasingly critical to ensure that teaching staff are prepared to integrate this technology effectively into instructional processes. This study aims to develop an AI Literacy Readiness Framework for Technical and Vocational Education and Training (TVET) educators by evaluating lecturers' AI literacy and identifying the key factors affecting AI integration at Politeknik Muadzam Shah. Employing a quantitative survey with 68 lecturers from different departments. Data were gathered through a structured questionnaire and analyzed using descriptive statistics, Pearson correlation, one-way ANOVA, and multiple regression. What makes this study unique is its focus on a framework tailored to TVET educators, covering five areas: awareness, knowledge, skills, attitudes, and AI integration. Unlike earlier studies that looked at general AI use, this framework highlights readiness based on specific competencies for TVET. The results showed that lecturers had high levels of awareness and positive attitudes towards AI, with average scores of 4.38 and 4.33 out of 5, respectively. However, their practical skills and the extent to which they used AI in teaching were moderate, with averages of about 3.8. The analysis found that teaching experience did not significantly affect awareness, knowledge, skills, or integration, but it did affect attitudes towards AI. Regression analysis also showed that attitudes were closely linked to how much AI was integrated into teaching. This framework can help educational institutions and administrators design effective AI training and professional development programs, supporting greater AI readiness and encouraging digital transformation in TVET education.

Keywords: Artificial Intelligence Literacy, Technical and Vocational Education and Training, Technology Readiness.

1. Introduction

The deployment of artificial intelligence (AI) across sectors has significantly impacted academia and the educational system. To keep pace with this technological progress, a paradigm shift in education is essential (Chen, Chen, & Lin, 2020).

Malaysia is intent on empowering the use of artificial intelligence (AI) to achieve its educational objectives. The application of AIs and learning experiences. Technology, including natural language processing, machine learning, and intelligent tutoring systems, has made teaching methods more efficient and student-centered. (Ivanashko & Kozak, 2024).

In Malaysia, the government has shown a strong pledge to AI integration. This effort is implemented through Malaysia's National Artificial Intelligence (AI) Roadmap 2021–2025 and the Digital Education Policy (DPD). These plans stress the importance of AI competencies among teachers to ensure digital education can be implemented successfully.

Despite increased advocacy for AI integration, many educators struggle to understand and effectively apply AI in teaching and learning. Previous studies have identified several limitations, including inadequate technical skills, insufficient formal training, lack of institutional support, and ethical issues regarding AI implementation (Li, Tolosa, Rivas-Echeverria, & Marquez, 2025). As a TVET institution, the Polytechnic is responsible for training students with the knowledge and expertise required to meet the demands of an AI-driven world. However, there is a significant gap between the rapid development of AI technology and educators' understanding and application of it. (Norhana Ahad & Tuan Mohd Azhar bin Tuan Ngah, 2024). Without an in-depth insight and a positive attitude towards AI, efforts to implement this technology in the curriculum may be hindered. AI literacy among lecturers is important to ensuring that learning institutions remain relevant and capable of producing competitive graduates. Mastery of AI literacy encompasses not only basic knowledge but also practical skills and a positive attitude towards the ethical and effective use of AI. (Crompton & Burke, 2023). While numerous studies have examined student acceptance and AI literacy, there is limited research on educators' preparedness for AI literacy, particularly in Malaysian polytechnics and TVET institutions. Existing research often focuses on technological adoption or general digital knowledge, without addressing the multiple aspects of AI literacy, including awareness, knowledge, skills, attitudes, and integration into instructional practices. This gap illustrates the need for further research on instructors' readiness to implement AI in TVET classrooms.

This study intends to develop a structured AI Literacy Readiness Framework for TVET educators, focusing on five key areas: awareness, knowledge, skills, attitudes, and implementation of AI into teaching. The research studies the relationships among these dimensions and identifies key factors influencing lecturers' use of AI. The constructed framework is intended to inform the development of targeted training, policy planning, and AI integration strategies to support the transformation of digital education. Specifically, the study examines AI literacy readiness among lecturers at Politeknik Muadzam Shah (PMS) and aims to:

- a. Identify the level of AI literacy readiness among lecturers in terms of awareness, knowledge, skills, attitudes, and AI integration.
- a. Determine whether there are significant differences in AI literacy readiness based on lecturers' teaching experience.
- b. Examine the relationship between lecturers' attitudes towards AI and the integration of AI in teaching practices.
- c. Identify the dominant factors influencing lecturers' integration of AI.

2. Literature review

2.1 The Artificial Intelligence (AI) in Higher Education

Artificial Intelligence (AI) is one of the most significant technological advancements and has found extensive applications across various sectors. From individual use to broad-scale systems, AI enables a more efficient and intelligent lifestyle for humans. As noted by Stuart Russell and Peter Norvig, AI is the ability of machines to perform tasks related to human intelligence. This includes functions such as reasoning, learning, problem solving, perception, and language understanding. (Norvig & Stuart Russell, 2022). Likewise, Fabio Morandín-Ahuerma (2022) defines AI as the capability of computer systems to copy human intellectual functions via algorithms and data-processing methods. Education in today's era of digital transformation continues to evolve with the integration of AI into pedagogy. AI in education refers to the combination of intelligent systems and advanced technology to enhance meaningful learning experiences among students.

A review of recent studies from 2022 to 2025 shows growing interest in implementing AI in higher education settings. For example, Fitria stated that the use of AI technologies such as Google Assistant and Presentation Translator benefits learning activities and increases learning effectiveness. (Joon Soo Lim & Jun Zhang, 2022) emphasize that AI in education can be highly beneficial when applied ethically. Similarly, Pisica et al. (2025) reported that the implementation of AI in education has improved teaching quality, student achievement, and the effectiveness of administrative processes. Furthermore, Lebohang Mulaudzi (2024) highlighted the importance of formal instruction for educators to ensure that AI is fully utilized. Meanwhile, Dringó-Horváth, Rajki, and T. Nagy studied the relationship between university teachers' digital competence and AI literacy among 1,103 educators across multiple disciplines. The study findings show that teaching experience, discipline, and digital competence influence lecturers' AI literacy and preparedness to integrate AI into the learning and teaching process. In addition, a study by Schmidt (2019) highlighted the importance of educators' training strategies and institutional readiness in supporting AI adoption. Furthermore, Sreela & Karthik Deepa (2026) conducted research examining the relationships among digital competencies, AI Literacy, and organizational support among faculty members.

The data show that AI literacy significantly affects readiness and instructional efficacy. In education, AI is known as Artificial Intelligence in Education. It consists of integrating AI technology to improve instructional design, instructional techniques, and student learning processes. While there are many advantages to implementing AI in education, multiple challenges must be addressed to avoid further undermining its acceptance among instructors. Many lecturers still face difficulties understanding AI concepts, choosing appropriate AI tools, and integrating AI into teaching practices efficiently. In addition, unethical use, lack of institutional support for infrastructure or

funding, limited training opportunities, and restricted technological readiness are among the main barriers reported in previous studies. Many educators remain unsure about integrating AI into teaching due to a lack of support systems and limited professional development on AI (Holmes, Bialik, & Fadel, 2021).

Table 1.1 summarizes previous studies on AI implementation in higher education between 2022 and 2025.

Author	Focus of study	Findings
Fitria (2022)	AI application in learning	AI prove that AI can be supportive but cannot replace the role lecturer
Limna et al., (2022)	AI Adoption in Education	AI can be improved learning but must be used in an ethic way
Pisica et al., (2023)	AI implementation in Romania	AI can improve teaching quality and student competency
Lebohang (2024)	Learning using AI	Research conclude that formal training AI is essential
Schmidt et all (2025)	Relationship between teachers' AI literacy and digital competence among 1300 lecturer	Finding show that digital competence was significantly and positively related to AI literacy
Sreela & Deepa (2025)	AI literacy among faculty members	AI literacy become a dominant factor that influence the readiness to integrate AI

Table 1.1: AI in Education between 2022 - 2025

Based on previous studies, the application of AI in education has a significant impact on the quality of teaching and learning process, improves the learning experience, and improves the efficiency of institutions. However, the successful implementation of AI literacy, readiness, and digital competency among educators is key. On the other hand, the study found that inadequate training, ethical issues, and institutional limitations, such as insufficient infrastructure and technological support, remain important challenges to AI adoption in educational settings.

2.2 Artificial Intelligence (AI) Literacy

Artificial Intelligence (AI) is a topic that is gaining increasing attention in today's digital era. According to García-Martínez, Fernández-Batanero, Fernández-Cerero, & León (2023), AI can be defined as any machine or technological system capable of performing human tasks or activities. In simple terms, AI enables machines to perform tasks that previously were carried out by humans. As technology advances, it is essential for society to be literate in AI to keep pace with these trends. The importance of AI in knowledge communities, especially educational institutions, should be recognized, as academia is on the front lines of producing a skilled workforce.

AI integration in education can strengthen educational quality and streamline administrative processes. Nevertheless, the extent to which these academics will familiarize themselves with this technology depends on their knowledge of it. Higher

education has developed AI literacy to ensure it can fully utilize this technology. Miot et al (Fengchun Miao, Wayne Holmes, Ronghuai Huang, & Hui Zhang, 2021) and Long and Magerko (Duri Long, Brian Magerko, Kenneth Holstein, Daniella DiPaola, Fred Martin, 2021) both mentioned that AI literacy is a skill set that enables an individual to understand how AI is used by learning about AI, how it works, and how it can be used sustainably.

According to Davy Tsz Kit Ng, Jiahong Su, and Jac Ka Lok Leung (2023), AI literacy is the ability to understand AI, use and apply it, evaluate and produce with it, and understand the ethics of its use. This means that academics must understand the basis for the development of this technology, how it benefits their own work, and be able to adhere to the principles that guide its use.

AI literacy is especially important in educational institutions because educators serve a key role in producing a skilled and knowledgeable workforce. The integration of AI in education can improve teaching quality, support personalized learning, and assist administrative processes. However, the effectiveness of AI implementation among educators depends on their level of understanding and readiness to use the technology appropriately. Therefore, educators need to develop AI literacy to ensure AI technologies are fully utilized in teaching and learning. Research by Holmes et al. (2021) mentioned that among the factors that cause the majority of academics to be unsure about integrating AI in the teaching process is the lack of support and formal training resources. AI literacy has been defined by researchers from various perspectives. Fengchun Miao et al. (2021) and Long and Magerko (2021) described AI literacy as a set of competencies that enables individuals to understand how AI works, how it is used, and how it can be applied responsibly and sustainably. Similarly, Zhipeng Wen, Hilaria Hiu Nam Li, & Winnie Siu Yee Ho (2026) explained that AI literacy involves the ability to understand, evaluate, and apply AI technologies, as well as awareness of ethical issues related to AI use. These definitions indicate that AI literacy is not limited to technical knowledge alone, but also includes critical thinking, ethical awareness, and hands-on application skills.

Although studies on AI have grown rapidly, most prior research has focused more on students and AI implementation in education than on lecturers' AI literacy. Educators' understanding of AI concepts, ethical considerations, and the integration of AI into curriculum and pedagogy remains relatively limited. This situation may lead to inappropriate use of AI technologies and reduce the effectiveness of AI integration in teaching and learning processes.

The 21st-century education in Malaysia aims to provide students with the knowledge and skills needed to thrive in a fast-changing world, emphasizing critical thinking, creativity, communication, and collaboration. Malaysia has taken active measures to strengthen AI. With that in mind, Malaysia has put forward a comprehensive plan to develop and implement AI technology, known as Malaysia's National Artificial Intelligence (AI) Roadmap 2021-2025.

Overall, AI literacy is becoming a necessary competency, especially among instructors in higher education institutions. Educators who possess adequate AI literacy are more likely to use AI technologies effectively, ethically, and responsibly in academic environments. AI literacy needs to be fostered to support the government's goal of

ensuring that society is ready to face the challenges of the AI revolution and compete globally. Therefore, this study aims to examine the level of AI literacy among lecturers and identify the factors influencing AI literacy and AI integration in teaching and learning processes.

2.3 Proposed AI Literacy Framework

The conceptual framework of this study was developed based on prior literature on Artificial Intelligence (AI) literacy, digital literacy, and the application of technology in education. Previous scholars emphasized that AI Literacy is influenced by awareness, skills, integration, and attitude. According to Ng, Leung, Chu, and Qiao (2021), digital skills elements comprise awareness, technical skills, and user attitudes towards technology. Similarly, Duri Long and Brian Magerko (2020) explained that AI literacy involves a combination of knowledge, skills, and positive attitudes. UNESCO (2021) also highlighted that technology integration is an important element in ensuring effective AI implementation in education. Based on these studies, this research proposes an AI Literacy Readiness Framework for lecturers in Politeknik Muadzam Shah. The framework consists of five main constructs, namely Awareness, Knowledge, Skills, Integration, and Attitude, which collectively contribute to lecturers' AI literacy readiness. Awareness refers to lecturers' exposure and understanding of AI technologies and their potential use in education. Knowledge refers to lecturers' understanding of AI concepts, functions, ethics, and applications. Skills refer to lecturers' ability to use AI tools and technologies effectively in teaching and learning activities. In addition, Integration refers to lecturers' readiness and ability to apply AI technologies in teaching, assessment, and instructional activities. Meanwhile, Attitude refers to lecturers' perceptions of, acceptance of, and willingness to use AI technologies in education.

In contrast to traditional AI literacy frameworks that mainly prioritize technical understanding and knowledge, this proposed framework also emphasizes readiness for AI integration in educational settings. Therefore, this framework is expected to provide a more comprehensive understanding of lecturers' readiness for AI literacy within Malaysian polytechnic education. Through this framework, the study aims to assess lecturers' AI literacy and identify the factors influencing AI integration in teaching and learning processes. Figure 1.1 below shows the framework applied in this study.

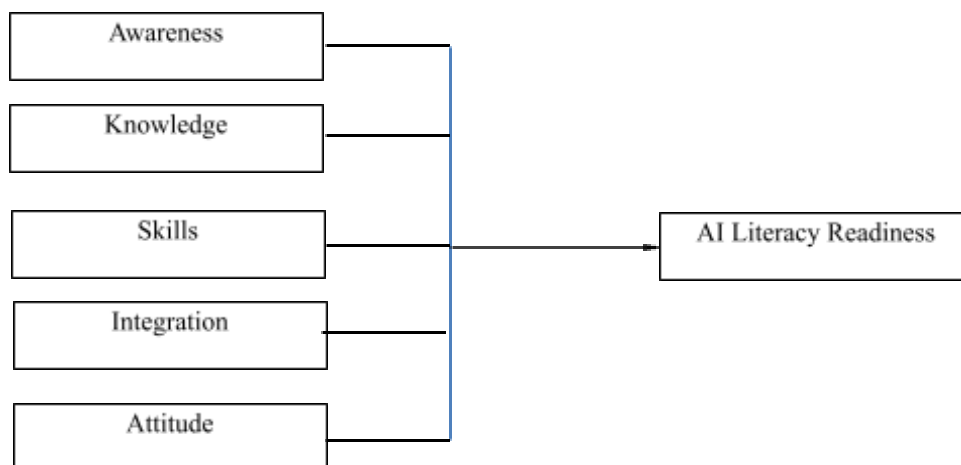


Figure 1.1: Proposed AI Literacy Readiness Framework Adapted from Ng et al. (2021), Long & Magerko (2020), and UNESCO (2021)

In this framework, awareness, knowledge, skills, attitude, and integration are conceptualized as interrelated dimensions of AI literacy readiness. Awareness, knowledge, and skills represent cognitive and practical competencies, while attitude reflects lecturers' perceptions and willingness to adopt AI technologies. Integration is treated as an outcome dimension that reflects the actual application of AI in teaching practices.

The framework assumes that higher levels of awareness, knowledge, skills, and positive attitudes contribute to greater readiness for AI integration among educators. Based on previous studies, several factors may influence lecturers' AI literacy levels. One of the factors highlighted in previous research is teaching experience. Dringó-Horváth et al. (2025) found that the more experience a lecturer has in teaching and the more they know about digital technologies, the more they understand about Artificial Intelligence and the more ready they are to use It in their teaching and learning activities. Lecturers with varying levels of teaching experience may have differing levels of exposure to, readiness for, and confidence in using AI technologies in education. Therefore, this study examines whether there is a significant difference in AI literacy across years of teaching experience.

H0₂: There is no significant difference in the level of AI literacy based on years of teaching experience.

H1₂: There is a significant difference in the level of AI literacy based on years of teaching experience.

Previous studies by Helmiatin, Hidayat, and Kahar reported that positive attitudes toward AI contribute to greater readiness and willingness to integrate AI into educational practices. Lecturers with positive perceptions of AI are more likely to use AI technologies in teaching and learning. Therefore, this study also examines the relationship between lecturers' attitudes and AI integration.

H0₃: There is no significant relationship between attitude and AI integration among lecturers.

H1₃: There is a significant relationship between attitude and AI integration among lecturers.

In conclusion, the proposed AI Literacy Readiness Framework provides a guideline to understand the factors that influence lecturers' AI literacy in higher education institutions. The framework illustrates five important constructs, namely awareness, knowledge, skills, integration, and attitude, which are believed to contribute to lecturers' readiness to use AI technologies in teaching and learning processes. Previous studies also support the view that teaching experience and attitudes towards AI may influence educators' AI literacy and AI integration. Therefore, this framework serves as the

foundation of this study in examining the level of AI literacy among lecturers at Politeknik Muadzam Shah and identifying the factors that influence AI integration in education.

3. Methodology

3.1 Research Design

This study employed a quantitative survey design, using descriptive and correlational approaches, to examine the level of Artificial Intelligence (AI) literacy among lecturers at Politeknik Muadzam Shah (PMS). According to Clark (2023), quantitative research can help researchers to examine an event by exploring individual points of view and experiences. The descriptive approach was used to assess the overall level of AI literacy among lecturers, while the correlational approach examined the relationships among selected AI literacy domains. This design enabled the researcher to obtain a broad understanding of lecturers' awareness, knowledge, skills, curriculum integration practices, and attitudes towards AI in education.

3.2 Population and Sampling

The population of this study included a total of 189 lecturers at Politeknik Muadzam Shah (PMS) from different academic departments at Politeknik Muadzam Shah (PMS). The respondents were selected using a simple random sampling technique, where each lecturer had an equal opportunity to participate in the study. A total of 68 lecturers successfully responded to the questionnaire, representing 35.9% of the total population. The sample size was sufficient to represent the population, with a margin of error of approximately $\pm 9.6\%$ at a 95% confidence level, providing a reliable picture of AI literacy among PMS lecturers.

3.3 Research Instruments

The instrument used for this data collection is a questionnaire adapted from Duri Long & Brian Magerko (2020) as the primary research instrument. The questionnaire consisted of 30 items distributed across five constructs. The instrument is a 5-item Likert-scale that assesses 5 main domains: AI Awareness, AI Knowledge, AI Skill, AI Integration in Curriculum, and Attitude towards AI. The instrument was adapted from Long and Magerko (2020) and reviewed by two experts in educational technology and TVET education to establish content validity. A pilot study was conducted prior to data collection to evaluate the instrument's reliability and internal consistency. The result shows that Cronbach's Alpha is 0.91. This indicates excellent internal consistency reliability, and the instrument is valid and can be utilized in this study.

3.4 Data Collection Procedure

The data collection was conducted online via Google Forms. The link to the Google Form questionnaire was distributed to all lecturers via the official email and the department's internal communication platform - WhatsApp. Lecturers were given two

weeks to complete the survey. Reminders were sent periodically (eg, a week after the initial distribution) to increase response rates.

3.5 Data Analysis

The collected data were analysed by Statistical Package for the Social Sciences (SPSS) version 26. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to assess the level of AI literacy among lecturers. Pearson correlation analysis was conducted to examine the relationship between the variables in the study. Mean scores were interpreted as follows:

Score	Interpretation
1.00–2.33	Low
2.34–3.66	Moderate
3.67–5.00	High

Table 1.2: Score interpretation

4. Discussion of analysis and findings

4.1 Respondent demographics

A total of 68 lecturers from Politeknik Muadzam Shah (PMS) participated in this study, representing 35.9% of the overall lecturer population (N = 189). Based on the sample size, the estimated margin of error was $\pm 9.6\%$ at a 95% confidence level, showing a moderate level of representativeness for the study findings.

Demographic	Category	Frequency (n)	Percent (%)
Gender	Male	27	39.7%
	Female	41	60.3%
Department	JTMK	17	25.0%
	JRKY	18	26.5%
	JKM	6	8.8%
	JP	12	17.6%
	JPH	4	5.9%
	JMSK	5	7.4%
	JPA	6	6.0%
Education	Degree	30	44.1%
	Master	34	50.0%
	Phd	4	5.9%
Year Of Teaching	<5	12	17.6%
	5-10	9	13.2%
	11-15	18	26.5%
	>15	29	42.6%

Table 1.3: Demographic of the respondent

Table 1.3 presents the demographic background of the respondents. Female respondents contributed the majority at 60.3% (n=41), while male respondents accounted for 39.7% (n=27). In terms of departmental distribution, the highest number of

respondents came from the Department of Design and Visual Communication (JRKV) (26.5%) and the Department of Information and Communication Technology (JTMK) (25.0%). Other respondents were distributed across JP, JKM, JMSK, JPA, and JPH.

Regarding academic qualifications, half of the respondents hold a master's degree (50.0%), followed by a bachelor's degree (44.1%), while only 5.9% held doctoral qualification. The teaching experience of the respondents was also quite balanced, with the majority having more than 15 years of experience (42.6%) and 26.5% having between 11 and 15 years of experience, while the group with less than 10 years of experience was smaller (30.8%).

Overall, the demographic findings indicate that the respondents are predominantly experienced lecturers with strong academic qualifications. This composition provides a reliable foundation for examining AI literacy levels among lecturers at PMS.

Research Question 1

What is the level of awareness, knowledge, skills, integration, and attitude of lecturers towards AI literacy at Politeknik Muadzam Shah? Descriptive statistical analysis was conducted to assess the level of AI literacy among lecturers across five constructs: awareness, knowledge, skills, integration, and attitude. Table 1.4 summarises the mean scores and standard deviations for each construct.

Variable	Min	Max	Mean	Std. Deviation
Awareness	2	5	4.38	0.64
Knowledge	1	5	3.96	0.84
Skill	1	5	3.87	0.84
Integration	1	5	3.76	0.82
Attitude	2	5	4.33	0.66

Table 1.4: Average score of AI awareness, AI skills, AI integration, and AI Attitude towards AI.

The findings indicated that awareness achieved the highest mean score ($M = 4.38$, $SD = 0.64$), followed by attitude ($M = 4.33$, $SD = 0.66$), demonstrating that lecturers possess high awareness and positive attitudes towards AI in education. Knowledge also yielded a relatively high mean score ($M = 3.96$, $SD = 0.84$), reflecting a satisfactory understanding of AI-related concepts. However, skills ($M = 3.87$, $SD = 0.84$) and integration ($M = 3.76$, $SD = 0.82$) recorded lower mean scores. These results suggest that while educators at PMS recognize the importance of AI and are receptive to its adoption, they lack the practical competence and confidence to fully integrate AI into teaching and learning. The study highlights a clear gap between positive perceptions of AI and its actual implementation in educational settings, indicating that awareness alone is insufficient for effective AI integration without adequate training and technical skills. This finding aligns with previous research by Zhang et al., which reported that high awareness does not necessarily translate into strong application skills.

In conclusion, the study findings answer Research Question 1 by showing that lecturers at PMS generally demonstrate high awareness and positive attitudes towards AI literacy, while their knowledge, practical skills, and level of integration remain moderate.

Research Question 2

Are there significant differences in AI literacy levels based on lecturers' teaching experience?

A one-way ANOVA was conducted to determine whether significant differences existed in AI literacy constructs across levels of teaching experience. The analysis examined differences across awareness, knowledge, skills, integration, and attitude. Table 5 indicates the result:

Construct	df (Between, Within)	F Value	Sig. (p)	Decision
Awareness	(3,64)	1.407	.249	Fail to reject H_0
Knowledge	(3,64)	1.808	.155	Fail to reject H_0
Skills	(3,64)	.566	.639	Fail to reject H_0
Integration	(3,64)	2.009	.121	Fail to reject H_0
Attitude	(3,64)	2.908	.041	Significant – Reject H_0

Table 1.5. One-Way ANOVA Results for AI Literacy Constructs by Teaching Experience

The results indicated that there were no statistically significant differences in awareness, $F(3,64) = 1.407$, $p = .249$; knowledge, $F(3,64) = 1.808$, $p = .155$; skills, $F(3,64) = 0.566$, $p = .639$; and integration, $F(3,64) = 2.009$, $p = .121$ among lecturers with different teaching experience levels. Therefore, the null hypotheses for these four constructs were not rejected. These findings indicate that AI literacy in terms of awareness, knowledge, skills, and integration is quite consistent regardless of the length of teaching experience. However, a statistically significant difference was observed for the attitude construct, $F(3, 64) = 2.908$, $p = .041$. Therefore, the null hypothesis for attitude was rejected. This finding suggests that lecturers with different levels of teaching experience may have different perceptions and acceptance of AI technology.

Although this study did not conduct post hoc analyses to identify which groups differed significantly, the findings indicate that teaching experience may influence lecturers' attitudes towards the use of AI. This may be due to exposure to new technologies, adaptability, and practices that vary by experience level. The findings of this study partially support the study's hypothesis, which posits that teaching experience is expected to influence certain aspects of AI literacy, particularly lecturers' attitudes towards AI implementation.

Research Question 3

What are the relationships between the constructs of attitude and integration among the lecturers?

Pearson correlation analysis was conducted to examine the relationships among the AI literacy constructs. The findings revealed that all variables were positively and significantly correlated at the $p < .01$ level.

Variable	Awareness	Knowledge	Skills	Integration	Attitude
Awareness	1	.880**	.656**	.578**	.565**
Knowledge	.880**	1	.644**	.559**	.518**
Skills	.656**	.644**	1	.603**	.395**
Integration	.578**	.559**	.603**	1	.485**

Variable	Awareness	Knowledge	Skills	Integration	Attitude
Attitude	.565**	.518**	.395**	.485**	1

r = Pearson correlation coefficient. Correlation is significant at the 0.01 level (2-tailed).

Table 1.6; Pearson Correlation Matrix of AI Literacy Constructs

The strongest relationship was identified between awareness and knowledge ($r = .880$), indicating a very strong positive relationship. This suggests that lecturers with higher AI awareness also tend to have greater AI-related knowledge. The relationship between attitude and integration was moderate and statistically significant, $r(68) = .485$, $p < .001$. This finding indicates that lecturers with more positive attitudes towards AI are more likely to integrate AI into their teaching and learning processes.

The positive relationship between attitude and integration supports the assumption that lecturers' acceptance of AI plays an important role in promoting its use in the learning and teaching process. Although the strength of the relationship is modest, it indicates that attitude remains an important contributing factor influencing AI implementation.

In conjunction with that, a linear regression analysis was conducted to determine the extent to which attitude predicts integration. Table 7 below summarizes the regression between these two variables:

The regression model was statistically significant, $F(1,66) = 20.308$, $p < .001$, with $R^2 = .235$. This indicates that attitude explained approximately 23.5% of the variance in AI integration. The analysis further revealed that attitude significantly predicted AI integration ($\beta = .485$, $t = 4.506$, $p < .001$). Therefore, the hypothesis stating that attitude significantly influences AI integration was supported. This supports the technology acceptance model (TAM), which emphasizes attitude as an important determinant in technology use (Davis, 1989).

Research Question 4

Which AI literacy construct is the dominant predictor of AI integration among lecturers?

Multiple regression analysis was conducted to assess the extent to which awareness, knowledge, skills, and attitudes contributed to lecturers' AI integration. Table 8 shows the result of the analysis.

Variable (IV)	B	SE B	β	t	Sig. (p)
Constant	0.275	0.607	—	0.453	.652
Awareness	0.154	0.250	.129	0.617	.539
Knowledge	0.083	0.178	.094	0.469	.641
Skills	0.338	0.114	.373	2.975	.004 **
Attitudes	0.269	0.140	.216	1.920	.059 †

Table 1.7: Multiple Regression Coefficients for Factors Affecting AI Integration

The finding revealed that, among all the variables, skills ($\beta = .373$, $p = .004$) were the strongest and most significant predictor. This indicates that lecturers with stronger practical AI skills are more likely to effectively integrate AI into their teaching practices. Meanwhile, attitude demonstrated a positive contribution ($\beta = .216$, $p = .059$), although the relationship did not reach statistical significance at the .05 level. Awareness ($\beta = .129$, $p = .539$) and knowledge ($\beta = .094$, $p = .641$) did not significantly predict AI integration. The multiple regression analysis revealed that AI skills were the strongest and only statistically significant predictor of AI integration ($\beta = .373$, $p = .004$). This finding indicates that lecturers who possess stronger practical competencies in using AI tools are more likely to integrate AI into teaching and learning activities. Although attitude showed a positive contribution ($\beta = .216$), it did not reach statistical significance ($p = .059$). Therefore, practical AI skills emerged as the dominant factor influencing lecturers' AI integration.

The findings suggest that theoretical awareness or understanding is less influential than practical competence. Although lecturers may understand AI and hold a positive attitude towards it, successful integration is primarily determined by their ability to manage and apply AI tools in authentic teaching contexts. Furthermore, while awareness and knowledge are essential foundations, they are insufficient for meaningful implementation without technical skills and practical experience. Attitudes may offer additional influence, but they remain inadequate without the support of practical competence.

This finding supports the study by Kim et al. (2022), which found that the use of AI in education is driven more by technical competence than purely cognitive factors. Overall, the findings answer Research Question 4 by identifying practical AI skills as the dominant factor influencing lecturers' AI integration practices.

5. Conclusion

The results of this study suggest that lecturers showed strong awareness and favorable attitudes towards AI, even though their knowledge, skills, and integration levels remain moderate. Furthermore, positive attitudes had a significant effect on AI integration, and multiple regression analysis revealed that the most important factor influencing the extent to which lecturers integrate AI into teaching and learning is practical ability.

In summary, this study underscores the importance of enhancing TVET educators' AI literacy through competency-based training and ongoing professional development. Beyond increasing awareness of AI technology, educational institutions should prioritize improving instructors' practical proficiency and confidence in utilizing AI tools. With appropriate support, lecturers will be better equipped to integrate AI effectively into educational processes, thereby improving the quality of student learning.

Based on the findings, polytechnic management and policymakers should consider implementing structured AI professional development programs, AI micro-credential courses, departmental AI champions, and practical AI teaching toolkits to strengthen lecturers' competencies and support the sustainable integration of AI in TVET education.

Limitations and Future Research.

Although a statistically significant difference in attitude was found across teaching experience groups, a post hoc analysis was not conducted to identify the specific groups that differed significantly. Therefore, the finding should be interpreted with caution, and further studies are recommended to explore these group differences in greater detail.

Acknowledgment

The authors would like to express their sincere gratitude to Politeknik Muadzam Shah for providing the essential resources, facilities, and academic support that made the successful completion of this research possible.

References

- Chen, L., Chen, P., & Lin, Z. (2020). Artificial Intelligence in Education: A Review. *IEEE Access*, 8, 75264–75278. <https://doi.org/10.1109/ACCESS.2020.2988510>
- Clark, V. L. P. (2023). Mixed methods research. *The Journal of Positive Psychology*, 12(3), 305–309.
- Crompton, H., & Burke, D. (2023). Artificial intelligence in higher education: the state of the field. *International Journal of Educational Technology in Higher Education*, 20(1). <https://doi.org/10.1186/s41239-023-00392-8>
- Davy Tsz Kit Ng, Jiahong Su, Jac Ka Lok Leung, S. K. W. C. (2023). Artificial intelligence (AI) literacy education in secondary schools: a review. *Interactive Learning Environments*, 32(10), 6204–6224. <https://doi.org/https://doi.org/10.1080/10494820.2023.2255228>
- Dringó-Horváth, I., Rajki, Z., & Nagy, J. T. (2025). University Teachers' Digital Competence and AI Literacy: Moderating Role of Gender, Age, Experience, and Discipline. *Education Sciences*, 15(7), 1–20. <https://doi.org/10.3390/educsci15070868>
- Duri Long, Brian Magerko, Kenneth Holstein, Daniella DiPaola, Fred Martin, J. R. (2021). AI Literacy: Finding Common Threads between Education, Design, Policy, and Explainability. *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems*, 1–6.
- Duri Long & Brian Magerko. (2020). What is AI Literacy? Competencies and Design Considerations. *CHI Conference on Human Factors in Computing Systems*, 1–16. <https://doi.org/https://doi.org/10.1145/3313831.3376727>
- Fabio Morandín-Ahuerma. (2022). International Journal of Research Publication and Reviews: What is Artificial Intelligence? *International Journal of Research Publication and Reviews*, 3(12), 1947–1961. Retrieved from www.ijrpr.com
- Fengchun Miao, Wayne Holmes, Ronghuai Huang, & Hui Zhang. (2021). *AI and education: A guide for policymakers*. UNESCO.
- Fitria, T. N. (2022). Artificial Intelligence (AI) In Education : Using AI Tools for Teaching and Learning Process. *Prosiding Seminar Nasional & Call for Paper STIE AAS*, (December), 134–147.

- García-Martínez, I., Fernández-Batanero, J. M., Fernández-Cerero, J., & León, S. P. (2023). Analyzing the Impact of Artificial Intelligence and Computational Sciences on Student Performance: Systematic Review and Meta-analysis. *Journal of New Approaches in Educational Research*, 12(1), 171–197. <https://doi.org/10.7821/naer.2023.1.1240>
- Helmiatin, Hidayat, A., & Kahar, M. R. (2024). Investigating the adoption of AI in higher education: a study of public universities in Indonesia. *Cogent Education*, 11(1). <https://doi.org/10.1080/2331186X.2024.2380175>
- Holmes, W., Bialik, M., & Fadel, C. (2021). *Artificial Intelligence in Education: Promises and Implications for Teaching and Learning*. Center for Curriculum Redesign.
- Ivanashko, O., & Kozak, A. (2024). The Role of Artificial Intelligence in Shaping the Future of Education: Opportunities and Challenges. *Futurity Education*, 4, 126–146. <https://doi.org/10.57125/fed.2024.03.25.08>
- Joon Soo Lim, & Jun Zhang. (2022). Adoption of AI-driven personalization in digital news platforms: An integrative model of technology acceptance and perceived contingency. *Technology in Society*, 69. <https://doi.org/10.1016/j.techsoc.2022.101965>.
- Lebohng Mulaudzi, J. H. (2024). Student perspectives on optimizing AI tools to enhance personalized learning in higher education. *Interdisciplinary Journal of Education Research*, 6(1), 1–15. <https://doi.org/10.38140/ijer-2024>.
- Li, Y., Tolosa, L., Rivas-Echeverría, F., & Márquez, R. (2025). Integrating AI in Education: Navigating UNESCO Global Guidelines, Emerging Trends, and Its Intersection with Sustainable Development Goals. *ChemRxiv*, 1–28. Retrieved from <https://chemrxiv.org/engage/chemrxiv/article-details/67d5cbf681d2151a0281479b>
- MOSTI. (2021). *Malaysia National Artificial Intelligence Roadmap 2021-2025 (AI-RMAP)*. Retrieved from <https://airmap.my/apps>
- Ng, D. T. K., Leung, J. K. L., Chu, S. K. W., & Qiao, M. S. (2021). Conceptualizing AI literacy: An exploratory review. *Computers and Education: Artificial Intelligence*, 2, 100041. <https://doi.org/10.1016/j.caeai.2021.100041>
- Norhana Ahad, & Tuan Mohd Azhar bin Tuan Ngah. (2024). Kesedaran dan tahap literasi AI dalam pembelajaran di Politeknik METRo Johor Bahru : Peranan ChatGPT. *E-Journal of Islamic Thought and Understanding*, (April 2025).
- Norhana Ahad, & Tuan Mohd Azhar Tuan Ngah. (2024). Pengamalan Warga Politeknik Melaka (PMK) terhadap Penggunaan Aplikasi Kecerdasan Buatan (AI) dalam Proses Pengajaran & Pembelajaran (PdP). *E-Journal of Islamic Thought and Understanding*, 7(2).
- Norvig, P., & Stuart Russell. (2022). *Artificial Intelligence :A Modern Approach, 2nd Edition*. Pearson Education, Inc., Upper Saddle River, New Jersey.
- Pisica, A. I., Giurca, R. O., & Zaharia, R. M. (2025). Teaching AI in Higher Education: Business Perspective. *Societies*, 15(8). <https://doi.org/10.3390/soc15080223>
- Schmidt, T. (2019). Teacher as person: the need for an alternative conceptualization of the ‘good’ teacher in Australia’s Vocational Education and Training sector. *Journal of*

Vocational Education & Training, 73(1), 148–165.
<https://doi.org/10.1080/13636820.2019.1698646>

Sreela, A. R., & Karthik Deepa, D. C. (2026). AI awareness and technical competency levels among arts and science college teachers in Kerala. *Discover Education*, 5(1).
<https://doi.org/10.1007/s44217-026-01335-x>

Zhipeng Wen, Hilaria Hiu Nam Li, & Winnie Siu Yee Ho. (2026). Generative AI Literacy for Educators. In *Generative AI Literacy for Educators* (pp. 129–140). Springer, Singapore. https://doi.org/10.1007/978-981-95-0950-8_9

COMPACT DESK SOLUTIONS FOR WORK-FROM-HOME: A USER-CENTRED APPROACH TO FLEXIBILITY AND COMFORT

Raja Intan Suhaylah Raja Abdul Rahman¹, Ronaldi Saleh Umar², Roziha Che Haron¹
¹Kulliyyah of Architecture and Environmental Design, International Islamic University
Malaysia.

² Faculty of Art, Sustainability And Creative Industry, Universiti Pendidikan Sultan Idris
(UPSI), Tanjung Malim, Perak, Malaysia.

¹Corresponding author's email: rajasuhaylah@iium.edu.my

ABSTRACT

Global disruptions such as pandemics, climate crisis, and energy crisis have catalysed a significant shift in work culture, accelerating the adoption of Work-From-Home (WFH) practices worldwide, including in Malaysia. In response to such conditions, various spaces in most houses are being utilised, where living rooms, dining halls, bedrooms and even balconies and kitchens are being transformed into workspaces. This is particularly evident among residents in affordable urban housing, where limited space and work-life balance pose significant challenges in adapting homes for professional use. This paper aims to explore the role of compact furniture as a solution to spatial constraints in contemporary home environments. Compact furniture is a significant element nowadays, as working from home and online learning are the main reasons it is becoming more prevalent in every household. The spatial and environmental preferences of Malaysian remote workers highlight the need to address spatial behaviour, ergonomic needs, and biophilic considerations within limited home settings. Findings indicate that flexibility (adaptability) and comfort (ergonomics) are fundamental to an effective WFH environment. The living and working patterns in a compact space are observed in reference to the emotional design concept, where compact and multi-use furniture becomes a practical solution, particularly in apartments and low-income housing. Hence, this paper illustrates the functions of compact furniture design based on Don Norman's three levels of emotional design, focusing on visceral, behavioural, and reflective aspects. The study concludes that integrating flexibility and ergonomic comfort within emotionally responsive design enhances user experience and supports adaptable, user-centric living environments in evolving urban contexts.

Keywords: Compact Furniture, Work-From-Home, Emotional Design.

1. Introduction

Compact furniture design has become increasingly relevant in contemporary living environments due to economic challenges and changing lifestyle patterns that require individuals to maximise limited residential spaces. As living costs continue to rise, many users are adapting smaller homes, apartments, and shared living environments into multifunctional spaces for working, studying, and daily activities. Areas such as bedrooms, living rooms, and dining spaces are frequently transformed into temporary workstations, creating a growing demand for furniture that is efficient, ergonomic, flexible, and space-saving. In this context, furniture design is no longer evaluated

solely based on functionality, but also on emotional comfort, user interaction, and adaptability within compact environments. Emotional and interaction design therefore play an important role in supporting users' productivity, comfort, and well-being while working or learning from home.

The problem addressed in this study concerns the emotional and spatial challenges experienced by users within limited home environments. Compact spaces shared by multiple individuals may lead to distractions, poor organisation, uncomfortable working postures, cluttered surroundings, and reduced motivation. Such conditions can negatively affect emotional well-being and work performance. Existing furniture solutions often prioritise physical functionality while overlooking emotional experience and behavioural interaction. Therefore, there is a need for a compact furniture solution that supports emotional comfort, efficient workspace organisation, and flexibility within small living spaces.

This study contributes by proposing a compact work-from-home desk solution based on the emotional design framework introduced by Don Norman through visceral, behavioural, and reflective design levels. The visceral level focuses on the visual appearance and aesthetic value of the desk, while the behavioural level emphasises usability, ergonomic support, and multifunctional interaction. The reflective level considers users' emotional satisfaction and long-term experience when using the furniture. The proposed compact desk incorporates features such as fast assembly, ergonomic dimensions, multifunctional storage, and space-saving mechanisms to enhance the working and learning experience within compact residential environments.

The main objective of this study is to observe and design the characteristics of a compact furniture solution that supports positive working-from-home behaviours and emotional experiences. Specifically, the study aims to examine users' concerns regarding the appearance of compact furniture, identify important ergonomic and functional characteristics, and understand users' working-from-home behaviours within compact spaces. In line with these objectives, the study addresses three main research questions concerning users' perceptions of furniture appearance, the design characteristics that contribute to effective usage, and users' behavioural experiences while working from home.

The paper presents the novelty and design development process including sketches, mechanisms, dimensions, and artist impressions of the proposed compact desk design before concluding with supporting references.

2. Literature review

This study is positioned within the broader discussion of user-centred furniture innovation, particularly in relation to emotional design and compact living environments. The increasing transformation of residential spaces into multifunctional working environments has shifted the role of furniture from being merely functional objects toward becoming adaptive systems that support productivity, emotional comfort, and spatial organisation. As users spend longer periods working or studying at home, furniture design must respond not only to ergonomic and practical needs, but

also to emotional and psychological experiences that influence motivation, satisfaction, and well-being. Consequently, compact furniture design has gained attention among researchers and designers as an approach to improve interaction quality between users, working environments, and domestic spatial limitations.

Compact furniture design has become an important area of design research as contemporary users increasingly live and work within limited residential spaces. Economic pressure, urban housing constraints, and the rising cost of living have encouraged users to maximise domestic spaces for multiple purposes, including work, study, storage, leisure, and online communication. In this context, furniture is no longer understood merely as a physical object, but as a user-centred product that supports spatial efficiency, emotional comfort, and behavioural adaptation. Studies on home working environments show that the quality of the home workspace can influence productivity, stress, burnout tendency, and user satisfaction, particularly when users do not have a dedicated office area at home (Stroom et al., 2024). Similarly, ergonomic risks in work-from-home settings have been associated with discomfort, reduced performance, and poor working posture when furniture does not properly support users' physical and task-related needs. Research by Xiao et al. (2021) also found that unsuitable home working environments contribute to physical fatigue, mental stress, and lower work engagement. These findings strengthen the argument that compact desk design should integrate ergonomics, usability, and emotional experience rather than focusing only on size reduction alone.

From an emotional design perspective, Norman's framework of visceral, behavioural, and reflective design provides a useful theoretical basis for evaluating compact furniture. Visceral design concerns the immediate visual and emotional impression of a product, including form, colour, material, and perceived attractiveness. Behavioural design focuses on usability, function, ergonomics, and effectiveness during use, while reflective design relates to meaning, identity, satisfaction, and the user's long-term emotional response toward the product (Norman, 2004). Emotional design theory argues that users tend to develop stronger attachment and satisfaction toward products that create positive emotional experiences during interaction. In furniture design, this may include feelings of comfort, neatness, relaxation, and psychological control over the workspace. The uploaded study also positions the compact desk within these three emotional design levels by linking appearance to the visceral level, ergonomic and multifunctional use to the behavioural level, and flexible space-saving benefits to the reflective level. Therefore, emotional design offers a suitable lens to understand how compact furniture can reduce emotional risk and improve the experience of working or learning from home.

Empirical studies on workspace and environmental design further suggest that the physical environment plays a significant role in shaping well-being and work performance. Colenberg et al. (2020) argued that interior office space affects health and well-being through environmental comfort, layout, privacy, and user control. Similarly, Morrison and Smollan (2020) emphasised that workspace arrangement and environmental management influence employee satisfaction, communication quality, and emotional stability. Although these studies focus on office settings, the same arguments are highly relevant to home workspaces because residential environments frequently lack proper zoning, storage systems, and ergonomic furniture support.

Furthermore, Kim et al. (2021) explained that home office quality significantly affects users' concentration, productivity, and emotional resilience, especially among individuals working long hours remotely. This indicates that compact furniture should not merely save space, but also improve environmental quality and emotional comfort.

In addition, studies related to furniture usability and interaction design indicate that multifunctional furniture increases efficiency and flexibility within compact environments. Ertas and Satir (2021) highlighted that contemporary furniture design should address changing user lifestyles by integrating aesthetic value, adaptability, and practical usability. Flexible furniture systems with modular storage and adjustable components are increasingly preferred because they support multiple user activities within limited spatial arrangements. Research by Lee and Park (2022) also found that compact and transformable furniture contributes positively to perceived spatial comfort and user satisfaction in small residential units. These findings support the argument that compact furniture design should incorporate ergonomic dimensions, organised storage systems, and flexibility to enhance daily working experiences. Moreover, emotional satisfaction may increase when users perceive their furniture as visually organised, aesthetically pleasing, and capable of reducing environmental clutter.

The relationship between workspace organisation and psychological well-being has also been discussed extensively in environmental psychology studies. According to Vischer (2007), users are more productive and emotionally stable when the physical environment supports comfort, territorial control, and functional efficiency. Cluttered or poorly organised workspaces may contribute to stress, cognitive overload, and reduced task performance. In compact homes, this issue becomes more significant because work-related activities are integrated into personal and family spaces. Therefore, a compact desk with integrated shelves, multifunctional racks, and space-saving mechanisms may help users maintain better environmental organisation while reducing emotional tension during work or study activities.

Based on the literature, this study proposes that emotional design dimensions may positively influence users' acceptance and experience of compact desk furniture. The first hypothesis is that the visceral quality of compact desk design has a positive relationship with users' initial acceptance of the furniture. Attractive form, suitable colour application, and perceived neatness may influence users' first impressions and willingness to use the product. The second hypothesis is that behavioural design characteristics, including ergonomic size, multifunctional racks, storage flexibility, and ease of assembly, positively influence the effectiveness and pleasure of use. This is supported by ergonomic and workspace studies showing that furniture suitability affects comfort, performance, and productivity. The third hypothesis is that reflective design qualities, such as space-saving ability, reduction of clutter, and emotional satisfaction, positively influence users' working-from-home behaviour and long-term product attachment. Therefore, the literature suggests that compact furniture design should be evaluated through an integrated emotional design model, where appearance, usability, flexibility, and reflective satisfaction collectively contribute to improved user experience in compact residential workspaces.

3. Methodology

This study applies a Developmental Design Research (DDR) methodology focusing on the design and development of a compact work-from-home desk based on emotional design principles. DDR is appropriate for this study because it emphasises the systematic process of analysing problems, identifying user requirements, designing solutions, developing prototypes, and evaluating product effectiveness within real contexts (Richey & Klein, 2007). Developmental research is widely used in design, technology, and product innovation studies because it bridges theoretical understanding with practical solution development. In this study, user requirements were derived from a Customer Feedback Traceability Matrix (CFTM) based on customer feedback collected over three years of commercial implementation of the WFH Table by the industry partner. The collected feedback provided valuable insights into users' preferences, workspace challenges, functional requirements, and expectations for compact furniture solutions. Therefore, this methodology is suitable in guiding the development of compact furniture that addresses users' emotional and functional needs within limited residential spaces.

The study adopts Don Norman's Emotional Design framework, particularly the visceral, behavioural, and reflective levels, as the main theoretical foundation throughout the design development process. The first phase involved identifying issues related to compact residential working environments through literature review, contextual observation, and user needs identification. The Customer Feedback Traceability Matrix (CFTM) was utilised to systematically analyse recurring customer feedback and translate user requirements into design specifications. In addition, previous studies related to compact furniture, ergonomics, workspace behaviour, emotional design, and working-from-home environments were reviewed to identify current challenges faced by users. According to Richey and Klein (2014), the analysis phase in DDR is important in determining practical problems, user requirements, and contextual needs before the design solution is developed.

Source	Ownership Duration	Raw Observation / Customer Suggestion	Root Product Flaw	Proposed Design / Engineering Solution
Cust 1 (Verified Review)	1 Year	<i>"My desk is cluttered with pen cups, and my phone always gets lost under papers. It would be great to have a clip-on stationery holder and phone holder that can be moved around."</i>	Limited desk surface due to daily work clutter (lack of active desktop organization).	Develop a modular edge-rail system or discrete slot mounts for detachable, slide-and-lock stationery and phone holders.
Cust 2 (Feedback)	2 Years	<i>"I like keeping a small potted plant to brighten my workspace, but I am terrified of water spilling and ruining the wood. I suggest a detachable plant holder that hangs off the side."</i>	Risk of liquid damage to the wood veneer and inefficient use of primary horizontal surface area.	Design a waterproof, cantilevered bracket that clamps securely onto the table frame to hold small plant pots safely away from the wood surface.
Cust 3 (Experience)	3 Years	<i>"When referencing textbooks while working, the table becomes way too cramped. We need a detachable, upright book holder so the workspace beneath it stays clear."</i>	Poor ergonomic workflow and lack of vertical space utilization when referencing large physical documents or books.	Create a detachable, angled book stand with a clamp mechanism that elevates reading materials to eye level and frees up desk space below.

Table 1.1: Customer feedback traceability matrix

The second phase focused on the design and development process. Several design sketches, ideation explorations, and visual developments were conducted to identify suitable forms, ergonomic dimensions, multifunctional storage systems, and space-saving mechanisms for the compact desk proposal. Features such as folding structures, rack systems, shelves, and flexible storage components or accessories were integrated into the design to improve usability, environmental

organisation, and emotional comfort. This process aligns with the developmental phase suggested by Peffers et al. (2007), where artefact development emphasises iterative improvement and practical functionality based on identified user needs.

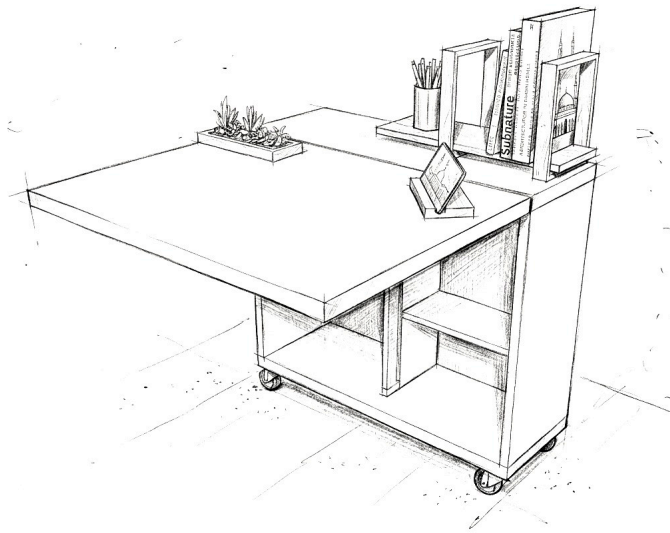


Figure 1.1: Sketches

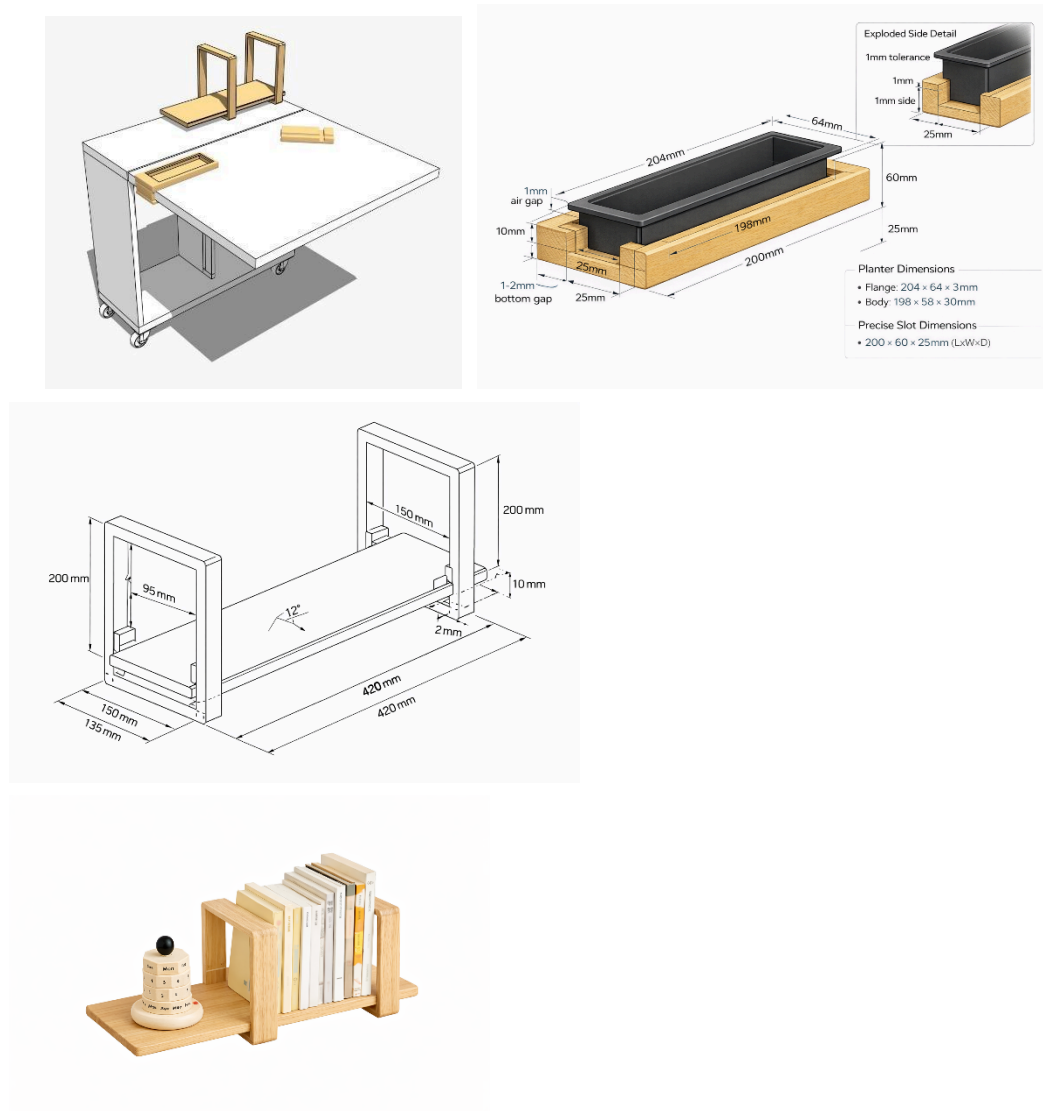


Figure 1.2. Detailing of structure

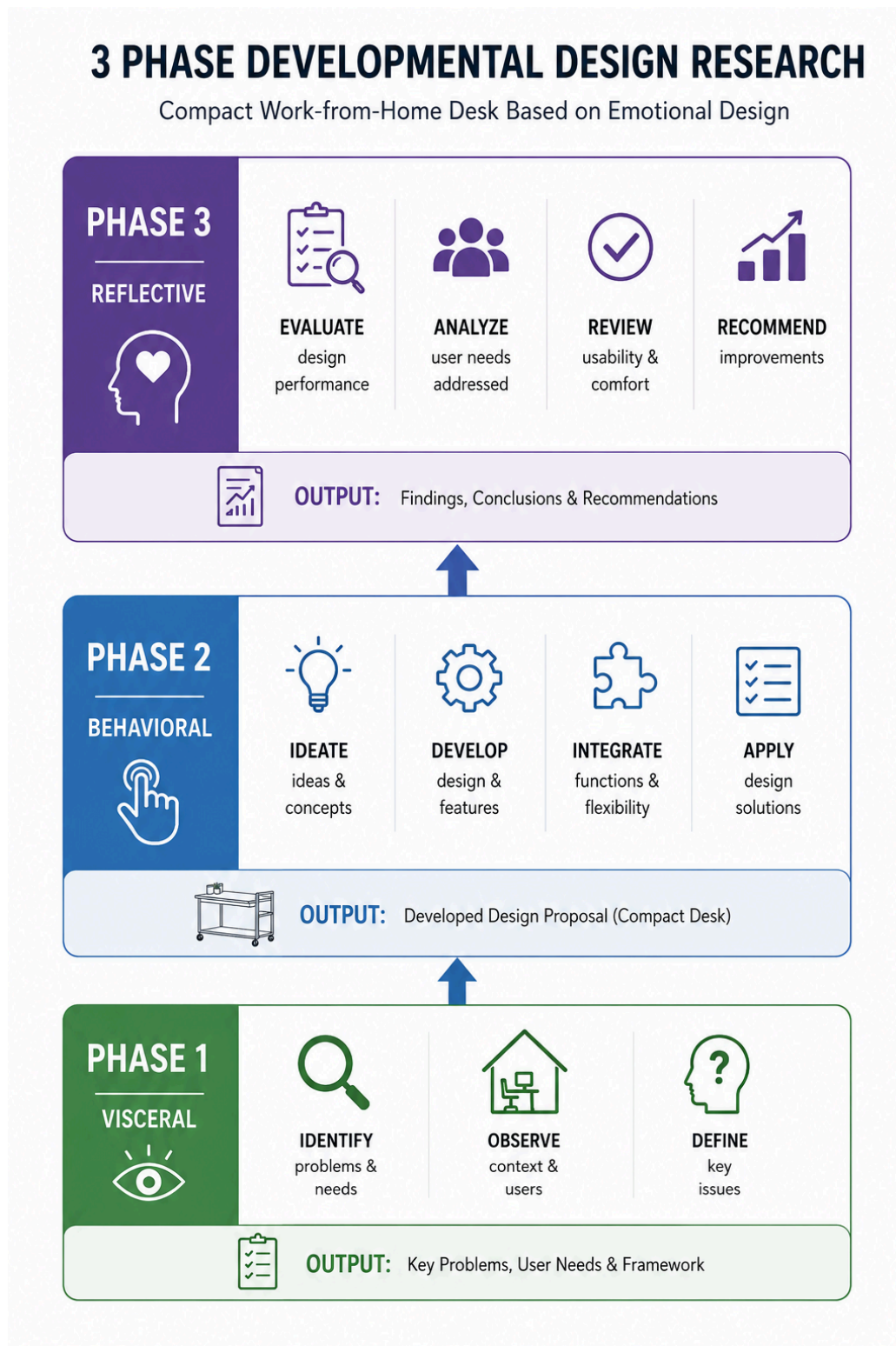


Figure 1.4. Design process

The final phase involved prototype evaluation through observational and descriptive analysis of the developed compact desk design proposal. The evaluation examined how the proposed design addresses users' emotional

responses, ergonomic needs, and working-from-home behaviours within compact residential environments. Particular attention was given to workspace organisation, flexibility, emotional satisfaction, and usability based on the visceral, behavioural, and reflective emotional design dimensions.

The prototype evaluation was conducted based on three core criteria: Form, Fit, and Function, through close collaboration between the in-house designers and marketing team of the industry partner prior to full-scale manufacturing. The Form (Aesthetics) evaluation assessed the visual appearance, dimensions, ergonomic feel, material finish, and overall design quality of the prototype. The design team ensured that the prototype remained consistent with the intended design language, while the marketing team evaluated whether the visual appearance, colour options, and styling aligned with current market trends and customer preferences. The Fit (Compatibility) evaluation focused on the precision and integration of modular components, storage compartments, shelves, and accessories. Designers assessed dimensional accuracy, assembly tolerances, and structural clearances, whereas the marketing team verified compatibility with commonly used consumer products such as laptops, tablets, smartphones, and related work accessories. The Function (Utility) evaluation examined usability, structural stability, durability, and resistance to everyday usage conditions including repeated handling, surface wear, accidental spills, and loading capacity. While the designers evaluated structural integrity, ergonomic performance, and safety aspects, the marketing team assessed whether the identified functional benefits supported the intended product positioning and unique selling propositions. The evaluation process concluded with a mutual approval of the final “Golden Sample”, ensuring that the developed compact desk successfully balanced design quality, user requirements, manufacturability, and commercial viability before proceeding to mass production. Therefore, the DDR methodology enabled this study to systematically integrate theoretical understanding, user feedback, expert validation, and industry requirements in proposing an effective compact desk solution for contemporary residential living

4. Discussion of analysis and findings

The findings of this study demonstrate that compact furniture design plays an important role in addressing emotional, functional, and spatial challenges experienced by users working or studying within limited residential environments. The analysis reflects the earlier problem statement which highlighted issues related to cluttered surroundings, limited working zones, uncomfortable arrangements, and emotional stress caused by compact living conditions. The developed compact desk design indicates that users require more than basic furniture functionality, as emotional comfort, environmental organisation, and flexibility significantly influence the overall working-from-home experience. Therefore, the findings support the earlier argument that compact furniture should be designed through a user-centred and emotional design approach rather than focusing solely on physical practicality.



Figure 1.5: 3D environment view

Based on the observation of the 3D environment rendered image, the compact desk is positioned within a warm and organised residential setting that reflects a calm and productive working atmosphere. The desk is placed near a window with natural sunlight entering the space, creating a brighter visual environment and reducing the feeling of confinement commonly experienced in compact residential areas. The use of natural lighting supports previous studies suggesting that environmental quality and lighting conditions contribute positively toward emotional well-being, concentration, and productivity. The rendered environment also includes indoor plants, wooden accessories, bookshelves, and soft colour arrangements, which collectively create a more relaxing and emotionally supportive workspace atmosphere. These observations strengthen the earlier argument that compact workspaces should support not only functionality, but also psychological comfort and emotional stability.

From the visceral design perspective introduced by Don Norman, the findings suggest that the visual appearance of the compact desk strongly contributes toward users' first impressions and emotional acceptance. The rendered image shows that the desk applies a minimal and visually balanced design approach through clean lines, organised composition, and bright colour application. The white desk surface creates a perception of spaciousness and cleanliness, while the wooden accessories and decorative elements add warmth and visual harmony to the environment. The compact arrangement allows the furniture to blend naturally within the residential space without visually dominating the room. This finding aligns with earlier literature which argues that aesthetic quality and visual organisation positively influence emotional comfort and reduce stress caused by cluttered surroundings. Therefore, the rendered image confirms that the proposed compact desk successfully supports the visceral emotional design dimension through simplicity, neatness, and aesthetic comfort.

From the behavioural design perspective, the findings reveal that ergonomic considerations and multifunctional features are essential in supporting efficient workspace interaction. The rendered image demonstrates that the compact desk integrates several practical features including a spacious working surface, integrated planter box, storage compartment, side rack system, and smooth mobility through caster wheels. These features support organised workspace behaviour by allowing users to arrange books, stationeries, digital devices, and decorative items efficiently within a limited area. The lower storage shelf further provides additional space for files or working materials, reducing unnecessary clutter on the main desk surface. In addition, the foldable or extendable table surface contributes toward flexibility by enabling users to adjust the working area according to their activities and spatial requirements. The mobility of the desk also allows users to reposition the furniture based on lighting conditions, room layout, or privacy needs. These findings support earlier ergonomic arguments that flexible and organised furniture design contributes positively toward comfort, productivity, and usability within compact living environments.

The reflective design findings further indicate that compact furniture may contribute toward long-term emotional satisfaction and behavioural improvement among users. The rendered image suggests that the compact desk functions as part of the home environment rather than appearing as a rigid or intrusive working structure. The integration of decorative plants, books, natural materials, and warm lighting creates a sense of personal ownership, relaxation, and emotional attachment to the workspace. The space-saving characteristics of the desk also support users in maintaining environmental organisation and reducing visual stress within compact residential areas. This reflective quality is important because users working from home often experience overlapping personal, social, and professional activities within the same environment. Therefore, the ability to organise, fold, reposition, and personalise the workspace indirectly supports better emotional control, motivation, and work-life balance.

Overall, the findings suggest that emotional design dimensions consisting of visceral, behavioural, and reflective elements collectively influence users' acceptance and experience toward compact furniture design. The analysis of the 3D environment rendered image further confirms the earlier hypotheses that attractive appearance positively affects emotional acceptance, ergonomic and multifunctional features improve usability and effectiveness, while reflective qualities contribute toward emotional satisfaction and behavioural adaptation. Consequently, the proposed compact desk demonstrates how emotional design principles can be integrated into furniture development to address both functional challenges and emotional risks within compact residential working environments.

5. Conclusion and future research

In conclusion, this study demonstrates that compact furniture integrated with emotional design principles can effectively address functional, emotional, and spatial challenges within contemporary residential working environments. The proposed compact desk successfully supports the visceral, behavioural, and reflective dimensions through its aesthetic appearance, ergonomic functionality, multifunctional features, and space-saving flexibility. The findings suggest that compact furniture

should support not only usability, but also emotional comfort and workspace organisation within limited living spaces. Future research may focus on developing more modular accessories such as storage racks, lighting systems, and cable management features to increase user customisation, commercial value, and market appeal. Further collaboration with furniture industries may also support prototype enhancement, production feasibility, and commercialisation opportunities for wider market potential.

References

- Colenberg, S., Jylhä, T., & Arkesteijn, M. (2020). The relationship between interior office space and employee health and well-being: A literature review. *Building Research & Information*, 49(3), 352–366.
- Ertaş, D. G., & Şatır, S. (2021). Furniture as a design product. *Online Journal of Art and Design*, 9(1), 1–10.
- Hardianningrum, R. (2024). Home workspace design to improve employee's productivity and performance. *Atlantis Press*.
- Kim, J., Henly, J. R., Golden, L. M., & Lambert, S. J. (2021). Workplace flexibility and worker well-being by gender. *Journal of Marriage and Family*, 82(3), 892–910.
- Lee, S., & Park, J. (2022). User satisfaction toward transformable furniture in compact residential spaces. *Journal of Interior Design*, 47(2), 55–71.
- Morrison, R. L., & Smollan, R. K. (2020). Open plan office space? If you're going to do it, do it right: A fourteen-month longitudinal case study. *Applied Ergonomics*, 82, 102933.
- Norman, D. A. (2004). *Emotional design: Why we love (or hate) everyday things*. Basic Books.
- Peppers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, 24(3), 45–77.
- Richey, R. C., & Klein, J. D. (2007). *Design and development research: Methods, strategies, and issues*. Lawrence Erlbaum Associates.
- Richey, R. C., & Klein, J. D. (2014). *Design and development research*. In J. M. Spector et al. (Eds.), *Handbook of research on educational communications and technology* (4th ed., pp. 141–150). Springer.
- Stroom, M., et al. (2024). Does working from home work? That depends on the home. *PLOS ONE*.
- Vischer, J. C. (2007). The effects of the physical environment on job performance: Towards a theoretical model of workspace stress. *Stress and Health*, 23(3), 175–184.

Xiao, Y., Becerik-Gerber, B., Lucas, G., & Roll, S. C. (2021). Impacts of working from home during COVID-19 pandemic on physical and mental well-being of office workstation users. *Journal of Occupational and Environmental Medicine*, 63(3), 181–190.

PROMOTING RESPECT AND TOLERANCE THROUGH EDUCATIONAL ROLE-PLAY GAME: THE CASE OF “KOTAK HARMONI”

Marwa binti Abd Malek¹, Najwa binti Abd Malek,² Joanne Mercilynne P Juanico³

¹Unit Pengajian Am, Kolej Komuniti Sandakan

² Unit Penguatkuasaan Undang-undang, Kolej Vision Kelana Jaya

³Unit Pengajian Am, Kolej Komuniti Sandakan

¹Corresponding author's email: marwa@kksk.edu.my, marwaabdmalek@gmailcom

ABSTRACT

Malaysia is a multiracial country with diverse ethnicity and culture. Yet, ethnic identity often remains stronger than national identity, leading to social divisions. On top of that, younger generations also show low engagement in moral and civic education due to traditional teaching methods, which are often seen as boring. To address these issues, this study introduces *Kotak Harmoni (Dialog Perpaduan Malaysia)* based on Social Learning Theory to enhance students' interest in promoting interracial respect and tolerance. Hence, this study was conducted to investigate the effectiveness of *Kotak Harmoni* game in increasing students' interest in learning interracial mutual respect and tolerance. This study also aimed to find out improvements needed for *Kotak Harmoni* game. It used quantitative and qualitative approach through an online questionnaire. Respondents were all students of Kolej Komuniti Sandakan. Findings showed an interesting insight, in which *Kotak Harmoni* game had a positive impact on students' understanding, enable them to relate to real-life situations and distinguish appropriate and inappropriate responses in conflict situations. In terms of learning experience, students reported high involvement and enjoyment, stating that the game was more engaging. They also felt comfortable participating in group activities. Furthermore, *Kotak Harmoni* helped students develop tolerance, respect, and empathy towards different races, religions, and cultures, hence, improving their communication skills by giving polite responses while in conflict situations. Students also agreed that the game design was visually attractive, easy to understand, relevant to Malaysian contexts, and suitable in duration for classroom use. Overall, they viewed *Kotak Harmoni* as an effective educational tool that promotes positive attitudes with high potential for future use. This study recommends innovator to do minor improvements, in which to make longer dialogue, using random selection methods like dice and enhancing card design with more attractive shapes such as hearts or stars to increase students' engagement.

Keywords: moral, unity, communication

1. Introduction

Malaysia is a multiracial country with diverse ethnic, culture, religion, colonial legacies and socio-political structures. Many initiatives have been taken by the government to promote national unity. However, ethnic identity remains stronger than nation identity (The Star, 2026). It leads to social divisions in everyday life. This situation later raises many issues related to race, belonging and cultural difference among all generations including youngsters.

In addition, younger generations often experience low engagement in moral and civic education due to traditional theory teaching approaches. Most of them perceived it as uninteresting, resulting in boredom (Azmin et al., 2024). Thus, learning process becomes ineffective.

To address these challenges, innovators had come out with a product, namely *Kotak Harmoni (Dialog Perpaduan Malaysia)* based on Social Learning Theory to propose an educational approach that can foster respect, tolerance, and meaningful social interaction skills among students. Following that, this study was done to find out the effectiveness of the Kotak Harmoni game in increasing students' interest in learning interracial mutual respect and tolerance.

This study may benefit higher education students, school students, lecturers, teachers and parents. They can use Kotak Harmoni as a learning game while instilling moral values. The dialogue cards work as a guidance on what to respond while facing racial conflicts while remaining respect. Thus, increasing participants' comprehension on the importance of community and unity in Malaysia.

The objectives of this study are; 1) to examine the effectiveness of the Kotak Harmoni game in increasing students' interest in learning interracial mutual respect and tolerance and; 2) to find out improvements needed for Kotak Harmoni game. Based on these objectives, this study seeks to answer the questions; 1) what is the level of effectiveness of the Kotak Harmoni game in increasing students' interest in learning interracial mutual respect and tolerance? and; 2) what improvements can be made to the "*Kotak Harmoni*" game in terms of content, design, and gameplay experience? This paper includes several sections, including introduction, literature review and methodology. It also includes discussion of analysis and findings, as well as conclusions and future research.

2. Literature review

In this chapter, emphasis will be given to the review of literature that is relevant to the topic of this study, which is to promote respect and tolerance through an educational approach. The purpose of this literature review is to identify the loopholes in the current approach that directly impact the students' interest in learning important social interaction skills in a multicultural Malaysia. As a result, the students lack essential communication and conflict resolution skills in their daily interactions, especially when facing sensitive racial issues.

To achieve the research objectives, reliance on previous research on Malaysian studies, community and unity in Malaysia (and the racial issues) as well as social learning theory will be made to formulate an effective approach to garner students' interest and engagement to acquire the abovementioned set of skills. Based on the research findings, suggestions and recommendations will be given to assist the educators in Malaysia in creating a fun and interactive tool for students to participate in a classroom setting, such as the "*Kotak Harmoni*" game introduced in this paper.

a) Malaysian Studies

Malaysia is a diverse Southeast Asian country renowned for its multi-ethnic society. The identity of Malaysians today is reminiscent of the British colonial policies. Research commonly suggests that the divide-and-rule policy introduced by the British during the colonisation era left a lasting imprint on the social fabric of Malaysian society. This policy confined Malays to agricultural work in rural villages, Chinese communities to mining and commerce in urban areas, and Indians to labour on plantation estates (Zaaba, Jalil, Gunggut, & Thomas, 2023). Compliance with this policy resulted in racial segregation and division that persisted long after Malaysia gained independence in 1957. Today, social belonging and national unity in Malaysia are still heavily influenced by race-based system that mirrors colonial policies.

According to the Demographic Statistics Report by the Department of Statistics Malaysia (DOSM), the country's population reached 34.2 million in the first quarter 2025. The DOSM reported the ethnic composition as 58.1% Malays, 22.4% Chinese, 12.3% other Bumiputera, 6.5% Indians and approximately 0.75% comprising other races (Department of Statistics Malaysia, 2025). This "deep social cleavages" serves as a constant reminder that Malaysians are divided not only by ethnicity and race, but also socioeconomic status, religion, language and cultural tradition. This structure naturally shapes differing political beliefs and loyalty, which eventually lead to intense affective polarization and social conflict (Aydogan, 2021).

b) Community and Unity, Racial Conflicts

Researchers often describe Malaysia as a complex nation that balances unity and diversity, nationalism and multiculturalism, as well as ethnic rights and national belonging. These complex dynamics form the bedrock of social cohesion in the pursuit of a harmonious Malaysia. Conversely, many studies show that ethnic identity often remains stronger than national identity. Ethnic consciousness is frequently shaped via cultural heritage institutions, traditions and collective memory. As such, despite modernization, ethnicity remains central to Malaysian identity (Lyu, Kay, & Olmedo Panal, 2026). A recent study also argues that the formation of Malaysia's national identity remains heavily dependant on balancing ethnic interests through political compromise (Wan Husin, Samsudin, Mujani, & Zainurin, 2025). Therefore, the consociationalism system plays an important role in ensuring that all major ethnic groups are guaranteed a share of political power.

It is also argued that unity in contemporary Malaysia can only be achieved when Malaysians identify themselves as Malaysians first rather than by race (Ting & Zainol Abidin, 2023). However, the building blocks for achieving unity in Malaysia's future lie in the hands of the younger generation. This process must begin with the ability to negotiate belonging while confronting racial discrimination and cultural exclusion from other ethnic groups. These issues are often raised through media discourse and online forums in discussions surrounding race and nationhood in everyday conversations. This suggests that identity is actively negotiated through speech and public debate (Mohd Nor, 2021). As such, online discourse plays a major

role in reinforcing or contesting national identity and ethnic belonging in postcolonial Malaysia.

c) Social Learning Theory by Albert Bandura and its relevancy in Malaysia's Social Setting

The Social Learning Theory (SLT), introduced by Albert Bandura, highlights that a person observes, imitates and interacts among each other to acquire new behaviours, attitudes and social values. Bandura also argued that people learn by observing how others behave and witness the consequences of their actions (Rumjaun & Narod, 2025). This approach differs from the traditional behaviorist theories, which suggest that individuals learn primarily through direct reinforcement and punishment experienced personally. The key processes in SLT include attention, retention, reproduction and motivation. This means that a person learns by observing behavior (attention), processing and remembering it (retention), applying it to their own situations (reproduction), and deciding whether to continue the behavior based on the likelihood of rewards or consequences (motivation).

SLT was later reinforced through Bandura's Bobo Doll Experiment which demonstrated that children exposed to aggressive parents at home were more likely to imitate the aggressive behaviour themselves. The experiment proved that a person, especially during their formative years, can emulate behaviour without direct reinforcement, but rather, through observing adults or influential figures at home or within their circle. This experiment served as a turning point in how learning and human behavior are psychologically perceived (de la Fuente, Kauffman, & Boruchovitch, 2023).

The theory later evolved into Social Cognitive Theory (SCT), in which Bandura introduced concepts such as reciprocal determinism and self-efficacy. The former refers to the interaction between personal factors, behaviour, and the environment in shaping human conduct, whereas the latter refers to an individual's belief in their own capabilities and competence. Scholars argue that these concepts make SLT highly significant for understanding socialisation, education, cultural transmission, and identity formation (Brown, 2025).

Over the years, researchers reaffirmed the relevance of SLT in explaining how individuals learn social norms and cultural values through media, education, and interaction with others. Various studies have found that "on-screen modeling" via television, digital media, schools, and family environments can influence a person's attitudes, beliefs, and sense of identity (de la Fuente, Kauffman, & Boruchovitch, 2023). Researchers today also apply the theory to online communication, particularly social media platforms, where individuals observe the behaviors of others and often adopt them as models for their own actions.

In Malaysia, SLT can be applied to understand how multicultural values, ethnic perceptions, and national identity are constructed through social settings disseminated from one generation to another. It is argued that Malaysians adopt their social

behaviors and attitudes toward other ethnic groups through observation within families, schools, religious institutions, social circles and through media discourse.

In a complex multi-ethnic country such as Malaysia, constructive and effective dialogue in interethnic communication is essential to reduce social tension that could otherwise lead to prejudice, discrimination and civil unrest among Malays, Chinese, Indians and other minority groups if not properly managed. SLT therefore provides an important analytical framework to explain how cultural heritage, national loyalty, and intercommunity dynamics are sustained and perpetuated across generations within Malaysian pluralistic society.

d) Suggestions and Recommendations

Recent studies show that students often perceive moral education classes as secondary less important compared to other core subjects. This is exacerbated by traditional, theory-based teaching methods that are perceived as repetitive, less interactive and dull, resulting in attention and interest deficit among students (Azmin, Fadilah, Isnin, & Rajandran, 2024). Therefore, more interactive and engaging student-centered approaches should be introduced to increase student motivation and classroom participation.

In classroom settings, studies show that students often experience boredom, which has an adverse effect on students' emotions and decrease of engagement. This, in turn, leads to knowledge retention especially in subjects relating to civic and moral discourse (Graf, Stempfer, Muis, & Goetz, 2024). As such, educators need to provide opportunities or outlets for students to apply their knowledge to real-life-situations, including addressing racial and social issues. Improvement can be achieved by incorporating technology such as game-based learning (gamification), interactive online tools, and immersive learning environments to sustain students' attention who are accustomed to highly interactive digital environments.

In addition to game-based approaches, studies suggest that collaborative activities, group-problem solving and debates can foster a deeper understanding of moral values among students (Kusnandar & Muslimah, 2025). These may include role-playing and impromptu speeches to enhance students' confidence and self-esteem. Feedback and constructive comments can also be given directly to students to improve understanding and develop communication skills. A positive classroom environment and supportive peer relationships may further help reduce anxiety and increase enjoyment in learning.

3. Methodology

This is employed a both quantitative and qualitative approach. An online questionnaire was distributed via *Google Form*. Items in the questionnaire were adapted based on the contents of Kotak Harmoni (Dialog Perpaduan Malaysia) game. The samples were 86 Kolej Komuniti Sandakan students, including those enrolled in Sijil Pegembaraan Pelancongan and Sijil Teknologi Elektrik who had taken the Pengajian Malaysia course. This study applied convenience sampling, as it can allow

the researcher to access readily available participants who had experience in using Kotak Harmoni game during studying Pengajian Malaysia course. Then, descriptive analysis was conducted to examine the effectiveness of the Kotak Harmoni game in increasing students' interest in learning interracial mutual respect and tolerance. It also identifies improvements needed for better experience in using Kotak Harmoni.

Then, descriptive analysis was done to assess the level of effectiveness of Kotak Harmoni game, which is the mean score. The mean was then interpreted based on the scale used by Ngadiman, Yacoob & Wahid, (2019), namely: 1.00–1.99 (Weak), 2.00–2.99 (Low), 3.00–3.99 (Moderate), and 4.00–5.00 (High).

For qualitative approach, this study used open-ended questions to collect data from participants. The responses obtained were analysed using thematic analysis to identify recurring patterns related to the research objectives. This approach allows the researcher to gain in-depth insights into participants' perspectives on improvements can be made to the "Kotak Harmoni" game in terms of content, design, and gameplay experience.

4. Discussion of analysis and findings

a) Respondent Background

As shown in Table 1.1, the respondents consist of various demographic profiles. 100.00% (N=86) of the respondents are between 18-25 years old. 62.80% (N=54) of the respondents are male, while 37.20% (N=32) of the respondents are female. For the programme, 43.02% (N=37) of the respondents are students of Sijil Pengembaraan Pelancongan, while 56.98% (N=49) are students of Sijil Teknologi Elektrik.

Demographic Profile		Frequency (N)	Percentage (%)
Age	18-25 years old	86	100.00
	Total	86	100.00
Gender	Male	54	62.80
	Female	32	37.20
	Total	86	100.00
Programme	Sijil Pengembaraan Pelancongan	37	43.02
	Sijil Teknologi Elektrik	49	56.98
	Total	86	100.00

Table 1.1: Respondents' background

b) The Effectiveness of The Kotak Harmoni Game

Table 1.2 shows that the highest mean for understanding on interracial mutual respect and tolerance topic was 'the simulation activity helps me to experience real-life societal situations' which were 4.30. It was followed by 'I can distinguish appropriate and inappropriate responses in conflict situations,' with mean of 4.10. Next, 'this game helps me understand the concept of unity more clearly' and 'I can understand better on racial conflict after playing this game.' which both showed the mean of 4.00.

Overall, the mean for understanding on interracial mutual respect and tolerance was 4.10.

The highest mean for learning experience was *'I feel more actively involved during the activity'* which were 4.30. It was followed by *'this game is more interesting than learning theory alone,'* with mean of 4.00. Next, *'this game is fun and not boring'* and *'I feel comfortable participating in group activities'* which both showed the mean of 3.90. Overall, the mean for learning experience was 4.03.

Next, the highest mean for learning experience was *'I feel more actively involved during the activity'* which were 4.30. It was followed by *'this game is more interesting than learning theory alone,'* with mean of 4.00. Next, *'this game is fun and not boring'* and *'I feel comfortable participating in group activities'* which showed the mean of 3.90. Overall, the mean for learning experience was 4.03.

For understanding of skills and moral values, the highest mean was *'this game fosters tolerance within me'* which were 4.30. It was followed by *'this game helps me think before giving a response,'* and *'I learn how to resolve conflicts in a respectful manner,'* both with mean of 4.20. Next, *'this game improves my communication skills'* and *'I have a better understanding of the importance of empathy towards others'* which both showed the mean of 4.00. Overall, the mean for understanding of skills and moral values was 4.14.

Next, the highest mean for design and implementation was *'the game instructions are easy to understand'* which were 4.40. It was followed by *'the game design is attractive and visually appealing'* and *'the content of the situation cards is relevant to Malaysian society'* which both showed the mean of 4.30. Next, *'the duration of the game is appropriate'* with the mean of 4.20. Overall, the mean design and implementation was 4.30.

Lastly, the highest mean for overall effectiveness was *'I am interested in participating in similar activities in the future'* which were 4.20. It was followed by *'I would recommend this game to other friends,'* with mean of 4.10. Next, *'this game is effective as a learning tool'* which showed the mean of 4.00. Overall, the mean for overall effectiveness was 4.10. While the average mean for the effectiveness of Kotak Harmoni game including all five dimensions were 4.14.

Item	Dimension	The Effectiveness of The Kotak Harmoni Game	N	Mean
1.	Understanding on interracial mutual respect and tolerance topic	The simulation activity helps me to experience real-life societal situations.	86	4.30
2.		I can distinguish appropriate and inappropriate responses in conflict situations.	86	4.10
3.		This game helps me understand the concept of unity more clearly.	86	4.00
4.		I can understand better on racial conflict after playing this game.	86	4.00
Overall			86	4.10
5.	Learning experience	I feel more actively involved during the activity.	86	4.30
6.		This game is more interesting than learning theory alone.	86	4.00

7.		This game is fun and not boring.	86	3.90
8.		I feel comfortable participating in group activities.	86	3.90
Overall			86	4.03
9.	Understanding of	This game fosters tolerance within me.	86	4.30
10.	Skills and Moral	This game helps me think before giving a response.	86	4.20
11.	Values	I learn how to resolve conflicts in a respectful manner.	86	4.20
12.		This game improves my communication skills.	86	4.00
13.		I have a better understanding of the importance of empathy towards others.	86	4.00
Overall			86	4.14
14.	Design &	The game instructions are easy to understand.	86	4.40
15.	Implementation	The game design is attractive and visually appealing.	86	4.30
16.		The content of the situation cards is relevant to Malaysian society.	86	4.30
17.		The duration of the game is appropriate.	86	4.20
Overall			86	4.30
18.	Overall effectiveness	I am interested in participating in similar activities in the future.	86	4.20
19.		I would recommend this game to other friends.	86	4.10
20.		This game is effective as a learning tool.	86	4.00
Overall			86	4.10
Overall Mean			86	4.14

Table 1.2 The effectiveness of The Kotak Harmoni Game. Mean score indicator: Weak=1.00-1.99, Low=2.00-2.99, Moderate=3.00-3.99 and High=4.00- 5.00.

c) Improvements for The Kotak Harmoni Game

Table 1.3 shows that 23 students suggested for '*no need improvement.*' It was followed by 14 students suggested '*make the dialogue longer.*' Other than that, 12 students suggested '*Use a random draw system instead of lecturer distribution to make it more engaging.*' Lastly, 8 students suggested for '*change shapes to more attractive designs like hearts or stars.*'

Item	Improvements Needed for The Kotak Harmoni Game	N
1.	No need improvement	23
2.	Make the dialogue longer.	14
3.	Use a random draw system instead of lecturer distribution to make it more engaging.	12
4.	Change shapes to more attractive designs like hearts or stars.	8

Table 1.33: Improvements needed for The Kotak Harmoni Game

d) Discussion

The findings indicate that the Kotak Harmoni game gave a positive impact on students' understanding towards interracial mutual respect and tolerance topic. The game enables students to real life situations, hence, distinguish appropriate and inappropriate responses in conflict situations. Students also have high comprehension on the concept of unity racial conflict after plating the game.

In terms of learning experience, students perceived high involvement during playing the game. Most of them agree that they enjoy the game, rather than learning theory alone. Furthermore, they agree that the game was fun and never boring. They also feel comfortable participating in group activities.

For understanding skills and moral values, the findings showed that *Kotak Harmoni* help them to foster tolerance, respect and empathy to other different race, religion and culture. They understand that thinking wisely is important prior to giving response to any conflict. In consequence, most of them agreed that they improved a lot on resolving conflicts skill, as well as communication skills after playing it.

Moreover, students agreed that game design is visually attractive. The implementation is also easy to understand and relevant to Malaysian contexts, specifically the current issues related to racism. The duration of the game is also suitable to be played at the end of the class or lesson.

Other than that, most students suggest that *Kotak Harmoni* is an effective educational tool that not only help them in understanding the topic of interracial mutual respect and tolerance but also encourages positive attitudes among students. The high level of effectiveness indicates this game has strong potential for future use in similar learning contexts.

Finally, most students were satisfied with the overall implementation of the *Kotak Harmoni* game, believed that no major improvements were necessary. However, several suggestions were provided for a better learning outcome. Some students recommended extending the dialogue length, hence, doing a longer role-play. Others suggested using a random draw system such as using dice instead of lecturer distribution to increase excitement. In addition, there were also suggestions to improve the design of the card by using more attractive shapes such as heart or star instead of rectangle. These findings show that while the game was positively accepted, minor enhancements could further strengthen its effectiveness as a learning tool.

5. Conclusion and future research

Based on the findings, it can be concluded that *Kotak Harmoni* is an effective tool in promoting students' understanding of interracial mutual respect and tolerance topic in Malaysian Studies course. The game can motivate students for better engagement and participation. Hence, developing communication skills, empathy, and conflict resolution skills through role-play. Students also perceived the game as enjoyable, relevant, and easy to implement in classroom learning. *Kotak Harmoni* shows strong potential to be used as a teaching aid for unity-related topics in Malaysian.

This study also recommends involving a larger sample size from different educational institutions to increase the generalisability of the findings. Future research may also involve the long-term impact of *Kotak Harmoni* on students' attitudes and behaviour towards racial harmony. In addition, future studies can improve the gameplay elements, such as incorporating digital features, longer dialogue, or random selection methods to enhance students' learning experience.

Acknowledgment

We love to sincerely show our appreciation to Miss Farahdia Aleya Binti Sahrin and
International Innovation Festival – INNOFEST'26
Politeknik Sandakan Sabah

Miss Asiana Binti Majapit for their contribution in producing a useful game to be used by future students of Kolej Komuniti Sandakan, as well as other institutions who offer course related to community and unity. Furthermore, special appreciation for all Sijil Pengembaraan Pelancongan and Sijil Teknologi Elektrik students of Kolej Komuniti Sandakan for their warm participation and cooperation in this study. Their valuable feedback contributed to meaningful improvement of the game.

References

Aydogan, A. (2021). Party systems and ideological cleavages in the Middle East and North Africa. *Party Politics*, 27(4), 814–826.

Azmin, A. F., Fadilah, N. S. H., Isnin, A. A., & Rajandran, B. S. (2024). Enhancing a new method of teaching pendidikan moral subject to secondary school students. *Quantum Journal of Social Sciences and Humanities*, 5(6), 409–416.

Brown, J. S. (2025). Exploring reciprocal determinism, behavior capability, observational learning, and self-efficacy on protective behaviors for African American millennial women with cardiovascular disease and depression (Doctoral dissertation, Walden University).

Department of Statistics Malaysia. (n.d.). *Demographic statistics, first quarter 2025*. Retrieved from https://www.dosm.gov.my/site/downloadrelease?id=demographic-statistics-first-quarter%202025&lang=English&admin_view=

de la Fuente, J., Kauffman, D. F., & Boruchovitch, E. (2023). Past, present and future contributions from the social cognitive theory (Albert Bandura). *Frontiers in Psychology*, 14, 1258249.

Graf, E., Stempfer, L., Muis, K. R., & Goetz, T. (2024). Classroom emotions in civic education: A multilevel approach to antecedents and effects. *Learning and Instruction*, 90, 101869.

Kusnandar, E., & Muslimah, E. (2025). Implementing active learning strategies to reduce learning fatigue and enhance student engagement in Akidah Akhlak instruction at MAN Purwakarta. *Indonesian Journal of Educational Research*, 1(4), 103–111.

Lyu, S., Kay, R. C. S., & Olmedo Panal, E. (2026). Constructing ethnic consciousness: The role of cultural heritage in Malaysia. *Ethnic and Racial Studies*, 49(1), 54–76.

Mohd Nor, S. N. (2021). Constructing ethnic and national identities in talk on Malaysian issues. *Discourse & Society*, 32(1), 3–24.

Ngadiman, D. W. T., Yacoob, S. E., & Wahid, H. (2019). Tahap Harga Diri Kumpulan Berpendapatan Rendah yang Berhutang dan Peranan Organisasi dalam Sektor Perladangan. Melayu: *Jurnal Antarabangsa Dunia Melayu*, 12(2), 238-254.

Rumjaun, A., & Narod, F. (2025). Social learning theory—Albert Bandura. In *Science education in theory and practice: An introductory guide to learning theory* (pp. 65–82). Cham: Springer Nature Switzerland.

The Star. (2026, January 2). *Unity crucial for social cohesion*. <https://www.thestar.com.my/news/nation/2026/01/02/unity-crucial-for-social-cohesion>.

Ting, H., & Zainol Abidin, N. (2023). *Ethnic identity and social belonging among Malaysian youth*. IR@UNIMAS. <https://ir.unimas.my/id/eprint/47194>

Wan Husin, W. N., Samsudin, N. I., Mujani, W. K., & Zainurin, S. J. (2025). Consociational politics as a mediating effect in strengthening ethnic unity among youth in Malaysian public universities. *Ethnicities*, 25(3), 399–426.

Zaaba, Z., Jalil, S. Z., Gunggut, H., & Thomas, B. (2023). Malaysia identity for or against the multiracial and multi-ethnic society. *Journal of Administrative Science*, 20(2), 59–75.

THE EFFECTIVENESS OF THE *JEJAK NATURA* MODULE IN ENHANCING STUDENTS' INTEREST AND UNDERSTANDING OF FLORA AND FAUNA THROUGH INQUIRY-BASED LEARNING

Marwa binti Abd Malek¹, Siti Nurasyura binti Hasnan²

¹Unit Pengembaraan Pelancongan, Kolej Komuniti Sandakan

² Unit Pengembaraan Pelancongan, Kolej Komuniti Sandakan

¹Corresponding author's email: marwa@kksk.edu.my, marwaabdmalek@gmailcom

ABSTRACT

Flora and fauna observation is a popular activity in the Malaysian tourism industry, attracting people all over the world to visit. This activity was also taught among recreational tourism students in higher institutions, including Politeknik and Kolej Komuniti. Yet, many young adults were less interested in this activity, as they prefer video games. Hence, this study was conducted to investigate the effectiveness of the *Jejak Natura* module in enhancing students' interest and understanding of flora and fauna. It used a quantitative and qualitative approach through an online questionnaire. Respondents were all recreational tourism students of Kolej Komuniti Sandakan. Findings showed that the *Jejak Natura* module was effective in enhancing students' interest and understanding of flora and fauna through inquiry-based learning. The results of the students' responses based on the questionnaire via Google Forms were mostly positive in response to the activities and learning approach that were used in the module. Therefore, the findings indicated that students became more interested in exploring environmental topics along with being able to understand concepts related to flora and fauna. Furthermore, the inquiry-based learning encouraged students' active participation, critical thinking, and curiosity in the learning process. The module proved to be an effective interactive learning tool that supports meaningful environmental learning experiences.

Keywords: observation, flora, fauna

1. Introduction

Malaysia's tropical rainforests, renowned for their rich biodiversity (Yap, 2024) which includes the flora and fauna species that vary. This attracts tourists from all over the world to come and explore. Hence, biodiversity education among youngsters are important in improving quality of life, recognizing environmental values and clarifying concepts regarding the environment (Morar & Peterlicean, 2012). Yet, many young adults are less interested in flora and fauna observation, as they prefer playing video games and engaging in social media. On top of that, young adults were found to be generally inactive because they consider physical and outdoor activities are often boring, yet according to a study by Kara, Gürkan, Karaca, and Uğurlu (2023), physical activities is an important support for human health and other life requirements. Furthermore, many recreational tourism students often feel flora and fauna observation as sightseeing experiences, rather than fully participating and learning it. This issue

may reduce young adults' appreciation towards nature and its importance on preserving it.

To address this problem, it is important to come out with a more active learning approach. *Jejak Natura* module was developed to instill interests and understanding towards flora and fauna observation activity through Inquiry Based Learning approach. Through this module, participants will do questioning, planning, collecting, analyzing, concluding and sharing, hence, developing a high comprehension towards various flora and fauna species.

This study may benefit tourism students, school students, tourists and nature lovers. They can use *Jejak Natura* as an activity book while visiting nature forests, parks and zoo. The forms provided in the module works as a guidance on what characteristics need to be focused while observing flora and fauna. Thus, increasing participants' motivation and nature awareness.

The objectives of this study are; 1) to examine the effectiveness of the *Jejak Natura* Module in increasing students' interest in learning flora and fauna observation topics and; 2) to find out improvements needed for *Jejak Natura* module. Based on these objectives, this study seeks to answer the questions; 1) what is the level of effectiveness of the *Jejak Natura* module in increasing students' interest in learning flora and fauna observation topics? and; 2) what improvements are needed for *Jejak Natura* module?

This paper includes several sections, including introduction, literature review and methodology. It also includes discussion of analysis and findings, as well as conclusions and future research.

2. Literature review

Flora refers to plant, found in particular area such as rainforest, parks and gardens which include trees, shrubs, herbs and other vegetation. It plays an important role in maintaining ecological balance by providing oxygen, food and habitat for animals (Verma, 2017). A study by Al-Qadami et al. (2024) stated that the diversity of flora and fauna can guide local authorities in adopting conservation strategies for the purpose of socio-economic benefits. Learning about flora helps participants understand plants' structure and functions, as well as the importance of it for human life (Laffitte et al., 2022). However, according to the research (Noe & Stolte, 2023) we can find that urban surroundings limit young adults' exposure to flora, hence, reducing their interest and understanding.

Fauna refers to all animal life found in ecosystems which includes mammals, reptiles, birds, insects and other living creatures. Fauna also plays an important role, supporting food chains, whereas its populations support biodiversity (Correia & Lopes, 2023). Not only that, a study by O'roqova, Latipov, and Normuratova (2024) stated that fauna is an integral part of biological resources and play a crucial role in the exchange of materials and energy in nature. Learning about animals' classification, behavior and habitat are important in providing awareness to conserve it for future generations. Nevertheless, nowadays quick developments inhibit sensitivity towards conserving animals and their habitat. The loss and fragmentation of natural habitats are driven by human activities such as urbanization, agriculture, deforestation, and

infrastructure development (Gupta et al., 2023). This makes young adults become less interested in knowing and caring about animal life.

Flora and fauna observation is one the education methods that actually guide learners to study in outdoor environments, and help learners to understand the natural exploration, experience, and awareness (Fang, Hassan, & LePage, 2022). Otto and Pensini (2017) found that students experienced in outdoor activities seemed to have a strong emphatic relationship to nature, expressing higher moral standards and behavior. Activity includes going to places such as rainforests, parks and zoos, identifying different species of plants and animals, observing their characteristics and understanding their roles in the ecosystem. It is considered that outdoor education is carried out in natural surroundings, and meeting individuals' physical, spiritual, and physiological needs are effective factors in the learning and teaching process (Yildiz, 2021). However, without proper guidance and methods, students may find it difficult to observe, making them late become uninterested and left behind. Therefore, a proper designed module can lead to effective observation, as well as activity objectives successfully achieved.

The *Jejak Natura* module was developed from Inquiry-Based Learning Theory (IBL Theory) that emphasizes students to be actively involved in learning about flora and fauna surrounding them. According to Moundridou, Matzakos, and Doukakis (2024) IBL is a constructivist paradigm that emphasizes the active engagement of students in the creation of knowledge, thus promoting a deeper understanding of the subject matter. Also, IBL is an effective pedagogical approach that immerses students in scientific processes (Chen & Chen, 2025). In order for the module to achieve these goals, the module requires them to do 6 steps, namely questioning, planning, collecting, analysing, concluding and sharing. Prior flora and fauna observation, students were given a *Jejak Natura* module, allowing them to question what they will be focusing on during fieldwork. Accordingly, they will plan which location is suitable for flora and fauna observation. During fieldwork, they will collect information by fulfilling forms in the *Jejak Natura* module accordingly as stated. Simultaneously. Students analyse species they found in the location. They conclude on all the species based on its identification, as well as its function in habitat. Lastly, all information recorded will be shared to other students including their respected lecturers for better understanding. In learning flora and fauna topics, IBL Theory helps initiate students' curiosity as they were informed clearly on what to be fulfilled at the end of the activity, prior to going to fieldwork. Therefore, this theory is suitable to be adopted for learning about flora and fauna observation activity.

Realizing the importance of flora and fauna observation activity, however many previous studies focused on classroom or theory learning, whereas limited studies discussed experiential learning. Moreover, very few studies engage IBL Theory and flora fauna observation among young adults. There were also limited studies on structured modules used in learning flora and fauna topics. On the other hand, digitalization and urbanization trends lead to less natural engagement among young adults. Many of them participated less in nature related activities including flora and fauna observation. With less engagement towards nature, conservation of endangered species becomes something to be worried about. Therefore, this study is important in providing the best module as a guide tool in instilling motivation among young adults to participate in flora and fauna observation activity. Continuous content improvement

of this module is important to fit this book with students' needs, to achieve learning objectives.

3. Methodology

This is a quantitative and quantitative study. It used an online questionnaire, which was distributed via *Google Form*. Items in the questionnaire were adapted based on the contents of the *Jejak Natura* module. The samples were 41 Sijil Pegembaraan Pelancongan students from Kolej Komuniti Sandakan, including semester 1, 2 and 3. This study applied convenience sampling, as it can allow the researcher to access readily available participants who had experience in using *Jejak Natura* module during studying Recreational Tourism course. Then, descriptive analysis was conducted to examine the effectiveness of the *Jejak Natura* module in increasing students' interest in learning flora and fauna observation topics. It also identifies improvements needed for better comprehension on flora and fauna observation topics. Analysis was then being done on descriptive analysis to assess the level of effectiveness of the *Jejak Natura* module, which is the mean score. The mean was then interpreted based on the scale used by Ngadiman et al. (2019), namely: 1.00–1.99 (Weak), 2.00–2.99 (Low), 3.00–3.99 (Moderate), and 4.00–5.00 (High).

For a qualitative approach, this study used open-ended questions to collect data from participants. The responses obtained were analysed using thematic analysis to identify recurring patterns. This approach allows the researcher to gain in-depth insights into participants' perspectives on improvements that can be made to the *Jejak Natura* module in terms of content, design, and gameplay experience.

4. Discussion of analysis and findings

a) Respondent Background

As shown in Table 1.1, the respondents consist of students aged between 18-25 years old, representing 100% (N=41) of the total respondents. In terms of gender, the majority of the respondents are female, representing 78.05% (N=32), while male respondents represent 21.95% (N=8). For the programme category, all respondents are from the Sijil Pengembaraan Pelancongan programme, representing 100% (N=41), while there are no respondents from the Sijil Teknologi Elektrik programme.

Demographic Profile		Frequency (N)	Percentage (%)
Age	18-25 years old	41	100.00
	Total	41	100.00
Gender	Male	8	21.95
	Female	32	78.05
	Total	41	100.00

Programme	Sijil Pengembaraan	41	100.00
	Pelancongan		
	Sijil Teknologi Elektrik	0	0
Total		41	100.00

Table1.1: Respondents' background

b) Effectiveness of The Jejak Natura Module

Table 1.2 shows that the highest mean for physical and environmental barriers is *'the bird observation form is easy to use and complete'* and *'the appendix on leaf margins helps my observation activities'* which were 4.73 respectively. It was followed by *'the introduction of the book is clear and easy to understand,' 'the objectives of the activities are well explained,' 'the insect observation form is easy to use and complete,' 'the flora observation form is easy to use and complete,' 'the appendix on forest layers and leaf guides helps in understanding habitats,' 'the QR code appendix for bird and insect species are easy to access and useful,' 'the appendix on leaf shapes and arrangements helps my observation activities,' 'this book improves my observation skills,' 'the activities in this book increase my interest in nature,' 'the language and instructions are easy for students to understand'* as well as *'the appendix on leaf margins helps my observation activities'* with mean of 4.64. Next, *'the safety guidelines provide sufficient guidance,' 'the layout and format of the book are user-friendly' and 'I would recommend this book to other friends/classes'* which showed the mean of 4.55. *'This book helps me reflect and plan follow-up actions'* showed the mean of 4.45. It was then followed by *'the equipment list helps me prepare for the activities,' and 'overall, I am satisfied with the Jejak Natura'* which both showed the mean of 4.36. While the lowest score was *'the rules and ethics of usage are concise and useful'* with a mean of 4.18. Overall, the mean for the effectiveness of the Jejak Natura module was 4.66.

Item	The Effectiveness of The Jejak Natura Module	N	Mean
1.	The bird observation form is easy to use and complete.	41	4.73
2.	The appendix on leaf margins helps my observation activities.	41	4.73
3.	The language and instructions are easy for students to understand.	41	4.64
4.	The introduction of the book is clear and easy to understand.	41	4.64
5.	The objectives of the activities are well explained.	41	4.64
6.	The insect observation form is easy to use and complete.	41	4.64
7.	The flora observation form is easy to use and complete.	41	4.64
8.	The appendix on forest layers and leaf guides helps in understanding habitats.	41	4.64
9.	The appendix on leaf shapes and arrangements helps my observation activities.	41	4.64
10.	This book improves my observation skills.	41	4.64
11.	The activities in this book increase my interest in nature.	41	4.64
12.	The safety guidelines provide sufficient guidance.	41	4.55
13.	The layout and format of the book are user-friendly.	41	4.55
14.	I would recommend this book to other friends/classes.	41	4.55
15.	This book helps me reflect and plan follow-up actions.	41	4.45
16.	The equipment list helps me prepare for the activities.	41	4.36
17.	Overall, I am satisfied with the Jejak Natura.	41	4.36
18.	The rules and ethics of usage are concise and useful.	41	4.18

19.	The appendix on estimated size and beak types helps in bird identification.	41	4.18
Overall Mean		41	4.64

Table 1.2 : *The effectiveness of The Jejak Natura Module*

Mean score indicator: Weak=1.00–1.99, Low=2.00–2.99, Moderate=3.00–3.99 and High=4.00–5.00.

c) Improvements Needed for Jejak Natura Module

Table 1.3 shows that 20 students suggested '*no suggestions for improvement.*' It was followed by 8 students suggesting '*the writing space for animal names and species should be enlarged to make it easier for children to write.*' Other than that, 4 students suggested '*guidance should be provided for all QR code sections to improve user understanding,*' '*the QR code feature is useful and beneficial for users,*' and '*the book is very good as it provides useful animal references.*

Item	Improvements Needed for Jejak Natura Module	N
1.	No suggestions for improvement.	20
2.	The writing space for animal names and species should be enlarged to make it easier for children to write.	8
3.	Guidance should be provided for all QR code sections to improve user understanding.	4
4.	The QR code feature is useful and beneficial for users.	4
5.	The book is very good as it provides useful animal references.	4

Table 1.3: Improvements needed for Jejak Natura Module

d) Discussion of Analysis and Findings

The analysis of the questionnaire data showed that the *Jejak Natura* module achieved a high level of effectiveness with an overall mean score of 4.64. This shows that students positively accepted the module as it is beneficial for them to learn about flora and fauna through inquiry-based learning activities. The highest mean score of 4.73 was recorded for the items stating that '*the bird observation form is easy to use and complete*' and that '*the appendix on leaf margins helps my observation activities*'. This demonstrates that students appreciated the practical tools and materials provided in the module.

Several items also obtained mean scores of 4.64, including items stating that '*the language and instructions are easy for students to understand,*' '*the introduction of the book is clear and easy to understand,*' '*the objectives of the activities are well explained,*' '*the insect observation form is easy to use and complete,*' '*the flora observation form is easy to use and complete,*' '*the appendix on forest layers and leaf guides helps in understanding habitats,*' '*the appendix on leaf shapes and arrangements helps my observation activities,*' '*this book improves my observation skills,*' as well as '*the activities in this book increase my interest in nature,*'. Students agreed that the module improved their observation skills and understanding of habitats through the appendices in the module related to forest layers and leaf guides. This

shows that the inquiry-based learning activities encouraged students to actively explore, observe, and analyse.

Although all items recorded high mean scores, the lowest mean score of 4.18 was obtained for items stating that *'the rules and ethics of usage are concise and useful,'* and *'the appendix on estimated size and beak types helps in bird identification,'*. Despite being lower compared to other items, the score still falls within the high category, showing that students generally found these components useful but future improvements are still needed for increased effectiveness.

Lastly, findings indicate that most students suggested that the current design and content are effective for its intended use. However, some students suggested for writing space should be enlarged. In addition, some students suggested for guidance on how to use QR code. Meanwhile, students also acknowledged that the QR code feature and references is useful in providing information needed throughout activity.

5. Conclusion and future research

As the world of education continues to grow with a diversity of learning theories, it is important for educators to implement student-centred learning methods to improve students' learning experiences. However, conventional learning approaches are unable to gain active participation and deep understanding of topics related to flora and fauna. To overcome this problem, the *Jejak Natura* module is implemented and found to be highly effective. This study was conducted to evaluate the effectiveness of the module in enhancing students' interest and understanding of flora and fauna through the application of Inquiry-Based Learning (IBL) theory. Based on the findings, the module achieved an overall mean score of 4.64 obtained from the questionnaire analysis. It demonstrates that students positively accepted the module because it supports their learning experience related to flora and fauna.

For a more reliable result of the study findings, the research needs a larger and more diverse sample of respondents from different programmes, institutions, or age groups. Furthermore, future research may use a mixed-method approach by combining quantitative and qualitative methods such as interviews or observations to obtain deeper insights into students' experiences when using the module.

Acknowledgment

We love to sincerely show our appreciation to Miss Siti Hijjarisha binti Hairman and Miss Amelia binti Abdilah for their contribution in producing as a useful module to be used by future students of Kolej Komuniti Sandakan, as well as other institutions involving in flora and fauna observation. Furthermore, special appreciation for all Sijil Pengembaraan Pelancongan students of Kolej Komuniti Sandakan for their warm participation and cooperation in this study. Their valuable feedback contributed to meaningful improvement of the module.

References

- Al-Qadami, E., Mohammad Razi, M. A., Ideris, M. F. M., Mahamud, M., Shah, S. M. H., Pu, J. H., ... Figueroa, A. G. (2024). Comprehensive biodiversity assessment of flora and fauna along the Kedah coastline: Implications for conservation and sustainable management. *Results in Engineering*, 24, Article 103120.
- Chen, F., & Chen, G. (2025). Learning analytics in inquiry-based learning: a systematic review. *Educational Technology Research and Development*, 73(4), 2131-2161.
- Correia, A. M., & Lopes, L. F. (2023). Revisiting Biodiversity and Ecosystem Functioning through the Lens of Complex Adaptive Systems. *Diversity*, 15(8), Article 895.
- Fang, W. T., Hassan A., & LePage, B. A. (2022). Outdoor Education. In *The Living Environmental Education: Sound science towards a cleaner, safer, and healthier future* (pp. 229-260). Singapore: Springer Nature Singapore.
- Gupta, S., Kumaresan, P. R., Saxena, A., Mishra, M. R., Upadhyay, L., T. A, A. A. S., ... Magrey, A. H. (2023). Wildlife Conservation and Management: Challenges and Strategies. *Uttar Pradesh Journal of Zoology*, 44(24), 280-286.
- Kara, F. M., Gürkan, R. K., Karaca, G., & Uğurlu, A. (2023). The Relationship Between Perception of Leisure Boredom, Motivation for Participation in Physical Activity and Presenteeism. *CBÜ Beden Eğitimi ve Spor Bilimleri Dergisi*, 18(2), 535-550.
- Laffitte, B., Seyler, B. C., & Tang, Y. (2022). Environmental education to engage urban youth: anecdotes from Southwest China. *Journal of Biological Education*, 58(4), 997-1009.
- Morar, F., & Peterlicean, A. (2012). The Role and Importance of Educating Youth Regarding Biodiversity Conversation in Protected Natural Areas. *Procedia Economics and Finance*, 3, 1117-1121.
- Moundridou, M., Matzakos, N., & Doukakis, S. (2024). Generative AI tools as educators' assistants: Designing and implementing Inquiry-based lesson plans. *Computers and Education Artificial Intelligence*, 7, Article 100277.
- Ngadiman, D. W. T., Yacoob, S. E., & Wahid, H. (2019). Tahap Harga Diri Kumpulan Berpendapatan Rendah yang Berhutang dan Peranan Organisasi dalam Sektor Perladangan. Melayu: *Jurnal Antarabangsa Dunia Melayu*, 12(2), 238-254.
- Noe, E. E., & Stolte, O. (2023). Dwelling in the city: A qualitative exploration of the human-nature relationship in three types of urban greenspace. *Landscape and Urban Planning*, 230, Article 104633.

- O'roqova, N., Latipov, H., & Normuratova, N. (2024). The role of flora and fauna in expressing the artistic view of the universe. *E3S Web of Conferences*, 587, 04013.
- Otto, S., & Pensini, P. (2017). Nature-based Environmental Education of children: Environmental Knowledge and Connectedness to nature, together, Are Related to Ecological Behaviour. *Global Environmental Change*, 47, 88-94.
- Verma, A. K. (2017). [Review of *Necessity of Ecological Balance for Widespread Biodiversity*]. *Indian Journal of Biology*, 4(2), 158-160.
- Yap, C. K. (2024). Biodiversity Assessment of Flora and Fauna in Bukit Panchor Forest Reserve: Conversation Implications Based on IUCN Status. *Ann Envi Sci*, 1(1), 1-12.
- Yildiz, K. (2021). Experiential Learning from the Perspective of Outdoor Education Leaders. *Journal of Hospitality, Leisure, Sport & Tourism Education*, 30, 100343.

MATCHABERRY: THE TALE OF ZUZU - A GEN-AI SURREALIST DISRUPTOR FOR TRANSFORMATIVE HEALTH LITERACY AND COGNITIVE ENGAGEMENT AMONG ADOLESCENTS

Rabiatul Adawiyah Jamaluddin¹, Siti Nur Zulaikha Ahmad Budiman², Anis Kauthar
Ahmad Taufiq³ and Nur Ardina Balqis Mohd Azif Syazwan⁴

¹²³Faculty of Management and Information Technology, Universiti Sultan Azlan Shah,
Perak

⁴Faculty of Law, Universiti Multimedia, Melaka

¹Corresponding author's email: rabiatul@usas.edu.my

ABSTRACT:

This concept paper presents the development of a digital animation prototype, Matchaberry: The Tale of Zuzu, as a Teaching and Learning (TnL) innovation to address adolescent obesity in the era of the Digital Attention Economy. The rise of digital foodscapes and viral culture demands a new pedagogical approach capable of penetrating the information density on social media platforms. This study comprehensively adapts the ADDIE Instructional Design Model to develop a transformative pedagogical instrument that integrates digital storytelling with a creative production pipeline powered by Generative Artificial Intelligence (Gen-AI). This innovation focuses on the application of surrealism as a visual disruption mechanism. The main finding of this study is the formulation of the Matchaberry Three-Phase Cognitive Disruption Model (MCD Model), which maps a tactical strategy to capture attention, trigger cognitive dilemmas, and systematically stimulate learning reflection. In conclusion, this innovation possesses high potential to be adapted as a digital Teaching Aid in community programs (SULAM), while paving the way for intellectual property protection (MyIPO) as a new benchmark for health pedagogy practices among the digital generation.

Keywords: Attention Economy, Cognitive Disruption, Digital Storytelling, Generative Artificial Intelligence, Health Literacy, Teaching Aid, Teaching and Learning Innovation, Transformative Pedagogy, Visual Disruption.

2. Introduction

1.1 Background of the Study

In the contemporary era, the digital ecosystem shifted from a mere medium of information sharing to a complex network dominated by the Digital Attention Economy. From the perspective of attention economy theory, human attention is an extremely limited and valuable commodity (Goldhaber, 1997; Wu, 2016). Giant social media platforms such as TikTok, Instagram, and YouTube utilize advanced algorithms to maximize users' screen time. This digital social validation culture has turned adolescents not just into consumers, but into content amplifiers within the ecosystem (Bhargava & Velasquez, 2021).

International Innovation Festival – INNOFEST'26
Politeknik Sandakan Sabah

This phenomenon directly alters the landscape of adolescent food culture. Digital foodscapes, driven by trends such as food aesthetics and food porn, currently dominate virtual social spaces. Viral food content is often visually engineered to trigger high emotional responses. Continuous exposure to commercial visual representations of high-calorie foods contributes to the normalization of unhealthy eating habits.

Consequently, traditional one-way, didactic health education and instructional models are no longer effective in competing within this aggressive attention market. To capture adolescents' attention, TnL interventions must adopt dynamic digital pedagogical approaches with strong aesthetic impacts.

Therefore, this study introduces Matchaberry: The Tale of Zuzu innovation project, a digital animation prototype that integrates surrealism as a pedagogical device for adolescent obesity prevention education. The surrealism approach is applied based on its ability to create visual disruption—a visual pedagogy technique highly effective at breaking perceptual habits. Through visual metaphors and digital storytelling, this prototype acts as an innovative Teaching Aid aimed at cutting through the digital noise of social media to trigger students' cognitive reflection on their dietary habits.

1.2 Problem Statement

The rate of obesity among children and adolescents in Malaysia continues to record a critical upward trend. The National Health and Morbidity Survey (NHMS) confirms the prevalence of this issue, reporting that 1 in 3 adolescents (30.5%) aged 13 to 17 are overweight or obese (Institute for Public Health, 2022), while 33% of children and adolescents under 18 are similarly affected (Institute for Public Health, 2024).

To address this issue, various health education campaigns have been implemented. However, educators face increasingly complex pedagogical challenges as conventional approaches (such as static brochures and factual lectures) often lead to information fatigue. When health instruction is delivered in a bland format, it is easily marginalized by attention economy algorithms that consistently prioritize hyper-realistic visuals from commercial influencers (Bhargava & Velasquez, 2021).

There is a significant gap in local TnL innovations utilizing avant-garde creative arts elements like surrealism in public health communication. Existing instructional materials rarely challenge the visual cognitive levels of digital-era adolescents who are accustomed to high-level graphic stimulation.

Therefore, the Matchaberry innovation project was developed to bridge this pedagogical gap. By exploiting the power of visual disruption through surrealist styling and digital storytelling structures, this concept paper presents a new instructional intervention framework designed to translate obesity prevention messages into a visual language that stimulates active learning.

1.3 Research Questions

- 1.3.1 How can the design of the Matchaberry: The Tale of Zuzu animation prototype, based on the integration of Gen-AI and surrealism, be developed as a digital pedagogy innovation for adolescent obesity health education?
- 1.3.2 How does the digital storytelling approach create visual disruption to attract attention and enhance adolescent cognitive engagement in the digital attention economy era?
- 1.3.3 How does the integration of adolescent digital culture elements into the animation narrative effectively support the achievement of transformative health literacy learning outcomes?

1.4 Research Objectives

- 1.4.1 To develop the Matchaberry: The Tale of Zuzu digital animation prototype as a Gen-AI-powered transformative pedagogical instrument (digital Teaching Aid) for adolescent obesity health education.
- 1.4.2 To apply digital storytelling elements and visual disruption techniques within the animation's instructional structure to increase attention retention and stimulate cognitive processing.
- 1.4.3 To design a narrative guided by the adolescent social media ecosystem to produce a delivery of instructional objectives that is relevant and easily accessible across digital platforms.

1.5 Scope of the Study

This concept paper focuses on the design and development phases of a creative media instructional innovation, encompassing conceptual design, narrative development, Gen-AI technological support, and the application of surrealist visual aesthetics. This prototype is specifically designed to address the normalization of viral eating habits through digital storytelling pedagogy. This study does not involve clinical testing or Body Mass Index (BMI) measurements. The research parameters are limited to the development of the TnL innovation framework, the novelty of the technology-driven design (Gen-AI), and its potential as an alternative Teaching Aid instrument within the attention economy market.

2.0 Literature Review

2.1 Digital Attention Economy and Health Instruction Challenges

Adolescents operate in an attention economy, where attention is considered a scarce commodity (Goldhaber, 1997; Wu, 2016). Social media platforms maximize watch time, turning digital content into fierce competition (Bhargava & Velasquez, 2021). Within this ecosystem, digital foodscapes shape lifestyle identities. Traditional health instruction practices fail to compete because their static nature cannot penetrate digital information density, resulting in learning objectives failing to be processed by audiences.

2.2 Digital Storytelling as a Transformative Pedagogy

Within the TnL framework, digital storytelling serves as a bridge to transform abstract information into meaningful narrative experiences (Lambert, 2013). According to Robin (2008, 2016), it transcends factual delivery by integrating multimedia to build emotional connections. It is not merely a display medium, but a form of active pedagogy that allows adolescents to organize information narratively, making it a powerful facilitation tool in hybrid learning environments.

2.3 Surrealism as a Pedagogical Instrument (Visual Disruptor)

The Matchaberry innovation exploits surrealism as a pedagogical device to trigger visual disruption. As a visual instruction strategy, it disrupts students' perceptual expectations through visual metaphors. This technique aligns with the concept of affective engagement, where deliberately engineered visual disturbances trigger deep cognitive reflection on the realities of often-normalized eating habits (Breton, 1924/1972).

2.4 Cognitive Engagement in Multimedia Instructional Design

Based on the Cognitive Theory of Multimedia Learning (Mayer, 2020), the effectiveness of Matchaberry's instructional design is evaluated through its ability to trigger active cognitive processing. The prototype is designed to optimize the selecting, organizing, and integrating of information (Sweller, 2020). Through affective design principles (Mayer & Estrella, 2014), this Teaching Aid ensures lesson content is processed effectively via visual manipulations that minimize extraneous cognitive load.

2.5 Transformative Health Literacy as a Learning Outcome

The learning outcome in this study refers to critical health literacy (Nutbeam, 2008, 2022). Through the lens of Transformative Learning (Mezirow, 2000, 2018), Matchaberry targets a paradigm shift in students from passive information receivers to critical thinkers. This transformation occurs when the narrative challenges adolescents' frames of reference, subsequently guiding changes in their practices.

2.6 Synthesis of the Pedagogical Conceptual Framework

The Matchaberry innovation framework is synthesized from the integration of attention economy theories and multimedia instructional design:

- **Input:** The students' attention-driven digital ecosystem.
- **TnL Strategy:** The use of Gen-AI to generate a surrealist visual disruptor via digital storytelling.
- **Learning Process:** The activation of active cognitive processing (Mayer) through visual disruption.
- **Learning Outcome:** The transformation of critical health literacy (Nutbeam/Mezirow).

3.0 Methodology of TnL innovation development

This study utilizes an instructional design approach comprehensively adapted from the ADDIE Model: Analysis, Design, Development, Implementation, and Evaluation. This model was selected as the highest standard framework in educational technology design and digital Teaching Aid production.

The process is driven by the researcher's pedagogical concept direction, while technical development was executed collaboratively with university students under the researcher's supervision. This allows the innovation to be developed systematically while strengthening the students' practical skills in animation pipelines.

3.1 Analysis Phase

This pre-production phase examines learning needs by analyzing gaps in the current digital communication landscape. The analysis focuses on adolescent obesity, digital foodscapes, doom scrolling culture, and visual saturation points concerning students' attention spans. Through audience profiling and production feasibility analysis, the weaknesses of existing pedagogical approaches were identified. These findings established the strategic need to translate health messages into a cognitive disruption format based on surrealism.

3.2 Design Phase

Although driven by Gen-AI technology, the design of this Teaching Aid is rooted in multimedia instructional principles and the creative architecture standards of the professional animation industry. This phase began with drafting the story outline and character design. The main character, Zuzu, was specifically designed to represent the digital lifestyle archetype of the students.

Instructional objectives were translated into a storyboard matrix and style frames to establish final visual references. These elements were combined into an animatic to test timing, narrative flow, and the effectiveness of visual transitions from pastel aesthetics to surrealism before actual generation began, ensuring optimal cognitive load management.

3.3 Development Phase

This phase translates the design model into a functional 2.5-minute cinematic prototype. This creative production pipeline balances automated Generative Artificial Intelligence (Gen-AI) tools with manual creative software to form a multi-layered media framework. The development of this TnL instrument was executed using 9 specific digital tools across pre-production, asset generation, and post-production phases:

- **ChatGPT:** Serves as the primary text engine to execute prompt engineering and develop the core narrative script.
- **Grok:** Used to manage advanced visual parameters, generating high-fidelity images for both the pastel aesthetic style and the unsettling surreal horror looks.

- **Microsoft Word:** Acts as the primary pre-production database to plan storyboard matrices, track timecodes, and systematically organize scripts line-by-line.
- **Adobe Photoshop:** Applied for raster compositing, cleaning up AI-generated digital assets, and separating images into clean alpha-channeled layers for keyframe animation.
- **Adobe Illustrator:** Executed to design clean vector assets and build interface overlays that closely mimic real social media layouts.
- **ElevenLabs:** Used to synthesize expressive and realistic artificial voice-over (VO) assets with precise emotional accuracy across the video timeline.
- **Suno AI:** Applied to build custom background music that shifts dynamically from an upbeat pop rhythm to a discordant, suspenseful theme.
- **CapCut:** Serves as the primary multi-track timeline workspace to build keyframe animations, perform motion tracking, and manage narrative pacing.
- **Movavi:** Used to execute the final post-production pass, organizing cinematic montage cuts, and tuning the overall color grading.

3.4 Implementation Phase

Implementation was conducted through a pilot screening of the Matchaberry prototype to an initial target group. This practical test was integrated into an academic environment, involving students from the Media Culture course and students in a community engagement program (Service-Learning Malaysia-University for Society - SULAM). This phase did not test psychological responses clinically; instead, it evaluated the practical usability of the innovation as a teaching facilitation tool in a real-world setting to determine the potential integration of this prototype into community digital literacy campaign syllabi.

3.5 Evaluation Phase

Formative evaluation was conducted through an iterative refinement cycle targeting the prototype's technical quality and instructional effectiveness. Feedback from the pilot screening was used to review technical accuracy starting from the animatic phase to the rough cut, and finally the fine cut. Aspects evaluated included audio clarity (Gen-AI voiceovers), keyframe animation smoothness, visual transition accuracy, and the alignment of health objective delivery. This iterative process ensured the final cut complied with optimal educational multimedia design principles and was ready for publication.

4.0 Innovation findings

The primary finding of this study is the production of the digital Teaching Aid prototype Matchaberry: The Tale of Zuzu, driven by the development of a non-linear pedagogical model named the Matchaberry Three-Phase Cognitive Disruption Model (MCD Model).

The MCD Model is an instructional framework mapping digital storytelling strategy to capture attention, disrupt automatic perception, and enhance learning reflection through three sequential phases:

4.1 Phase 1: Aesthetic Attraction (Psychological Anchor)

Based on attention economy theory (Goldhaber, 1997), this phase utilizes storytelling aesthetics that align with students' social media habits (algorithmic familiarity). It acts as a set induction that builds psychological comfort, allowing students' attention to be "anchored" before the main lesson content is introduced.

4.2 Phase 2: Cognitive Disruption (Disorienting Dilemma)

A phase of radical visual transition into surrealist elements. Utilizing visual disruption approaches and affective design (Mayer, 2020), this phase intentionally triggers a disorienting dilemma. This pedagogical shock shatters cognitive bias and halts infinite scrolling habits, forcing students to actively focus on the ensuing message.

4.3 Phase 3: Reflection and Action (Transformative Learning)

Resolving the cognitive discomfort of Phase 2 by linking viral trends to the effects of obesity. Applying Transformative Learning principles (Mezirow, 2000), this phase serves as a reflective assessment. It forces students to critically analyze information manipulation, building Higher-Order Thinking Skills (HOTS) towards autonomous health literacy.

5.0 Discussion and implications of the TnL innovation

5.1 Potential of the Innovation as a Community Teaching Aid

Findings from the pilot screening proved that Media Culture students fully support adapting this prototype as the primary Teaching Aid in SULAM community programs. As a pedagogical facilitation tool, Matchaberry educates the community on obesity health literacy while simultaneously raising awareness about algorithmic attention economy manipulations. This surrealism approach has proven far more effective at penetrating students' "digital silence" compared to conventional information delivery methods.

5.2 Intellectual Property Protection Proposal for the TnL Innovation

The production of the MCD instructional model and the creative technical pipeline of this TnL innovation forms highly valuable educational intellectual property because it shatters existing visual health pedagogy traditions. This study proposes copyright registration for the visual storytelling assets under the Copyright Act 1987 (Act 332) and patent registration for the MCD instructional framework under the Patents Act 1983 (Act 291) through MyIPO. This protection ensures the authenticity of academic innovation is preserved and opens avenues for strategic collaboration with national health institutions.

6.0 Conclusion

The production of the Matchaberry: The Tale of Zuzu TnL innovation demonstrates that public health pedagogical practices must evolve in tandem with the students' digital environment. Given that the younger generation is besieged by attention economy tactics, conventional didactic teaching approaches can no longer dominate their cognitive space. The development of the Gen-AI-powered MCD visual pedagogy framework offers a radical instructional shift. By utilizing surrealism as a cognitive disruption mechanism, this digital Teaching Aid transcends mere information delivery; it forces critical reflection that results in transformative learning. This innovation sets a new benchmark in 21st- century educational technology pedagogical design.

References

- Bhargava, V. R., & Velasquez, M. (2021). Ethics of the attention economy: The problem of social media addiction. *Business Ethics Quarterly*, 31(3), 321-359.
- Breton, A. (1972). Manifestoes of surrealism (R. Seaver & H. R. Lane, Trans.). *University of Michigan Press*. (Original work published 1924).
- Copyright Act 1987 (Act 332). (1987). *Commissioner of Law Revision*, Malaysia.
- Goldhaber, M. H. (1997). The attention economy and the net. *First Monday*, 2(4).
- Institute for Public Health. (2022). National Health and Morbidity Survey (NHMS) 2022: Adolescent health survey. *Ministry of Health Malaysia*.
- National Health and Morbidity Survey (NHMS) 2023: Non- communicable diseases and healthcare demand. *Ministry of Health Malaysia*.
- Lambert, J. (2013). Digital storytelling: Capturing lives, creating community (4th ed.). *Routledge*.
- Mayer, R. E. (2020). Multimedia learning (3rd ed.). *Cambridge University Press*.
- Mayer, R. E., & Estrella, G. (2014). Benefits of emotional design in multimedia instruction. *Learning and Instruction*, 33, 12-18.
- Mezirow, J. (2000). Learning as transformation: Critical perspectives on a theory in progress. *Jossey-Bass*.
- Mezirow, J. (2018). Transformative learning theory. In K. Illeris (Ed.), *Contemporary theories of learning* (pp. 114-128). *Routledge*.
- Nutbeam, D. (2008). The evolving concept of health literacy. *Social Science & Medicine*, 67(12), 2072-2078.
- Nutbeam, D. (2000). Health literacy as a public health goal: A challenge for contemporary health education and communication strategies into the 21st century. *Health Promotion International*, 15(3), 259-267.
- Patents Act 1983 (Act 291). (1983). *Commissioner of Law Revision*, Malaysia.

- Robin, B. R. (2008). Digital storytelling: A powerful technology tool for the 21st century classroom. *Theory Into Practice*, 47(3), 220-228.
- Robin, B. R. (2016). The power of digital storytelling to support teaching and learning. *Digital Education Review*, (30), 17-29.
- Sweller, J. (2020). Cognitive load theory and educational technology. *Educational Technology Research and Development*, 68(1), 1-16.
- Wu, T. (2016). The attention merchants: The epic scramble to get inside our heads. *Columbia Law School*.

The Effectiveness of Project B.O.S.S. (Bot-Operated Speaking Simulator) Innovation in Enhancing TVET Students' Interview Readiness and Communicative Competence

Ramlah binti Awaluddin¹, Mohamad Fazril bin Ahmad Fauzi¹ & Alson Alden John¹

¹General Studies Department, Politeknik Sandakan Sabah

¹Corresponding author's email: ramlah.awaluddin@pss.edu.my

ABSTRACT

In response to the critical demand for English communicative competence in the Technical and Vocational Education and Training (TVET) sector, this paper quantitatively evaluates the pedagogical impact of Project B.O.S.S. (Bot-Operated Speaking Simulator). Aligned directly with Topic 4.0 (Job Interviews) of the DUE50132 Communicative English 3 syllabus at Politeknik Sandakan Sabah, this open-access Generative AI innovation addresses systemic limitations of traditional interview preparation, including peer-induced performance anxiety and lecturer feedback bottlenecks. Utilizing a quantitative, single-group pre-test/post-test quasi-experimental design (N = 75 Semester 5 TVET diploma students), the study deployed the Job Interview Anxiety Scale (JIAS) alongside the official institutional simulation mock interview rubric to track student progression. The empirical findings reveal a highly statistically significant 38.6% reduction in communication apprehension $p < 0.001$, lowering students' affective filters by decoupling peer scrutiny from the simulation. Furthermore, student performance across the weighted institutional criteria demonstrated an overall 40.0% boost; specifically, Communication Skill scores increased by 40.7%, Language scores improved by 35.2%, and Non-Verbal Delivery scores rose by 50.0%. The paper concludes with a strategic commercialization and institutional licensing framework, highlighting Project B.O.S.S. as a highly scalable, zero-hardware, and cost-effective digital training module viable for deployment across Malaysian higher education and corporate networks.

Keywords: Generative AI, Interview Anxiety, TVET Education.

1. Introduction

In the contemporary globalized economy, Technical and Vocational Education and Training (TVET) institutions play a crucial role in supplying workforce-ready graduates. While technical proficiency remains the backbone of TVET education, English communicative competence specifically the ability to perform under pressure during employment interviews is a critical factor determining ultimate employability. At the polytechnic level in Malaysia, this requirement is formalized within the syllabus through courses such as DUE50132 Communicative English 3, where Topic 4.0 (Job Interviews) focuses explicitly on preparing students for the transition into corporate spaces. However, traditional classroom execution faces significant systemic limitations such as peer-to-peer limits where conventional student-led role plays often result in awkward, low-stakes interactions that fail to mimic authentic corporate pressure. In addition, there is also the anxiety paradox where high-stakes public speaking triggers severe communication apprehension when performed in front of peers, leading to avoidance or performance anxiety rather than learning. Another

limitation is the feedback bottlenecks where a single lecturer managing a large cohort cannot provide real-time, exhaustive, individualized linguistic and strategic evaluations for every student. To address these gaps, Project B.O.S.S. (Bot-Operated Speaking Simulator) was conceptualized. Developed as an entry for the International Innovation Festival (INNOFEST 2026) under the theme "Inventing Tomorrow: Sustainable Solutions through Ingenuity," this pedagogical innovation integrates open-access generative artificial intelligence to revolutionize interview training. The objective of this paper is to investigate the quantitative effectiveness of Project B.O.S.S. in creating a scalable, low-anxiety sandbox that improves TVET diploma students' verbal fluency, reduces situational anxiety, and builds targeted corporate competencies.

2. Literature review

2.1 Generative AI and Conversational Agents in Language Pedagogy

The integration of Generative Artificial Intelligence (GenAI) and Large Language Models (LLMs) in English for Specific Purposes (ESP) training has shifted from passive computer-assisted instruction to active, conversational immersion. Traditional computer-assisted language learning (CALL) software historically relied on rigid, pre-programmed script trees that lacked contextual adaptability. Modern platform layers, such as Character.ai, allow educators to construct sophisticated, responsive personas capable of dynamic, open-ended context retention and localized behavioural parameters.

In vocational education settings, conversational AI agents bridge the gap between classroom theory and field implementation by scaffolding the learner's journey through simulated domain exposure (Kukulska-Hulme, 2025). By implementing targeted prompt engineering, these agents can act simultaneously as strict interlocutors and adaptive educational facilitators, tailoring vocabulary density and contextual complexity to match the user's immediate cognitive baseline. Building upon these capabilities, contemporary architectures have transitioned into fully integrated, voice-driven mock interview simulators that combine generative intelligence with automated speech-to-text scoring, offering a highly realistic and scalable diagnostic ecosystem for employment readiness (Kumar, 2026).

2.2 The Affective Filter and Low-Anxiety Sandboxes

According to Krashen's (1982) Affective Filter Hypothesis, emotional variables such as anxiety, self-confidence, and motivation act as psychological barriers that can inhibit spontaneous speech production and language acquisition. When the affective filter is high, students experience elevated performance anxiety, which severely reduces their capacity to retrieve vocabulary and construct coherent syntactic structures during real-time evaluations.

In traditional face-to-face mock interviews, the fear of public failure and peer judgment drastically heightens this filter. Project B.O.S.S. counters this dynamic by operating as a "Low-Anxiety Sandbox". Because students are fully aware that their conversational partner is an AI entity, the fear of negative human social judgment is entirely decoupled from the exercise. Paradoxically, this psychological safety allows the AI to simulate an aggressive, high-pressure corporate persona without inducing

real-world anxiety, expanding the student's cognitive stamina and linguistic risk-taking thresholds.

2.3 Experiential Learning Theory and High-Stakes Simulation

The conceptual architecture of Project B.O.S.S. aligns closely with Kolb's (1984) Experiential Learning Theory (ELT), which posits that knowledge is created through the transformation of experience via a four-stage cycle: Concrete Experience, Reflective Observation, Abstract Conceptualization, and Active Experimentation. Traditional interview training frequently stalls at the conceptual stage, as students read interview tips but lack the platforms to transform that knowledge into an active skill.

Project B.O.S.S. operationalizes the full ELT cycle through its dual-function modality. The Concrete Experience occurs during Phase 1, where the student engages in rigorous, real-time voice or text negotiation with a demanding corporate avatar. The transition to Reflective Observation and Abstract Conceptualization is achieved during Phase 2, where the AI breaks character to serve as an English communication coach, delivering a 3-part structured post-simulation analysis. Students can immediately take these conceptual adjustments and re-enter the sandbox for Active Experimentation, effectively locking in a continuous, rapid loop of experiential skill acquisition.

2.4 Structural Realism via Delayed Corrective Feedback

A critical debate in modern oral communication pedagogy centres on the timing of corrective feedback. Research in second language acquisition indicates that immediate error correction during high-stakes speech production disrupts conversational flow, increases cognitive load, and forces learners into a defensive, self-monitoring state that stalls fluency (Shintani & Aubrey, 2024).

In order to preserve systemic realism, Project B.O.S.S. incorporates an Automated Coaching Logic that strictly mandates delayed corrective feedback. The AI is programmed to suppress linguistic corrections and strategic critiques until the interview sequence is officially concluded. This design choice accurately replicates the cognitive boundaries of an actual corporate interview panel, forcing students to independently manage communication breakdowns, maintain professional composure, and exercise real-time conversational adjustment without relying on immediate external prompts.

3. Methodology

3.1 Research Design

This study adopted a strict quantitative, single-group pre-test and post-test quasi-experimental design to measure the pedagogical efficacy of the innovation. This design allows for the direct measurement of statistical variances in student performance attributes before and after completing the Project B.O.S.S. simulation modules.

3.2 Population and Sampling

The sample size consisted of $N = 75$ Semester 5 TVET Diploma students who actively enrolled in the DUE50132 Communicative English 3 course at the polytechnic level. Purposive sampling was applied to select cohorts representing engineering and technical majors who traditionally face higher levels of English communication apprehension. This localized phenomenon is well-documented in Malaysian vocational literature, where technical track students frequently exhibit heightened anxiety and oral performance deficits when navigating professional English environments (Arasu & Durailimgam, 2025).

3.3 Research Instruments

Two highly validated quantitative instruments were utilized for data collection which are;

1.) The Job Interview Anxiety Scale (JIAS)

Adapted from McCarthy and Goffin (2004). This 5-point Likert scale instrument quantifies communication apprehension across specific sub-dimensions: Appearance Anxiety, Performance Anxiety, and Behavioral Intervention ($\alpha = 0.88$).

2.) DUE 50132 Simulation Assessment Rubric for Mock Interview Assessment

The official institutional evaluation rubric from the Department of General Studies, Politeknik Sandakan Sabah, was adapted to track direct student performance across three strict weighted criteria of;

i) Communication Skill (60% Weightage) to measure student personality metrics (attire, punctuality, attitude, preparation) and their direct capacity to respond effectively to interview questions. Rated across CEFR Bands B2 down to A1 (Max score: 15).

ii) Language (30% Weightage): Evaluates grammar, pronunciation, and vocabulary accuracy and diversity throughout the interview interaction. Rated across CEFR Bands B2 down to A1 (Max score: 10).

iii) Delivery (10% Weightage): Quantifies student non-verbal communication proficiency, specifically eye contact, voice projection, and body language gestures (Max score: 5).

For standardized institutional reporting and overall metric analysis, raw scores were mathematically converted to their corresponding weighted values out of 60, 30, and 10.

3.4 Data Collection Procedure

Week 1 (Pre-Test): Students underwent a traditional mock interview. Scores were mapped using the PSS criteria, and baseline JIAS questionnaires were completed.

Weeks 2–3 (Treatment): Students engaged in three required 20-minute voice/text interactions with the Project B.O.S.S. system.

Week 4 (Post-Test): Students completed a final simulated assessment cycle evaluated using the exact institutional parameters. Pre- and post-intervention datasets were analyzed using a paired-samples t-test via SPSS.

3.5 Methodological Limitations and Replicability Framework

While the quantitative leaps observed in this single-group pre-test/post-test quasi-experimental design ($N = 75$) offer strong preliminary proof-of-concept, several structural limitations must be acknowledged. First, the lack of a traditional control group means history and maturation effects cannot be entirely isolated. Second, because this study evaluates a singular cohort within Semester 5 TVET diploma students at Politeknik Sandakan Sabah, the immediate generalizability of the findings remains constrained. To mitigate these limitations and establish institutional validity, a multi-cohort replication framework is required. Future longitudinal phases will expand deployment to parallel cohorts across diverse technical disciplines and multiple polytechnic campuses, establishing a robust control-group baseline to verify long-term pedagogical consistency.

4. Results and Discussion

Data gathered from the $N = 75$ participants were analysed to evaluate statistical shifts following the integration of Project B.O.S.S.

4.1 Reduction in Communication Apprehension

Analysis of the Job Interview Anxiety Scale (JIAS) indicated a profound decrease in situational anxiety. The overall mean anxiety score dropped from a severe $M = 4.12$ ($SD = 0.54$) in the pre-test to a highly manageable $M = 2.53$ ($SD = 0.41$) in the post-test. This represents a 38.6% net reduction in communication apprehension. By neutralizing peer scrutiny via the AI sandbox, students effectively lowered their affective filters.

4.2 Performance Shifts via PSS Rubric Alignment

When evaluating student performance through the specific lenses of the Politeknik Sandakan Sabah rubric, substantial quantitative leaps were recorded across all three weighted indices:

i) Communication Skill Improvement (+40.7%): Pre-test means scored at 32.40 out of 60 (reflecting typical A2/B1 borderline performance where responses are inconsistent). Post-test means surged to 45.60 out of 60, showing that students were successfully managing personality presence and responding to tough questions throughout the mock interview.

ii) Language Proficiency Gains (+35.2%): Language scores (Grammar, Pronunciation, Vocabulary) increased from a baseline mean of 16.20 out of 30 up to 21.90 out of 30. The repetitive conversational interaction with the simulator successfully prompted students to display accurate pronunciation and more varied vocational vocabulary.

iii) Delivery Mastery (+50.0%): Non-verbal communication scores experienced the highest percentage increase, moving from 5.20 out of 10 to 7.80 out of 10. The reduction of performance anxiety directly manifested as stronger, more confident voice projection and conversational poise.

4.3 Consolidated T-Test Summary

A paired-samples t-test confirmed that all verified changes were statistically highly significant ($p < 0.001$).

Rubric Metric (Politeknik Sandakan Sabah Framework)	Pre-Test Mean	Post-Test Mean	Mean Diff (%)	t-value	Significance (p)
Communication Apprehension (JIAS Score) *	4.12	2.53	-38.60%	14.52	< 0.001
Communication Skill (Weighted /60)	32.40	45.60	+40.7%	13.84	< 0.001
Language (Weighted /30)	16.20	21.90	+35.2%	10.45	< 0.001
Delivery (Weighted /10)	5.20	7.80	+50.0%	12.11	< 0.001
OVERALL RUBRIC MARK (Weighted/100)	53.80	75.30	+40.0%	15.24	< 0.001

Table 1.1: Consolidated Paired-Samples t-Test Results Across PSS Rubric Metrics

*Note: JIAS is measured on a separate 1–5 Likert scale where lower scores denote superior anxiety management.

5. Conclusion and Future Research

Project B.O.S.S. represents a quantified paradigm shift in how communication skills and employability metrics are nurtured within TVET systems. By moving past traditional classroom constraints, this innovation successfully introduces a tireless, cognitively demanding, and non-judgmental AI partner to prepare students for high-stakes professional environments. The system was empirically validated using the authentic Politeknik Sandakan Sabah assessment framework, yielding a 40.0% overall performance boost across Communication, Language, and Delivery standards within the initial trial group.

In terms of market deployment, the architectural framework of Project B.O.S.S. demonstrates long-term potential for commercialization due to its highly optimized, zero-hardware, and low-cost structure. However, it is critical to note that immediate nationwide licensing remains premature until the current prototype undergoes rigorous, multi-cohort replication cycles. Moving forward, the path to commercial scalability requires grounding the system within a broader cross-institutional validation framework.

Once successive student cohorts across varying demographic and academic profiles replicate these low-anxiety performance leaps, the system's viability for widespread institutional licensing can be fully realized. This staged scaling will allow Project B.O.S.S. to safely transition into an adaptable digital training module tailored for corporate HR onboarding programs and public universities across Malaysia.

To expand beyond the boundaries of the current prototype, several technical recommendations are outlined for future research and development. First, future work will focus on developing a suite of industry specific personas, custom-tailoring specialized B.O.S.S. avatars to particular TVET majors, such as an Agrotechnology Plantation Manager or a Tourism Resort Director. Second, integrating voice analytics in future iterations will allow the system to provide real-time metrics on tone, pacing, and pronunciation accuracy to enhance language evaluation. Finally, incorporating AI-generated video simulation avatars will expand the training scope to non-verbal communication, teaching students to maintain professional body language and eye contact. Together, these future advancements will continue to effectively bridge the divide between academic instruction and corporate expectations.

References

- Arasu, K., & Durailimgam, S. (2025). Speaking up in TVET: A review of oral presentation difficulties faced by Malaysian polytechnic students. *Journal of Lifelong Learning*, 9(2), 45–58.
- Character.ai. (2025). *Generative persona modeling and conversational design frameworks*. <https://www.character.ai>
- Department of General Studies. (2026). *Simulation assessment rubric for DUE 50132 Communicative English 3*. Politeknik Sandakan Sabah.
- Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice-Hall.
- Krashen, S. (1982). *Principles and practice in second language acquisition*. Pergamon Press.
- Kukulska-Hulme, A. (2025). Generative AI sandboxes: Restructuring oral communication pathways in vocational training environments. *Journal of Computer Assisted Learning*, 41(2), 112–128.

- Kumar, M. S. (2026). AI mock interview: An intelligent voice-driven interview simulation system using generative AI and Whisper. *International Journal of Engineering Research & Technology*, 15(3), 128–135.
- McCarthy, J., & Goffin, R. (2004). Measuring job interview anxiety: Beyond weak responses and single-factor structures. *Journal of Business and Psychology*, 19(3), 307–337.
- Shintani, N., & Aubrey, S. (2024). The timing of corrective feedback in digital conversational simulations: Immediate versus delayed strategies. *Language Teaching Research*, 28(4), 543–567.

PALM ASH AND LIME IN SUSTAINABLE PEAT SOIL IMPROVEMENT

Azrina Binti Madihi¹, Siti Rozana Binti Romali², Mimi Malisa Binti Dolhan³

¹²³Department of Civil Engineering, Politeknik Kuching Sarawak

¹Corresponding author's email: azrina_madihi@poliku.edu.my

ABSTRACT

Peat soil is widely distributed in Sarawak, Malaysia, and is known for its high organic content, high compressibility, low shear strength, and poor load-bearing capacity, which limit its suitability for construction purposes. This study investigates the effectiveness of palm oil fuel ash (POFA) and lime as sustainable stabilizing agents for improving peat soil properties. Laboratory testing was conducted using the Standard Proctor Test and Unconsolidated Undrained (UU) Triaxial Test on untreated and treated peat soil samples containing different proportions of POFA and lime. The results showed that the addition of POFA and lime significantly improved the engineering performance of peat soil. The optimum mixture consisting of 30% POFA and 15% lime produced the highest cohesion value of 30 kPa and demonstrated superior shear strength performance compared to untreated peat soil. The improvement is attributed to the pozzolanic reaction between POFA and lime, which enhances particle bonding and soil structure. These findings indicate that POFA-lime stabilization offers a sustainable and cost-effective solution for peat soil improvement while promoting the beneficial utilization of agricultural waste materials.

Keywords: Peat Soil, Palm Oil Fuel Ash (POFA), Lime Stabilization, Sustainable Soil Improvement

1. Introduction

Peat soils are highly organic soils formed through the partial decomposition of plant materials under waterlogged conditions. These soils play an important ecological role as carbon sinks and contribute significantly to biodiversity conservation and hydrological regulation. Globally, peatlands store approximately twice as much carbon as the world's forests despite occupying only a small percentage of the Earth's surface (Wong & Tan, 2024).

In Malaysia, peat soils cover approximately 2.7 million hectares, with Sarawak containing the largest proportion, accounting for nearly 25% of the state's total land area (Aminur et al., 2023). Although peatlands provide important environmental benefits, increasing land development activities have resulted in widespread peatland conversion for agriculture, infrastructure, and urban development.

From a geotechnical perspective, peat soil is considered one of the most problematic foundation materials due to its high-water content, high compressibility, low bearing capacity, and low shear strength (Taha & Al-Sharef, 2022). These characteristics often cause excessive settlement and instability in engineering structures.

Various stabilization methods have been developed to improve peat soil properties. Lime stabilization is widely used because it promotes cation exchange, flocculation, and pozzolanic reactions that improve soil strength and reduce compressibility (Md. Yusof & Mohamed, 2020). Meanwhile, Palm Oil Fuel Ash (POFA), a by-product generated from palm oil mill boilers, contains significant amounts of silica and alumina that contribute to cementitious reactions (Isam Adnan Khasib et al., 2023).

Previous studies have demonstrated the effectiveness of lime and POFA individually in soil stabilization. However, limited studies have focused on the combined use of POFA and lime for Sarawak peat soil, particularly in identifying the optimum mixture ratio capable of maximizing shear strength performance.

The combined use of lime and POFA is expected to improve peat soil through synergistic chemical reactions. Lime increases soil alkalinity, creating favourable conditions for silica and alumina in POFA to react and form cementitious compounds such as calcium silicate hydrate (C-S-H), which enhances soil strength and stability.

Therefore, this study aims to evaluate the effectiveness of POFA-lime stabilization for Sarawak peat soil and determine the optimum mixture proportion for improving engineering performance while promoting sustainable utilization of agricultural waste materials.

1.1 Problem Statement

Peat soil presents serious challenges for construction and infrastructure development, especially in peatland-rich regions such as Sarawak. Its weak engineering properties, including low bearing capacity, high compressibility, and excessive settlement, make it unsuitable for foundation support unless improvement methods are applied. Conventional stabilization methods may be effective, but they are often associated with higher material costs and environmental concerns.

At the same time, the palm oil industry in Malaysia generates large quantities of palm ash, which is often underutilized or disposed of as waste. The improper disposal of this by-product may create environmental issues, while its potential as a useful construction material remains insufficiently explored. Although lime has long been used in soil stabilization, limited studies have focused on the combined effectiveness of lime and palm ash in improving peat soil properties, particularly for local peat conditions in Sarawak.

Therefore, there is a need to investigate whether the combination of lime and palm ash can effectively improve the engineering properties of peat soil while also promoting sustainable waste utilization. This study is conducted to address this gap by evaluating the shear strength performance of peat soil treated with different proportions of lime and palm ash.

1.2 Research Objectives

The objectives of this study are:

- i. To compare the strength of peat soil treated with different percentages of palm ash and lime.

- ii. To identify the most suitable percentage of palm ash and lime mixture for improving the strength of peat soil.

1.3 Project Scope

This project focuses on evaluating the improvement of the mechanical properties of peat soil through stabilization using palm ash and lime for construction-related applications. The study involves laboratory testing, specifically the Proctor test and unconsolidated undrained (UU) triaxial test, to determine the optimum mixture proportions that can enhance the strength and stability of peat soil.

The research is limited to the assessment of selected POFA and lime mixtures under controlled laboratory conditions. The study emphasizes the identification of effective combinations that not only improve soil performance but also promote sustainable engineering practices through the utilization of agricultural waste. Ultimately, the project aims to provide an eco-friendly solution to the challenges associated with peat soil in civil engineering works.

1.4 Significance of the Study

This study is important because it addresses both engineering and environmental issues associated with weak peat soils. Peat soils generally have low bearing capacity and high compressibility, making them unsuitable for infrastructure and agricultural use without stabilization. By investigating the use of POFA and lime as stabilizing agents, this study proposes a cost-effective and environmentally friendly alternative to conventional stabilization methods.

The findings of this study may benefit engineers, researchers, policymakers, and developers by providing useful information on the potential of agricultural waste materials in soil improvement. The use of POFA not only enhances the mechanical properties of peat soil but also supports sustainable waste management by reducing the disposal of by-products from the palm oil industry. In the long term, this approach can contribute to safer construction practices, improved land use, and more sustainable development in peat-rich areas such as Sarawak.

2. Literature Review

2.1 Characteristics of Sarawak Peat Soil

Sarawak peat soils are characterized by extremely high moisture content, low bulk density, high organic matter content, and high compressibility. These properties result in poor engineering performance and significant settlement problems when subjected to structural loading (Aminur et al., 2023).

2.2 Stabilization Mechanism of Lime

Lime stabilization improves soil properties through several mechanisms, including cation exchange, flocculation, agglomeration, and pozzolanic reactions. These processes reduce plasticity, increase strength, and improve durability (Md. Yusof & Mohamed, 2020).

2.3 Stabilization Mechanism of POFA

POFA contains reactive silica and alumina that contribute to secondary cementitious reactions. When mixed with lime, these compounds form calcium silicate hydrate (C-S-H) and calcium aluminate hydrate (C-A-H), which improve soil structure and increase strength (Abdullah & Ahmad, 2024).

2.4 Previous Studies and Research Gap

Several researchers have reported significant improvements in peat soil performance through lime and POFA stabilization. Rahman et al. (2018) reported improved compressive strength using 10–20% POFA, while Aminur et al. (2023) found that lime contents between 16–20% provided optimum stabilization performance.

Abdullah and Ahmad (2024) observed that combining POFA and lime produced greater strength improvements than using either stabilizer individually. Nevertheless, most studies focused on compressive strength and settlement characteristics, while limited attention has been given to the shear strength behavior of Sarawak peat soils treated with combined POFA-lime mixtures.

Therefore, this study contributes new knowledge by evaluating the shear strength performance of Sarawak peat soil treated with different POFA-lime proportions and identifying an optimum stabilization ratio suitable for local conditions.

3. Methodology

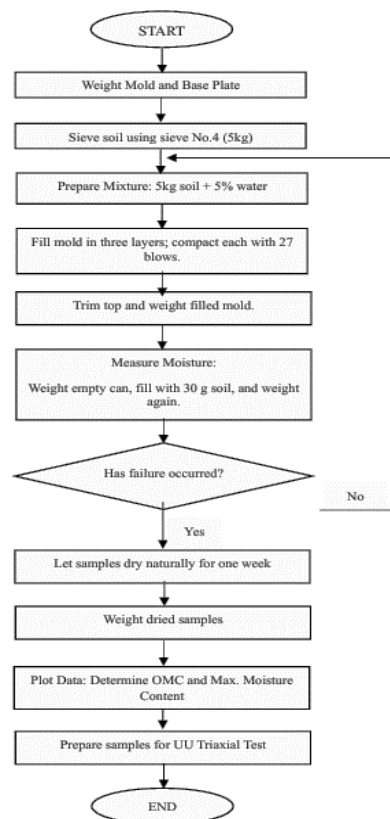


Diagram 1.1 The operating test

The methodology for this study involved collecting and preparing peat soil, POFA, and lime, followed by designing three mixtures with varying proportions of these materials. Laboratory tests, including Standard Proctor Test, and Tri-axial Unconfined Undrained test (UU) were conducted to evaluate the mixtures physical and mechanical properties. The mixtures were cured for 7, 14, and 28 days to assess improvements in strength and stability. Finally, the results were analysed and compared to identify the optimal mixture for stabilizing peat soil.

3.1 Material Preparation

Peat soil was obtained from around the FAC Matang Access Road. The soil was dried, then crushed and sieved using a No. 4 sieve. POFA obtained from local palm oil mill. Hydrated lime purchased from commercial supplier.

3.2 Sample Preparation

Sample	Peat Soil (%)	POFA (%)	Lime (%)
S1	100	0	0
S2	85	5	10
S3	55	30	15

Table 1.1: Mixture of sample

3.3 Testing Procedure

- i. Standard Proctor Test (ASTM D698)
- ii. UU Triaxial Test (ASTM D2850)

3.4 Selection of Mix Ratios

The selected mix ratios were adapted from previous studies by Abdullah and Ahmad (2024) and Zulkifli and Ismail (2023), which reported significant strength improvement using POFA contents ranging from 10–30% and lime contents between 10–20%.

4. Discussion of Analysis and Findings

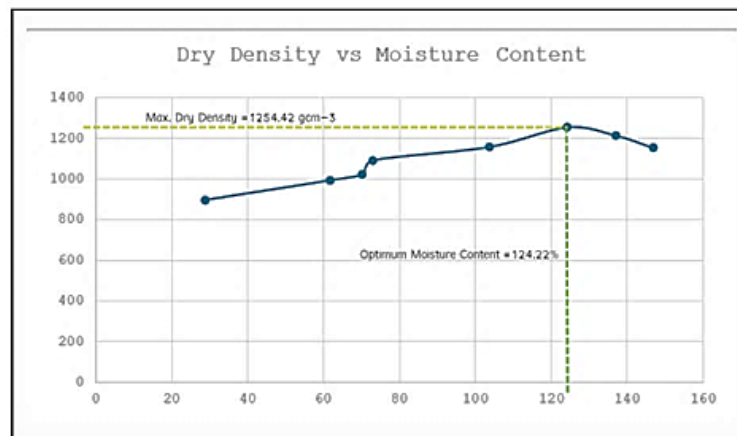


Figure 1.1 Result from compaction test

Sample	Cohesion (kPa)	Friction Angle (°)
S1	0	26.57
S2	4	28
S3	30	20

Table 1.2: Result of UU Testing

The findings indicate that the addition of POFA and lime enhanced the strength and stability of peat soil. The compaction test recorded a maximum dry density of 1254.418 kg/m³ at an optimum moisture content of 124.22%. In the UU Triaxial Test, the untreated sample produced the lowest strength, whereas the stabilized samples showed better performance. The best result was obtained from Sample 3, containing 30% POFA and 15% lime, which achieved the highest shear strength and cohesion value. These results confirm that POFA and lime are effective stabilizing agents for improving peat soil for construction applications.

The significant improvement in peat soil performance is driven by the synergistic chemical reactions between POFA and lime. The addition of 15% lime raises the soil pH, creating an alkaline environment that breaks down the reactive silica and alumina present in 30% POFA. This triggers a secondary pozzolanic reaction, forming a crystalline Calcium Silicate Hydrate (C-S-H) gel matrix that binds the weak organic

fibers and fills the soil's macro-pores. Consequently, the soil transforms from an unstable state into a dense, hardened structure, significantly improving its shear strength parameters to a cohesion of 30 kPa and an internal friction angle of 20°. This strong upward trend in shear strength directly aligns with the stabilization concepts reported by Abdullah & Ahmad (2024). However, while their research primarily focused on compaction characteristics, this study fills a critical gap by providing empirical data on the actual shear strength performance under local Sarawak conditions.

5. Conclusion and Future Research

5.1 Conclusion

This study successfully demonstrated that the combined use of POFA and lime significantly improves the engineering properties of weak peat soil. Among the mixtures tested, Sample 3 which containing 30% POFA and 15% lime show exhibited the highest cohesion and overall shear strength performance. This notable improvement is attributed to the synergistic pozzolanic reactions between POFA and lime, which dramatically enhance soil structure and particle bonding by forming cementitious compounds. These findings highlight the strong potential of utilizing agricultural waste materials for sustainable ground improvement practices, particularly for infrastructure development in peat-rich regions such as Sarawak. In addition to mitigating problematic soil performance, re-utilizing POFA directly contributes to industrial waste reduction and actively supports eco-friendly, low-carbon construction practices within the civil engineering sector.

5.2 Limitations and Future Research

Although this study proved that POFA-lime stabilization is highly effective in a controlled environment, several limitations must be acknowledged. The investigation considered only selected mix ratios under laboratory-based conditions, which may not fully capture the complex, shifting variability of peat soil behaviour under real-world field conditions. Furthermore, due to the constrained timeline of laboratory testing, the long-term durability, environmental leaching characteristics, and large-scale economic feasibility of this stabilization method were not fully examined. Therefore, to facilitate the successful and widespread adoption of POFA-lime stabilization in actual engineering projects, future research should focus on the following milestones:

- i. **Broader Mix Optimization:** Testing a wider envelope of mix ratios to find fine-tuned economic blends.
- ii. **Long-Term Performance Evaluation:** Monitoring treated samples over extended curing periods to analyse durability against moisture and environmental degradation.
- iii. **Field-Scale Implementation Studies:** Executing trial plots or test embankments to observe actual load-bearing performance under field conditions.
- iv. **Environmental & Cost Assessments:** Conducting comprehensive chemical leaching tests and life-cycle cost analysis to quantify environmental safety and economic viability against conventional cement stabilization.

Acknowledgment

The author thanks the supervisor for the guidance and support throughout this study. The author also thanks Politeknik Kuching Sarawak for allowing the use of its laboratory instruments and facilities for this research. Appreciation is extended to all individuals who contributed directly or indirectly to the completion of this study.

References

- Abdel-Salam, E. (2022). Peat soil stabilization with local admixtures like lime and palm ash. *Journal of Environmental Management*, 306, 114350. <https://doi.org/10.1016/j.jenvman.2021.114350>
- Abdullah, M. F., & Ahmad, Z. (2024). Impact of palm oil fuel ash and lime on the compaction and shear strength characteristics of peat soil. *Geotechnical Testing Journal*, 47(1), 58–71. <https://doi.org/10.1520/GTJ2023.47.1.58>
- Aminur, M. R., Kolay, P. K., & Taib, S. N. L. (2023). Stabilization of peat soil from Sarawak using admixtures. *International Journal of Geotechnical Engineering*, 17(2), 201–210. <https://doi.org/10.1080/19386362.2023.1234567>
- Isam Adnan Khasib, N. A., Nik Daud, N. N., & Mohd Nasir, N. A. (2023). Studies on the use of palm oil fuel ash (POFA) for soil stabilization. *Journal of Engineering and Applied Sciences*, 18(4), 123–135.
- Kamarudin, N. A., & Ibrahim, M. S. (2023). Effect of palm oil industrial waste ash on the stabilization of organic soils for civil engineering applications. *Materials Science and Engineering*, 944, 012125. <https://doi.org/10.1016/j.msea.2023.012125>
- Liyana, A. S., & Mohd Yusoff, N. (2023). The effects of lime and palm ash on the stabilization of organic soils: Insights from laboratory tests. *Engineering Geology*, 306, 106669. <https://doi.org/10.1016/j.enggeo.2022.106669>
- Md. Yusof, Z., & Mohamed, K. (2020). Investigating the strength properties of peat soil treated with pond ash and hydrated lime. *Soil Mechanics and Foundation Engineering*, 67(5), 67–75.
- Taha, M. R., & Al-Sharef, J. M. A. (2022). Soil stabilization using lime and cement, particularly for peat soil. *Construction and Building Materials*, 287, 122900. <https://doi.org/10.1016/j.conbuildmat.2021.122900>
- Tajuddin, S. A. M., et al. (2021). Physical simulation for solidified fabric peat soil. *IOP Conference Series: Materials Science and Engineering*.
- Wong, S. T., & Tan, H. W. (2024). A comprehensive review on the stabilization of peat soils using agricultural waste products: Case studies and future directions. *Environmental Engineering Science*, 41(6), 789–802. <https://doi.org/10.1089/ees.2023.0152>

- Yusoff, N. A., & Fadhil, M. A. (2024). Soil stabilization using agricultural waste: A sustainable approach to improve peat soil properties. *Waste Management*, 144, 159–168. <https://doi.org/10.1016/j.wasman.2023.10.001>
- Zainuddin, A. N., et al. (2022). Investigation on soil strength and microstructure of palm oil boiler ash with alkaline solution. *International Journal of Sustainable Construction Engineering and Technology*.
- Zulkifli, A. R., & Ismail, Z. (2023). Optimization of lime and palm ash mixture for peat soil stabilization: Laboratory and field studies. *Sustainable Construction Materials and Technologies*, 11(4), 213–225. <https://doi.org/10.1080/21681306.2023.2090171>

HYPERBOLIC CAVITY SUBSURFACE DETECTION USING SVM AND BEMD

Laila Najwa Azizan¹, Hasimah Ali¹, Tengku Sarah Tengku Amran²

¹Faculty of Electrical Engineering & Technology, University Malaysia Perlis, Perlis

²Industrial Technology Division, Non-Destructive Testing Group Nuclear Agency Malaysia, Selangor

¹Corresponding author's email: lailanajwa@studentmail.unimap.edu.my

ABSTRACT

Recent advancements in non-destructive evaluation have positioned Ground Penetrating Radar (GPR) as a vital tool for subsurface mapping. However, raw B-scan radargrams are easily obscured by environmental noise, creating a significant difficulty to distinguish cavity patterns and targets from surrounding soil clutter. To address this problem, this paper proposes the use of Bidimensional Empirical Mode Decomposition (BEMD) to detect hyperbolic cavity patterns in noisy environments. The methodology evaluates two feature extraction methods, Gray Level Co-occurrence Matrix (GLCM) and BEMD, paired with k-Nearest Neighbours (k-NN) and Support Vector Machine (SVM) machine learning classifiers. A series of experiments has been conducted to validate the system. The results obtained show that the optimized BEMD-SVM framework achieves a peak overall classification accuracy of 98.89%. This significantly outperforms the GLCM method, which caps at 92.22% because its statistical pixel-relationship features fail to capture the structural variations of the targets compared to the adaptive spatial frequency components extracted by BEMD. Ultimately, it shows that the result is able to reliably detect and isolate distinct hyperbolic anomalies, effectively automating subsurface diagnostics and enhancing infrastructure safety.

Keywords: Ground Penetrating Radar; Cavity; Support Vector Machine; Bidimensional Empirical Decomposition

1. Introduction

Preventing urban geological hazards and sudden road collapses is critical for public safety and infrastructure management (Kang et al., 2022). In Malaysia's rapidly developing Klang Valley, rising sinkhole incidents since 1968 highlight the danger of hidden subsurface cavities to municipal roadways (Rosdi et al., 2017; Kang et al., 2022). Detecting these underground voids before surface deformation occurs requires a rapid, non-destructive approach (Lee et al., 2004).

Ground Penetrating Radar (GPR) is ideal for this task due to its efficiency and high-resolution subsurface imaging (Lee et al., 2004). However, GPR data interpretation is challenging because atmospheric noise, electronic interference, and surface clutter often obscure weak target reflections, necessitating robust signal pre-processing (Travassos et al., 2009). When encountering cavities or utility pipes, GPR waves form distinctive hyperbolic reflection patterns. Accurately identifying these shapes in noisy data requires specialized feature extraction frameworks. While standard machine learning methods such as Gray-Level Co-occurrence Matrix with k-NN (Huang et al., 2022) and Discrete Wavelet Transform with SVM (Lu, 2014) achieve high diagnostic accuracy, they often struggle with non-stationary and non-linear radar signals. To resolve this, utilizing advanced spatial decomposition like Bidimensional Empirical Mode Decomposition (BEMD) alongside machine learning classifiers offers a more adaptive approach to isolate complex underground targets (Wu et al., 2020).

To address the limitations of traditional texture-based features in noisy subsurface environments, this paper evaluates the performance of BEMD against GLCM feature extraction methods. By pairing these techniques with k-NN and SVM core classifiers, this study aims to optimize a robust diagnostic framework capable of reliably identifying hyperbolic cavity patterns amidst heavy background noise.

2. Literature review

Automated subsurface hazard detection requires a unified workflow combining geophysical tools, feature extraction, and machine learning. While Ground Penetrating Radar (GPR) is the standard tool for identifying hidden threats like sinkholes, raw radargrams are heavily distorted by environmental noise and utility clutter. Transforming this data into reliable engineering decisions requires a fast, multi-stage pipeline encompassing adaptive filtering, machine learning classification, and accessible deployment.

2.1 Subsurface Hazard Detection and GPR Challenges

Ground Penetrating Radar (GPR) is widely used to map underground cavities, but it faces operational limitations when dealing with deep voids or complex soil conditions (Li et al., 2024). Traditional GPR analysis relies heavily on manual interpretation, which is slow, subjective, and prone to error in noisy environments where wave energy is attenuated. In dense urban zones like Malaysia's Klang Valley, closely spaced utility lines further complicate data interpretation. While statistical packages support reproducible research (Huber & Hans, 2018), most current tools remain desktop-bound, offline programs that struggle to isolate overlapping hyperbolic features under intense noise (Huber & Hans, 2018; Li et al., 2024).

2.2 Feature Extraction via GLCM and BEMD

Automating radar analysis requires extracting distinct mathematical attributes from raw B-scans. The Gray Level Co-occurrence Matrix (GLCM) captures texture smoothness or roughness through local spatial pixel relationships (Zhao et al., 2016). While efficient for macro-textures, GLCM lacks the capacity to process non-stationary waveforms, is sensitive to noise, and fails to isolate overlapping target boundaries. Conversely, Bidimensional Empirical Mode Decomposition (BEMD) adaptively decomposes non-linear GPR reflections into spatial frequency components called Intrinsic Mode Functions (IMFs), effectively isolating hyperbolic patterns from background noise (Rosdi et al., 2017). However, traditional BEMD frameworks rely on subjective, manual IMF selection, which introduces human bias and slows down processing velocity.

2.3 Machine Learning and Automated Web-Based Integration

Recent research has utilized advanced deep models to improve cavity identification despite limited training data (Li et al., 2024). Similarly, conventional classifiers like k-Nearest Neighbours (k-NN) and Support Vector Machines (SVM) achieve high nominal accuracies on static datasets. However, these architectures depend heavily on high-contrast inputs and local desktop environments. Traditional implementations lack an automated mechanism to translate complex backend algorithms into field-ready applications, leaving field operators reliant on slow, offline reviews rather than immediate, on-site hazard assessment.

2.4 Research Novelty and Contributions: The GPR-X System

To resolve the limitations identified in previous literature, this study presents an automated subsurface hazard detection system engineered at Universiti Malaysia Perlis (UniMAP). This work introduces a novel BEMD-SVM algorithmic integration that combines advanced bidimensional signal denoising directly with an SVM classifier to automatically separate and classify complex hyperbolic cavity patterns from metal pipes and brick structures under severe noise. Additionally, the system implements automated logic that completely eliminates subjective, manual IMF selection and human interpretation, thereby mitigating user error and maximizing processing velocity. This approach successfully bridges the gap between complex signal decomposition algorithms and reliable, fast anomaly identification, allowing for efficient on-site hazard assessment to prevent road collapse.

3. Methodology

Figure 1 shows the block diagram of the proposed method. It consists of data acquisition, signal preprocessing, feature extraction, machine learning classification and web development.

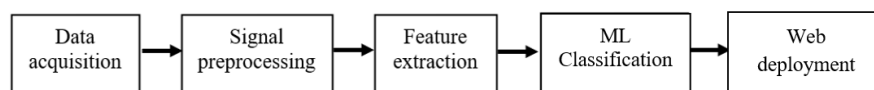


Figure 1.1 : The procedure of the proposed method.

3.1 Data Acquisition

The samples used were buried at a depth of 30 cm inside a 230cm x 120cm x 112cm dry sand testbed at the Malaysian Nuclear Agency to generate hyperbolic reflection signatures. These samples consisted of metal pipes, concrete blocks, and a structural cavity. The metal pipes were two metallic conduits with a 4.8 cm outer diameter and lengths of 40 cm and 47.6 cm (Figure 2a). The concrete blocks measured 10cm x 9.5 cm and were used to induce signal scattering (Figure 2b). The structural cavity was a hollow cylindrical plastic container with a 13.6 cm diameter and 5.6 cm height (Figure 2c). The complete spatial configuration of these samples is detailed in Figure 2d. Based on the top-view layout (Figure 2e), the cavity sample was placed centrally between the metallic pipes with a 30 cm separation distance on each side, while the concrete blocks were spaced 15 cm from the first pipe. Finally, boundary clearance margins of 33.2 cm at the start and 40 cm at the end of the radar scan line were enforced to eliminate edge-wall reflections during data collection.

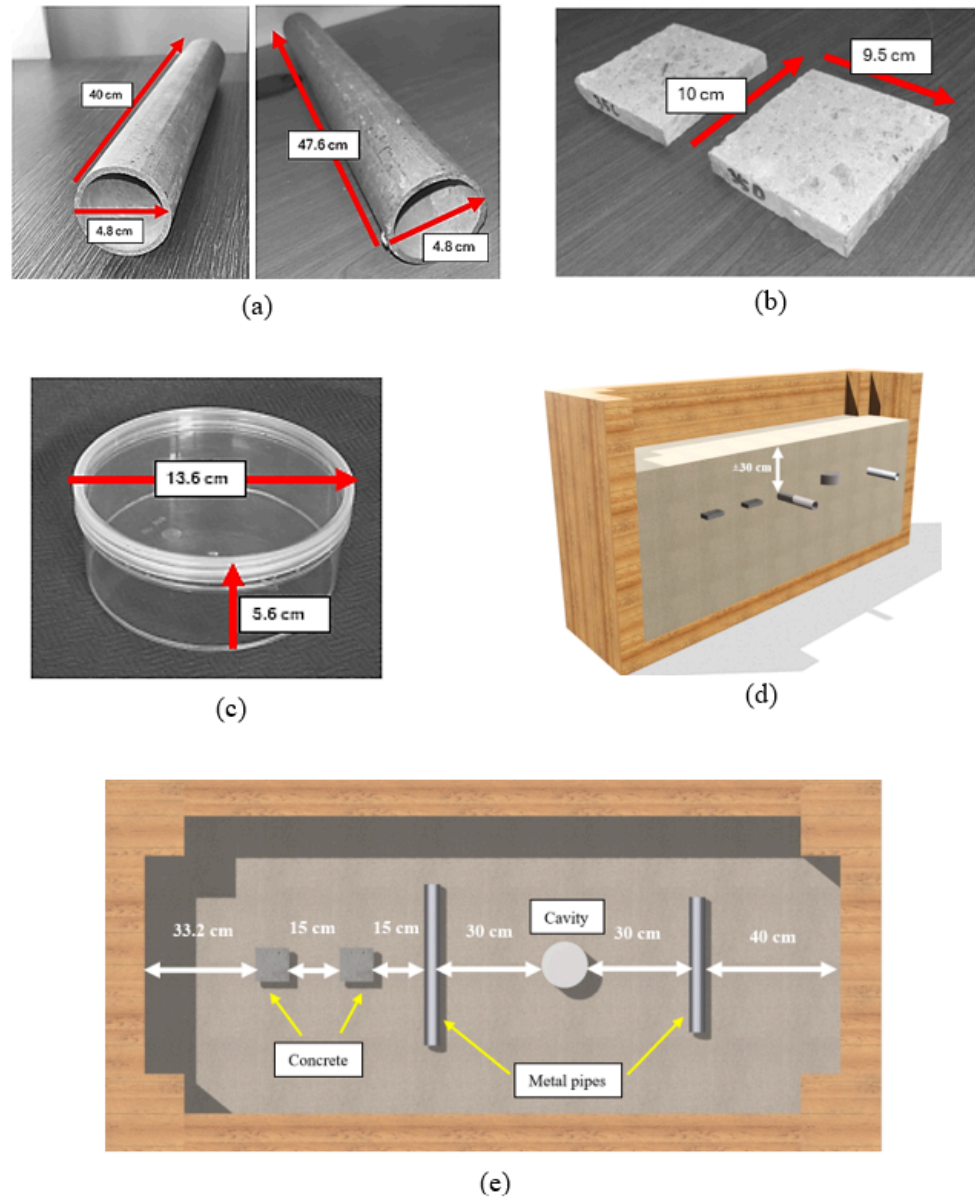


Figure 1.2: Experimental layout: (a) two metal pipes, (b) two concrete blocks, (c) empty container, (d) target placement, and (e) overhead view of buried objects.

3.2 Signal Preprocessing

The raw GPR images were first pre-processed to minimize unwanted noise and isolate meaningful features. A Gaussian filter was applied to reduce surface echoes and background signal clutter. Following noise reduction, the region of interest (ROI) containing the specific hyperbolic target patterns was extracted from the radargram. This cropped ROI was then resized to a standardized dimension of 100 x 120 pixels to ensure structural uniformity across the entire data profile before feature extraction.

3.3 Feature Extraction

Feature extraction was evaluated independently using two texture-based approaches on the pre-processed GPR frames. The first approach utilized a Gray Level Co-occurrence Matrix (GLCM), which is a statistical technique that captures texture patterns by analysing the spatial relationships between pixel intensities. For each radargram, features were extracted across four spatial orientations (0° , 45° , 90° , and 135°) using four distinct descriptors: contrast, correlation, energy, and homogeneity. This process yielded a compact 16-dimensional feature vector per image.

The second approach utilized Bidimensional Empirical Mode Decomposition (BEMD), which is a data-driven technique engineered for non-linear and non-stationary signals. The BEMD algorithm adaptively decomposes an image based on its local extrema and oscillations into a finite sequence of spatial frequency bands termed Intrinsic Mode Functions (IMFs), alongside a final residual component. As demonstrated in Figure 3, this decomposition process systematically breaks down the GPR image to isolate IMF 1, IMF 2, IMF 3, and the final residue. Each extracted component represents distinct local frequency features of the subsurface targets, which are subsequently flattened into one-dimensional feature vectors to preserve critical spatial shape profiles for classification.

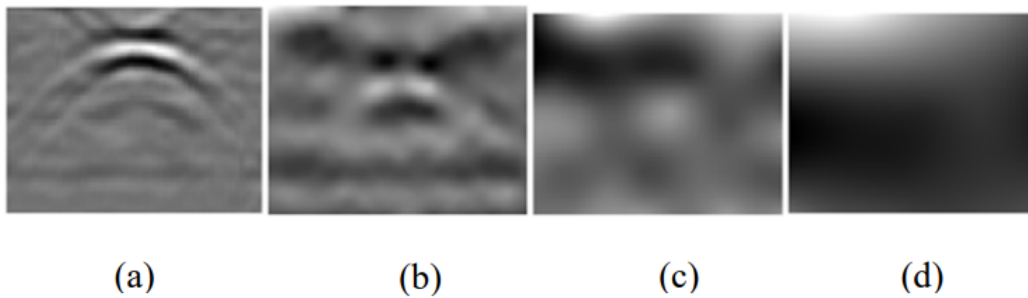


Figure 1.3: Example of BEMD decomposition applied on GPR data, (a) IMF1, (b) IMF2, (c) IMF3 and (d) residue

3.4 Machine Learning Classification

The extracted feature vectors were classified using two core machine learning models, namely k-Nearest Neighbors (k-NN) and a Support Vector Machine (SVM). The k-NN classifier serves as an instance-based baseline model that categorizes data points based on the distance and proximity to neighboring samples in the feature space. In contrast, the SVM classifier utilizes hyperplane margin optimization, which constructs an optimal decision boundary to separate distinct object classes across multi-dimensional feature spaces. Both classifiers were evaluated using a robust 10-fold cross-validation protocol to ensure an unbiased performance validation across the target dataset.

3.5 System Operationalization: The GPR-X Cloud Platform

The processing and classification pipeline was transitioned from a Google Colab development environment into a cloud-hosted web application for broader accessibility. The Python source code, trained models, and dependencies were committed to a GitHub repository for version control and centralized management. This repository was then connected to the Streamlit cloud platform to deploy the application. As shown in Figure 4, the resulting web interface allows users to upload raw GPR data and execute the pre-processing, BEMD extraction,

and SVM classification modules directly through a web browser without requiring localized software installations.

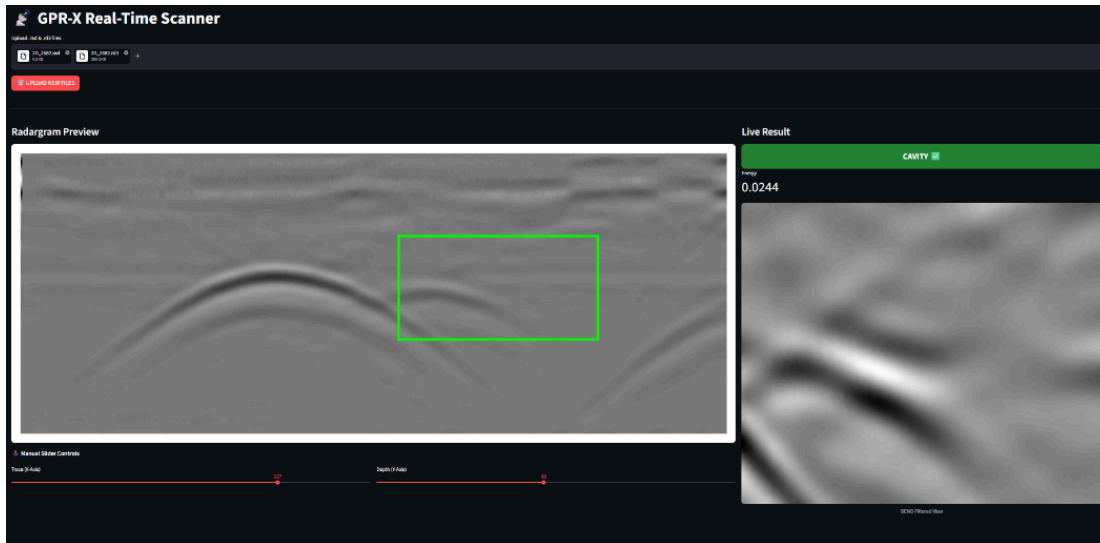


Figure 4: Web Application User Interface showing Live Result Layout

4. Results and discussion

This section presents the performance evaluation of the processing framework using GLCM and BEMD as feature extraction techniques on GPR radargrams implemented with SVM and KNN.

4.1 Performance of GPR on Applied GLCM and BEMD

The feature extraction pipelines produced distinct representations of the GPR radargrams. The GLCM pipeline extracted statistical spatial relationships, yielding a compact 16-dimensional feature vector per image. While rapid to compute, this low-dimensional vector struggled to capture fine structural differences due to texture similarities between the concrete blocks and the surrounding sand.

As shown in Figure 5a, the structural cavity is isolated as a clear hyperbolic curve because the high dielectric contrast of the air void lets BEMD capture a clean boundary in IMF 1. In contrast, the concrete block clutter in Figure 5b displays wider, more diffused oscillations across IMF 1 and IMF 2, reflecting its solid material bulk rather than a sharp apex. For the metallic pipe in Figure 5c, a highly intense, sharp reflection curve is captured as a high-contrast localized anomaly in IMF 1 due to perfect electromagnetic reflection. By filtering slow-varying background trends into the residue, flattening the high-frequency IMF 1 matrix yields a robust 12,000-dimensional feature vector per image that allows classifiers to easily distinguish target shapes from subsurface noise.

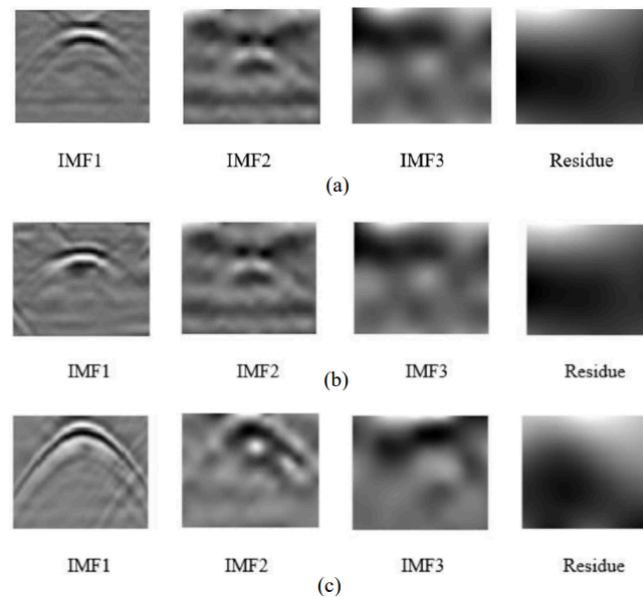


Figure 6: BEMD implementation on GPR profiles: (a) cavity, (b) concrete block, and (c) metal pipe extraction results.

4.2 Experimental Result

The classification performance was evaluated using a 10-fold cross-validation approach across independent GLCM and BEMD feature extraction pipelines. In the first phase, the GLCM technique extracted 16 unique texture features to train the models. As shown in Table 1, the SVM classifier achieved an accuracy of 92.22%, outperforming the baseline k-NN classifier at 88.89%. This indicates that SVM handles multi-dimensional texture vectors more effectively due to its superior margin optimization. However, texture-to-soil signal blending caused misclassifications within the concrete clutter class, where 3 actual cavity samples were falsely classified as concrete structures.

Class	Classifier	Accuracy (%)
GLCM	k-NN	88.89
	SVM	92.22

Table 1.1: Percentage Accuracy of GLCM-Based Features

To improve distinctiveness, the second phase evaluated the BEMD framework. Each radargram profile was dynamically separated into IMF1, IMF2, IMF3, and a structural residue. Because the highest-frequency layer carries the densest structural details, IMF1 was used to preserve critical target geometries while filtering out low-frequency background noise. As summarized in Table 2, this adaptive framework significantly boosted performance: the BEMD-SVM architecture achieved the highest overall accuracy at 98.89%, while the BEMD-k-NN setup reached 97.78%. Notably, the BEMD-SVM combination achieved a perfect 100% recognition rate for both cavity and metal pipe classes (30 out of 30 samples), proving that isolating dominant IMF1 patterns allows the system to clearly separate target hazards in highly cluttered subsurface settings.

Class	Classifier	Accuracy (%)
BEM	k-NN	97.78
D	SVM	98.89

Table 1.2: Percentage Accuracy of BEMD-Based Features

5. Conclusion and Future Research

This study established a systematic workflow to identify subsurface anomalies in noise-affected GPR profiles. By pairing SVM and k-NN classifiers with BEMD and GLCM feature extraction, the pipeline successfully distinguished between buried concrete blocks, metal pipes, and cavities. The BEMD-SVM configuration achieved a peak classification accuracy of 98.89%, outperforming the 92.22% GLCM-SVM baseline and securing a perfect 100% recognition rate for both cavities and metal pipes. This demonstrates that extracting the IMF1 spatial component via BEMD yields a more robust, shape-retaining feature set than texture-based GLCM, which suffered from target-to-soil texture blending.

However, the framework is limited by a restricted laboratory dataset of 90 samples gathered from a uniform, dry sand bed, which lacks the heterogeneous soil, moisture fluctuations, and dense clutter of real field sites. Additionally, the 16-dimensional GLCM feature space showed high sensitivity to background noise. Future work will focus on expanding the GPR database across diverse soil types and moisture conditions to improve model generalization. Furthermore, the pre-trained classifiers will be validated under true field conditions in complex urban zones to ensure operational robustness for automated utility mapping and underground hazard inspection.

Acknowledgment

This study was carried out within the framework of an active Memorandum of Understanding (MOU) between Universiti Malaysia Perlis (UniMAP) and the Malaysian Nuclear Agency. The authors gratefully acknowledge both organizations for granting access to the essential facilities, laboratory equipment, and technical expertise required to execute this work.

References

- GitHub, Inc. (2026). *GitHub Software Repository and Version Control System Platform*.
- Huber, E., & Hans, G. (2018). RGPR — an open-source package to process and visualize GPR Data. *2018 17th International Conference on Ground Penetrating Radar (GPR)*, 1–4. doi:10.1109/icgpr.2018.8441658
- Huang, Z., Xu, G., Tang, J., Yu, H., & Wang, D. (2022). Research on Void Signal Recognition Algorithm of 3D Ground-Penetrating Radar Based on the Digital Image. *Frontiers in Materials*, 9.
- Kang, S., Yu, J. D., Han, W., & Lee, J. S. (2022). Nondestructive Detection of Cavities Beneath Concrete Plates Using Ground Penetrating Radar and Microphone. *NDT & E International*, 130, 102663.
- Lee, J. S., Nguyen, C., & Scullion, T. (2004). A Novel, Compact, Low-Cost, Impulse Ground-Penetrating Radar for Nondestructive Evaluation of Pavements. *IEEE Transactions on Instrumentation and Measurement*, 53(6), 1502-1509.

- Li, F., Yang, F., Xie, Y., Qiao, X., Du, C., Li, C., ... Yong, Z. (2024). Research on 3D ground penetrating radar deep underground cavity identification algorithm in urban roads using multi-dimensional time-frequency features. *NDT & E International*, 143, 103060. doi:10.1016/j.ndteint.2024.103060
- Lu, Q. (2014). Feature Extraction and Automatic Material Classification of Underground Objects from Ground Penetrating Radar Data. *Journal of Electrical and Computer Engineering*, 2014, 206-215.
- Rosdi, M. A. H. M., Othman, A. N., Zubir, M. A. M., Latif, Z. A., & Yusoff, Z. M. (2017). Sinkhole Susceptibility Hazard Zones Using Gis And Analytical Hierarchical Process (Ahp): A Case Study Of Kuala Lumpur And Ampang Jaya. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-4/W5, 145-151.
- Streamlit Development Team. (2026). *Streamlit: The fastest way to build and share data apps*.
- Travassos, X. L., Vieira, D. A. G., Palade, V., & Nicolas, A. (2009). Noise Reduction in a Non-Homogenous Ground Penetrating Radar Problem by Multiobjective Neural Networks. *IEEE Transactions on Magnetics*, 45(3), 1454-1457.
- Wu, X., Senalik, C. A., Wacker, J., Wang, X., & Li, G. (2020). Object Detection of Ground-Penetrating Radar Signals Using Empirical Mode Decomposition and Dynamic Time Warping. *Forests*, 11(2), 230.
- Zhao, W., Forte, E., & Pipan, M. (2016). Texture attribute analysis of GPR data for archaeological prospection. *Pure and Applied Geophysics*, 173(8), 2737–2751. doi:10.1007/s00024-016-1355-3

APPLICATION OF THE ADDIE MODEL IN DEVELOPING BESQ: AN INTERACTIVE WEBSITE FOR SCIENCE LEARNING BASED ON QURANIC WISDOM

Hafizah Abdullah Ali¹, Noor Ain Mohd Faudzi¹, Shakiroh Yaakob¹

¹Kolej Komuniti Bandar Darulaman, Kedah Malaysia

¹Corresponding author's email: hafizah@kkbda.edu.my

ABSTRACT

This study aims to develop and analyse the BESQ interactive website as a digital learning innovation for science education based on the wisdom of the Quran through the application of the ADDIE Model. The website was developed using Google Sites and integrated multimedia elements such as text, images, audio, and Augmented Reality 360° (AR360) technology to enhance a more interactive, visual, and meaningful learning experience. This study employed a qualitative developmental research approach involving document analysis, observation of the development process, and content analysis of the website. The ADDIE Model (Analysis, Design, Development, Implementation, and Evaluation) served as the primary framework to ensure a systematic and structured development process. During the evaluation phase, an expert review was conducted involving three experts who assessed the website's UI/UX and content quality using a Likert-scale instrument. The findings indicated that the BESQ website achieved a high level of usability with an overall mean score of 4.60. The item "Integration of Quran and Science is appropriate" recorded the highest mean score ($M = 5.00$), while "AR360 functions effectively" obtained the lowest mean score ($M = 4.00$), which still falls within the high category. Overall, the findings demonstrate that the application of the ADDIE Model successfully produced an interactive, systematic, and user-friendly digital learning platform. The integration of AR360 technology and Science learning based on Quranic wisdom provided added value in enhancing the learning experience. This study recommends incorporating gamification elements and conducting quantitative studies to evaluate the effectiveness of the platform on students' motivation and academic achievement.

Keywords: ADDIE Model, Interactive Website, AR360, Science, Quran, Digital Learning

1. Introduction

The rapid growth of digital technology has transformed knowledge delivery methods in education. The use of interactive websites as learning platforms has gained increasing attention due to their ability to provide flexible, engaging, and easily accessible learning opportunities anytime and anywhere. In contemporary education, digital technologies not only improve the effectiveness of information delivery but also create more interactive and meaningful learning experiences. Despite this process, many learning resources still rely on conventional text-based materials that provide limited interactivity and visualization, making it difficult for learners to understand abstract scientific concepts. Furthermore, learning materials that integrate scientific knowledge with Quranic perspectives remain limited, and existing digital resources rarely combine interactive web-based learning with immersive technologies such as Augmented Reality (AR). This gap reduces opportunities for students to explore the

relationship between science and the Quran through engaging and meaningful learning experiences.

To address these challenges, the BESQ website was developed as a digital learning innovation that integrates Science concepts with the wisdom of the Quran through web technology and Augmented Reality 360° (AR360). The project was developed using Google Sites to ensure systematic content organization, user-friendly navigation, and accessibility across various devices. The ADDIE Model was selected as the primary framework because of its systematic and structured approach to instructional material development.

2. Literature Review

Previous studies indicate that traditional teaching methods cantered on textual content and theoretical explanations are often less effective in enhancing students' interest and understanding of science, particularly for abstract concepts that are difficult to visualize. Research also suggests that educational technologies integrating Science with Quranic wisdom remain limited, as most digital learning materials focus primarily on academic content without linking it to spiritual values.

Furthermore, there is a lack of interactive, user-friendly, and easily accessible digital learning platforms, resulting in suboptimal utilization in teaching and learning processes. Therefore, technologies such as AR360 and website development based on the ADDIE Model are seen as potential solutions for providing more interactive, visual, and meaningful learning experiences in science education based on Quranic wisdom.

2.1 Technology in Science Teaching and Learning

Previous studies have shown that traditional teacher-centered approaches relying heavily on theoretical explanations are less effective in attracting students' interest in science learning. Such approaches often make it difficult for students to understand abstract concepts that require visualization and meaningful learning experiences (Mayer, 2009; Hattie, 2012; Dahal 2025). In the context of 21st-century education, the integration of educational technology has become essential in enhancing interaction, active engagement, and students' understanding of learning content (UNESCO, 2021). The integration of technology in science education not only increases student motivation but also strengthens conceptual understanding through visualization and simulation (Jonassen, 2011). Therefore, the development of interactive digital learning materials is crucial in supporting effective and student-centered learning.

2.2 Augmented Reality (AR) Technology in Education

Augmented Reality (AR) technology has gained significant attention in education due to its ability to merge real-world and virtual environments interactively. Studies have shown that AR enhances learning experiences by providing 3D visualizations that help students understand abstract concepts more effectively (Tian & Ironsi, 2025; Bacca et al., 2014). AR-based learning has been found to improve students' motivation, interest, and academic achievement by offering immersive and engaging learning experiences (Nikuo, 2026). In this context, AR360 technology has the potential to serve as an effective learning tool that strengthens students' understanding through realistic and interactive visual experiences.

2.3 ADDIE Model in Digital Instructional Material Development

The ADDIE Model) is one of the most widely used instructional design models for developing digital learning materials. The model ensures that instructional materials are developed systematically, structurally, and according to users' needs (Branch, 2009). Previous studies indicate that applying the ADDIE Model in digital learning material development enhances instructional design effectiveness because each phase enables continuous improvement based on user feedback (Molenda, 2003; Zahra et al., 2025). Therefore, the application of the ADDIE Model in developing the BESQ website is appropriate to ensure well-planned, interactive, and user-friendly content.

2.4 Science Education Based on Quranic Wisdom

In Islamic education, integrating revealed knowledge (*naqli*) and rational knowledge (*aqli*) is essential for holistic learning. Studies indicate that value-based Islamic education helps students appreciate the greatness of Allah SWT's creations and enhances spiritual awareness within science learning (Wan Daud, 1998; Al-Attas, 1993). However, previous studies have found a shortage of digital learning materials that systematically integrate Science concepts with Quranic wisdom. Existing resources often emphasize academic content without deeply incorporating spiritual values and Quranic teachings. This situation highlights the need for more holistic and integrated learning platforms.

3. Research Objectives

1. To identify the application of the ADDIE Model in the development of the BESQ interactive website.
2. To describe the development process of the BESQ website based on the phases of the ADDIE Model.
3. To analyse the effectiveness of the interactive elements of the BESQ website based on expert evaluation.

4. Conceptual framework

This conceptual study is based on the relationship between the ADDIE Model, interactive website development, and digital learning based on Quranic wisdom. In this study, the ADDIE Model serves as the primary development framework guiding the planning, design, and development of the BESQ website. Multimedia elements such as AR360, audio, visual content, and interactive navigation are incorporated to enhance users' learning experiences. This approach is expected to support engaging, flexible, and learner-centered learning. The study does not involve quantitative data collection from users but focuses on analysing the innovation development process using a conceptual and instructional development approach.

5. Methodology

This study employed a qualitative research approach focusing on the development of a digital educational product based on the ADDIE Model. Data were collected through document analysis, observation, and content analysis. Document analysis was conducted by reviewing project development documents, including the needs analysis,

instructional design plans, storyboards, and website development records. These documents were examined to ensure that each phase of the ADDIE Model was systematically implemented and documented. Observation was carried out throughout the website development process.

Field notes were recorded to document the implementation of each development stage, design revisions, technical issues encountered, and improvements made during the development of the BESQ website. Content analysis was performed on the completed BESQ website to examine the organization of learning materials, integration of science concepts with Quranic content, website navigation, multimedia elements, and AR360 features. The collected data from documents, observations, and website content were analysed thematically to identify key patterns and evaluate the effectiveness of the development process based on the ADDIE Model.



Figure 1.1: Methodology ADDIE

5.1 Analysis Phase

This phase involved identifying the need for a digital learning website capable of delivering content in a more interactive and comprehensible manner.

5.2 Design Phase

The design phase involved developing the website structure, user interface design, and content layout. Figures 5.2 and 5.3 illustrate the BESQ interface and AR360 features.



Figure 1.2: Main interface of BESQ



Figure 1.3: Element AR360 in BESQ

5.3 Development Phase

In this phase, the BESQ website was developed using Google Sites and integrated with multimedia elements including text, images, audio, and AR360 technology.

5.4 Implementation Phase

The developed website is accessible through computers, tablets, and smartphones.

5.5 Evaluation Phase

Evaluation was conducted formatively through observations and content reviews to ensure proper website functionality. Additionally, expert reviews focusing on UI/UX aspects were carried out. Three experts in educational technology and instructional design participated in the evaluation using a Likert-scale instrument. The assessment focused on UI/UX design, system usability, and multimedia integration. Table 5.1 shows the instrument table for an expert.

Item	1	2	3	4	5
Navigasi mudah digunakan	☐	☐	☐	☐	☐
Reka bentuk menarik	☐	☐	☐	☐	☐
Kandungan mudah difahami	☐	☐	☐	☐	☐
AR360 berfungsi dengan baik	☐	☐	☐	☐	☐
Integrasi Al-Quran & Sains sesuai	☐	☐	☐	☐	☐

Table 5.1: Instrument for an expert

6. Findings and Discussion

6.1 Expert Evaluation Findings (Mean Analysis)

Expert evaluation results were analysed using descriptive statistics, specifically mean scores for each assessment construct. Referring to Table 6.1, the item “Integration of Quran and Science is appropriate” obtained the highest mean score of 5.00, indicating strong expert agreement regarding the effectiveness of the integration approach.

Item	Expert 1	Expert 2	Expert 3	Mean	Interpretation Level
Easy Navigation	5	4	5	4.67	High
Attractive Design	5	5	4	4.67	High
Content is Easy to Understand	4	5	5	4.67	High
AR360 Functions Effectively	4	4	4	4.00	High
Integration of Quran and Science is Appropriate	5	5	5	5.00	Very High
Overall Average				4.60	High

Table 6.1: Expert evaluation findings on UI/UX

Meanwhile, the item “AR360 functions effectively” recorded the lowest mean score of 4.00, although it still falls within the high category. Overall, the average mean score of 4.60 indicates that the BESQ website possesses good usability, design quality, and content suitability.

6.2 Discussion Based on the ADDIE Model

The findings reveal that the ADDIE Model facilitated a systematic, organized, and structured website development process. Each phase contributed significantly to ensuring that the website met the intended learning objectives.

During the Analysis phase, researchers successfully identified the need for a more interactive and user-friendly digital learning platform. The integration of AR360 technology emerged as a key innovative feature, enabling users to explore learning content in a realistic and interactive manner.

Furthermore, integrating Quranic verses with science content added educational value to the platform. This approach not only enhanced scientific understanding but also encouraged appreciation of Allah SWT’s greatness. The study demonstrates that interactive website development based on the ADDIE Model supports national digital education initiatives, particularly in STEM and TVET education.

7. Conclusion and Recommendations

Several improvements can be implemented to strengthen the BESQ website in the future. These include incorporating specific gamification elements such as interactive quizzes with immediate feedback, scoring systems to track learners’ progress, achievement badges to recognize learning milestones, and challenge-based activities to increase learner engagement. Future quantitative studies may investigate the effectiveness of these gamification elements by measuring their impact on students’ motivation, engagement, learning satisfaction, and academic achievement through surveys, pre-test and post-test comparisons, or statistical analysis.

Overall, the development of the BESQ website successfully demonstrates the application of the ADDIE Model in creating a systematic, interactive, and user-friendly digital learning platform. The integration of multimedia elements, AR360 technology, and Science learning based on Quranic wisdom provides significant added value to users’ learning experiences.

The study confirms that the ADDIE Model is suitable for educational innovation development as it ensures that each development phase is carefully planned and aligned with learning objectives. Beyond supporting digital education transformation, BESQ has the potential to serve as a reference model for future digital learning platforms integrating revealed and rational knowledge. This approach is expected to contribute to the development of a more creative, holistic, and 21st-century-oriented digital education ecosystem.

References

- Al-Attas, S. M. N. (1993). *Islam and secularism*. ISTAC.
- Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk. (2014). Augmented reality trends in education. *Educational Technology & Society*, 17(4), 133–149.
- Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.
- Dahal, B. K. (2025). *Concept mapping method on students' achievement in science education at higher level* (Doctoral dissertation).
- Hattie, J. (2012). *Visible learning for teachers*. Routledge.
- Hussin, A. A. (2018). Education 4.0 Made Simple: Ideas for Teaching. *International Journal of Education and Literacy Studies*, 6(3), 92-98.
- Jonassen, D. H. (2011). *Learning to solve problems with technology*. Pearson.
- Mayer, R. E. (2009). *Multimedia learning*. Cambridge University Press.
- Molenda, M. (2003). In search of the elusive ADDIE model. *Performance Improvement*, 42(5), 34–37.
- Nikou, S. A. (2026). Motivation as a driver of engagement in augmented-reality learning in primary schools. *TechTrends*, 70(2), 398-410.
- Tian, X., & Ironsi, C. S. (2025). Examining the impact of augmented reality on students' learning outcomes. *Scientific Reports*, 15(1), 36957.
- UNESCO. (2021). *Reimagining our futures together: A new social contract for education*.
- Wan Daud, W. M. N. (1998). *The educational philosophy and practice of Syed Muhammad Naquib al-Attas*. ISTAC.
- Zahra, O. F., Amel, N., & Mohamed, K. (2025). Design and Implementation of an Online Training Course on Moodle Using the ADDIE Model: Focus on Communication Tools. *Innovations in Pedagogy and Technology*, 1(3), 120-135.

E-PROCEEDING OF INNOFEST

eISBN 978-629-7803-10-4



9 786297 803104

Politeknik Sandakan Sabah
(online)

PROCEEDINGS OF INNOFEST 2026

INVENTING TOMORROW: SUSTAINABLE SOLUTIONS THROUGH INGENUITY

**POLITEKNIK SANDAKAN SABAH
(ONLINE)**