

AN INTERNATIONAL INNOVATION COMPETITION SHOWCASING MULTIDISCIPLINARY IDEAS AND IMPACTFUL SOLUTIONS



2ND OPEN INTERNATIONAL INNOVATIONS CHALLENGE

e-Proceedings

OF OPIIC 2026

Empowering Society through Inclusive and Sustainable Innovations

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(OpIIC 2026)

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FOREWORD FROM RECTOR

Assalamualaikum warahmatullahi wabarakatuh.

It is indeed a great honour and privilege to be part of this exciting journey of innovation and creativity. This year's theme, **“Empowering Society through Inclusive and Sustainable Innovations,”** provides a meaningful platform for us to explore transformative ideas that will shape the future of our societies and improve the quality of life for all.

First and foremost, I would like to extend my heartfelt appreciation to the dedicated organizing committee from the Department of Computer and Mathematical Sciences, Universiti Teknologi MARA, Pulau Pinang Branch, together with our esteemed collaborators, Universitas Airlangga, Indonesia, and Universitas Brawijaya, Indonesia. Your unwavering commitment, hard work, and pursuit of excellence have made OpIIC2026 a reality.

Our participants' involvement reflects a shared passion for innovation and a collective commitment to addressing some of the most pressing challenges facing our urban environments today. The diversity of ideas, perspectives, and expertise gathered here is truly inspiring, and I am confident that the innovations developed throughout this challenge will be both impactful and transformative.

I encourage each of you to connect with one another, exchange knowledge, and push the boundaries of innovation. May your innovations contribute to building a more sustainable and resilient future.



Finally, I would like to express my sincere appreciation to the organizing committee, our collaborators, and everyone who has worked tirelessly behind the scenes to ensure the success of this event.

Thank you.

Professor Dato' Ir. Dr. Hj. Ahmad Rashidy Razali

Rector

Universiti Teknologi MARA, Pulau Pinang Branch

FOREWORD FROM ADVISOR

Assalamualaikum warahmatullahi wabarakatuh.

As the Advisor of OpIIC2026, I am truly honoured to be part of this meaningful journey. I would like to express my sincere appreciation to the OpIIC2026 organising committee for their hard work. My heartfelt thanks also go to our collaborators from Universitas Airlangga and Universitas Brawijaya, Indonesia, for your trust, cooperation, and partnership.

The true value of innovation is not always measured by a medal or a certificate. Sometimes, the greatest achievement is knowing that your idea has helped someone, solved a problem, or inspired another person to think differently. That is when innovation becomes truly meaningful.

The theme of OpIIC2026, **“Empowering Society through Inclusive and Sustainable Innovations,”** carries a powerful message. Innovation should not belong only to those with advanced technology or abundant resources. Innovation should belong to everyone. It should reach our communities, include those who are often left behind, and protect the world we leave for the next generation.

A meaningful innovation is therefore not simply something new. It is something that is useful, inclusive, sustainable, and capable of creating positive change. When innovation begins with empathy, technology becomes more than a tool. It becomes a force for humanity.



May this platform create new connections, meaningful collaborations, lasting friendships, and ideas that continue to grow long after this event ends.

To every participant, be proud of what you have created. Be proud of the journey that brought you here. And most importantly, keep innovating.

Thank you.

Dr. Nor Hanim Abd Rahman

Advisor of 2nd Open International Innovations Challenge 2026 (OpIIC2026)
Department of Computer and Mathematical Sciences
Universiti Teknologi MARA, Pulau Pinang Branch

FOREWORD FROM CHAIRMAN

Assalamualaikum warahmatullahi wabarakatuh.

Innovation is most meaningful when it reaches people. It should widen access, strengthen communities and protect the resources that future generations will depend on. This conviction lies at the heart of the Open International Innovations Challenge 2026 (OpIIC2026), held under the theme **“Empowering Society through Inclusive and Sustainable Innovations.”**

This year’s theme asks innovators to look beyond novelty and consider who benefits from their ideas and for how long. An innovation is inclusive when it leaves no community behind. It is sustainable when its value endures economically, socially and environmentally.

OpIIC2026 brought together students, academics, researchers and practitioners from Malaysia and abroad. Their submissions show that creativity guided by empathy and responsibility can turn local problems into solutions relevant well beyond their borders.

These proceedings document this collective effort. We hope readers will find practical insights, promising directions for further research, and opportunities for collaboration and commercialisation. The value of a challenge like OpIIC lies not only in the recognition it gives but in the conversations and partnerships it starts.

On behalf of the organising committee, I extend my sincere appreciation to all participants, judges, reviewers, our international collaborating institutions, sponsors and supporters.



I also thank the Department of Computer and Mathematical Sciences, Universiti Teknologi MARA Cawangan Pulau Pinang, for its continued commitment to this programme.

Let us continue to innovate together, inclusively and sustainably, for a better shared future.

Thank you.

Dr. Azhar Ahmad

Chairman of 2nd Open International Innovations Challenge 2026 (OpIIC2026)
Department of Computer and Mathematical Sciences
Universiti Teknologi MARA, Pulau Pinang Branch

PREFACE FROM CHIEF EDITOR

Assalamualaikum warahmatullahi wabarakatuh.

Greetings and warm regards to all.

It is with great pleasure that I welcome you to the e-Proceedings of the Open International Innovations Challenge 2026 (OpIIC2026), themed **“Empowering Society Through Inclusive and Sustainable Innovations.”**

As the Chief Editor, I am honoured to present this collection of extended abstracts, which reflects the creativity, dedication, and innovative thinking of the contributors. Spanning diverse disciplines, these contributions demonstrate how ideas and knowledge can be transformed into innovative solutions that address contemporary challenges.

The theme emphasises innovation that goes beyond novelty. Meaningful innovation should be inclusive, sustainable, and responsive to the needs of society. The ideas presented in these proceedings offer perspectives and solutions that have the potential to contribute to a more sustainable and empowered society.

I extend my sincere appreciation to all authors, participants, evaluators, reviewers, collaborators, and members of the organising committee for their invaluable contributions and commitment.



It is my sincere hope that these ideas and innovations will inspire further research, collaboration, and practical applications. I wish you an inspiring and enriching reading experience.

Thank you.

Maisurah Shamsuddin

Chief Editor of 2nd Open International
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SECTION 1

CIVIL ENGINEERING



Building smarter solutions for a better future.

Firelite Mortar: A Sustainable Lightweight Fire Resistant Mortar

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Abstract

Firelite Mortar is an innovative, eco-friendly cementitious composite designed to address concrete's excess self-weight and post-fire structural degradation. It incorporates Ground Granulated Blast Furnace Slag (GGBS) as a sustainable binder and Expanded Perlite Aggregate (EPA) as a lightweight thermal insulator. This study evaluated the fresh, physical and residual mechanical performance of mixes containing 0% (CC0), 30% (CC30), and 50% (CC50) GGBS replacement subjected to room and elevated temperatures for 1 to 2 hours. GGBS incorporation significantly enhanced workability, increasing flowability from 113.3 mm (CC0) to a peak of 253.3 mm (CC30). Under thermal exposure, mass loss ranged from 5–10% due to moisture evaporation and from 9–11.5% due to hydration phase breakdown. Despite thermal stress, CC30 demonstrated superior residual endurance, achieving a peak of 254.79% residual flexural strength retention and retained 149.89% residual flexural strength and 109.95% compressive strength after 2 hours (56 days). The CC30 mix delivers an optimal balance of workability, thermal stability, and residual strength for fire-rated construction.

Keywords: Firelite Mortar; GGBS; Expanded Perlite Aggregate; Flowability; Mass Loss; Residual Strength.

1. INTRODUCTION

Lightweight mortar has gained significant attention in the construction industry due to its reduced self-weight, superior thermal insulation, and potential to enhance the sustainability of building materials. Expanded Perlite Aggregate (EPA) is widely used as a lightweight aggregate because of its porous structure and excellent heat resistance. However, its high porosity may reduce the mechanical strength of mortar (Liu et al., 2022). Ground Granulated Blast Furnace Slag (GGBS), a supplementary cementitious material, has been extensively used to improve the durability, strength, and long-term performance of cement-based materials while reducing cement consumption and environmental impact (Jiang et al., 2022; Mohamedsalih et al., 2025).

Previous studies have investigated the performance of expanded perlite mortar and GGBS separately under elevated temperatures (Liu et al., 2022; Soares et al., 2025). However, limited research has examined the combined use of EPA and GGBS in lightweight mortar, particularly regarding both physical and mechanical performance after thermal exposure (Bao et al., 2023; Soares et al., 2025). Therefore, this study aims to investigate the effect of incorporating GGBS into expanded perlite-based lightweight mortar exposed to elevated temperatures and to determine the optimum GGBS replacement level for improved thermal resistance.

2. MATERIALS AND METHODS

Three mortar mixtures were prepared, namely CC0, CC30, and CC50, containing 0%, 30%, and 50% GGBS as partial cement replacement, respectively, while maintaining a constant 20% replacement of natural sand with Expanded Perlite Aggregate (EPA). Ordinary Portland Cement (OPC), silica sand, GGBS, EPA, water, and a superplasticizer were used in all mixtures. The water-to-binder ratio and sand-to-binder ratio were maintained at 0.5 and 2.5, respectively.

Fresh mortar specimens were mixed according to ASTM C305 and evaluated using the ASTM C1437 flow table test before casting into prism moulds measuring $40 \times 40 \times 160$ mm and $100 \times 100 \times 100$ mm cubes. After demoulding, the specimens were water-cured for 28 and 56 days before being exposed to temperatures of 28°C, 200°C, and 400°C for one and two hours. The mass loss of the hardened specimen was determined, while flexural strength, compressive strength, and splitting tensile strength tests were conducted to evaluate the residual mechanical performance after heating.

3. RESULTS AND DISCUSSIONS

This study investigates the effects of GGBS replacement and elevated temperature exposure on the fresh and hardened properties of cement mortar, with particular emphasis on the influence of curing age and exposure duration on residual mechanical performance. The incorporation of GGBS significantly improved the flowability of the mortar, with the flow diameter increasing from 113.3 mm for CC0 to 253.3 mm for CC30, before slightly decreasing to 240.6 mm for CC50, as shown in Figure 1. The observed improvement in flowability is broadly consistent with Jiang et al. (2022), who reported the beneficial effect of supplementary cementitious materials on mortar workability.

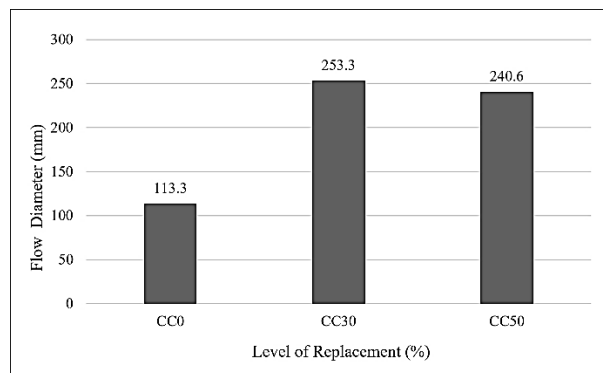


Figure 1. Flow Diameter of Mortar Mixtures at Different GGBS Replacement Levels.

Mass loss generally increased with exposure temperature, with higher values observed at 400°C due to the evaporation of free and chemically bound water. Similar thermal deterioration and changes in physical properties have been reported in cement-based materials exposed to elevated temperatures (Bao et al., 2023). Figure 2 presents the mass loss of the mortar mixtures at 28 and 56 days of curing after 1-hour and 2-hour exposure. At 28 days, the highest mass loss was 11.52% for CC50 exposed at 400°C for 2 hours, while at 56 days, the mass loss at 400°C ranged from 9.17% to 10.18%. These results demonstrate that elevated temperature and prolonged exposure contributed to moisture loss and thermal degradation of the mortar matrix.

The residual mechanical performance of the mortar was influenced by exposure temperature, exposure duration, curing age, and GGBS replacement. At 28°C, all mixtures retained approximately 100% of their initial flexural, compressive, and splitting tensile strengths. Similar reductions in residual mechanical properties following elevated-temperature exposure have been reported for lightweight cement-based

materials (Liu et al., 2022).

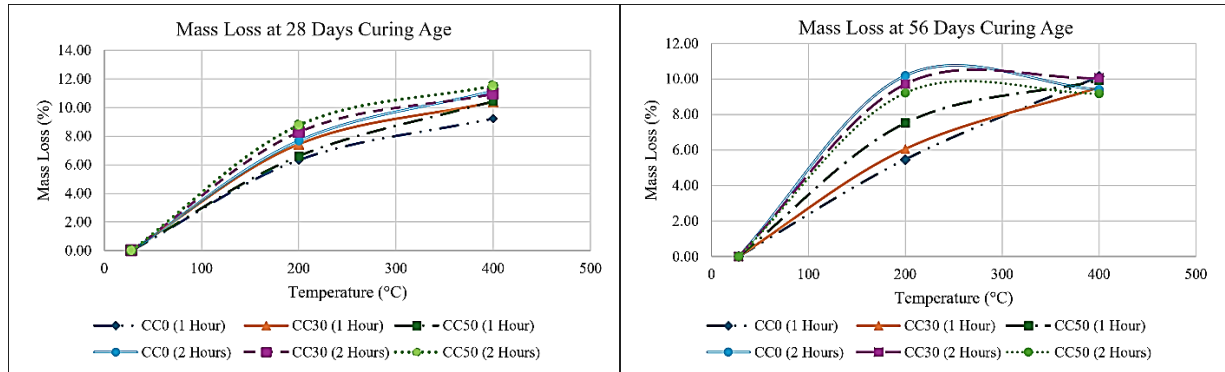


Figure 2. Mass Loss of Mortar Mixtures at 28 and 56 Days of Curing After Exposure to Elevated Temperatures for 1 and 2 Hours.

At 28 days of curing, the 1-hour exposure resulted in variable strength retention as the temperature increased to 200°C. Figure 3 presents the residual flexural, compressive, and splitting tensile strengths after 1-hour and 2-hour exposure at different temperatures for the 28-day curing age. CC30 showed relatively high residual compressive strength (167.94%), while CC0 exhibited a substantial reduction in splitting tensile strength to 26.72%. At 400°C, the residual strengths generally decreased, particularly for splitting tensile strength. Extending the exposure duration to 2 hours caused further deterioration in CC0, with splitting tensile strength decreasing to 27.98% at 200°C and 21.90% at 400°C. In comparison, CC30 generally maintained higher residual strengths, particularly in compression and splitting tensile strength, indicating better resistance to prolonged heating.

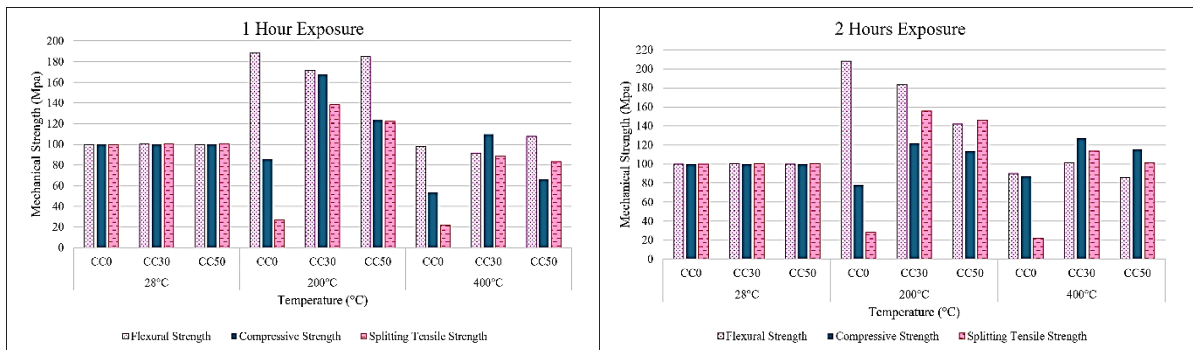


Figure 3. Residual Flexural, Compressive, and Splitting Tensile Strengths of CC0, CC30, and CC50 Lightweight Mortars After Exposure to Elevated Temperatures for 1 and 2 Hours at 28 Days of Curing.

An improvement in residual strength retention was generally observed at 56 days of curing, although some variations occurred depending on the mixture and exposure condition. Figure 4 presents the residual flexural, compressive, and splitting tensile strengths after 1-hour and 2-hour exposure at different temperatures for the 56-day curing age. Under 1-hour exposure at 200°C, CC30 demonstrated good residual strength performance, with values of 178.36% in flexure, 164.54% in compression, and 163.66% in splitting tensile strength. However, CC50 recorded a higher residual compressive strength of 222.95% under the same exposure condition. At 400°C, CC30 generally maintained relatively high residual strengths compared with CC0, particularly for flexural and compressive strengths.

Increasing the exposure duration to 2 hours resulted in mixed changes in residual strength, with reductions observed in several conditions, particularly at 400°C, although some strength increases were observed at 200°C. CC30 continued to demonstrate relatively consistent residual mechanical performance across the

different exposure conditions. The observed influence of GGBS on residual strength is broadly consistent with findings reported by Rawat et al. (2025), where GGBS-based mixtures demonstrated enhanced post-fire strength recovery. Overall, longer exposure generally increased thermal deterioration, particularly at 400°C, while the 56-day specimens generally demonstrated better resistance to elevated temperatures than the 28-day specimens.

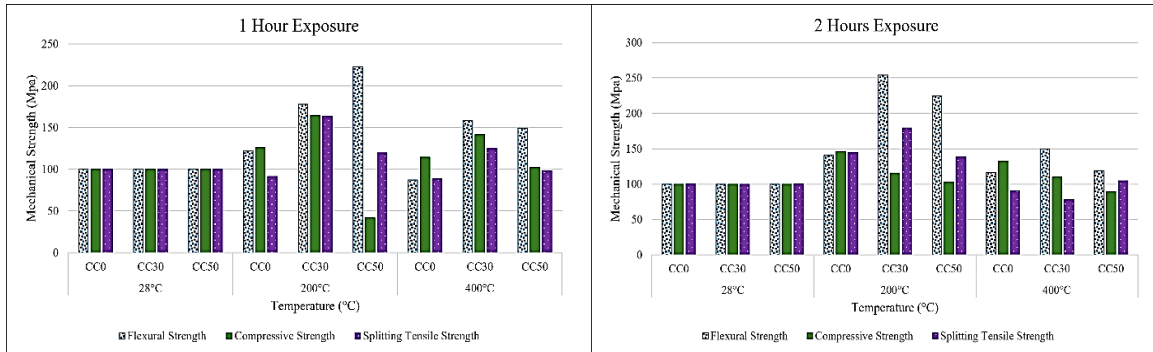


Figure 4. Residual Flexural, Compressive, and Splitting Tensile Strengths of CC0, CC30, and CC50 Lightweight Mortars After Exposure to Elevated Temperatures for 1 and 2 Hours at 56 Days of Curing.

Overall, the 56-day specimens generally performed better than the 28-day specimens, while 2-hour exposure generally resulted in greater thermal deterioration, particularly at 400°C. Among the mixtures, CC30 showed the most consistent residual mechanical performance, particularly under prolonged elevated-temperature exposure.

4. CONCLUSION

This study evaluated the effects of GGBS replacement, curing age, exposure temperature, and exposure duration on the performance of expanded perlite-based lightweight mortar. The GGBS incorporation improved the flowability of the mortar, while elevated temperature exposure generally increased mass loss and affected the mechanical performance of the mortar. Longer exposure generally resulted in greater thermal deterioration, particularly at 400°C, although some strength increases were observed under specific conditions at 200°C. The 56-day specimens generally demonstrated better residual strength performance than the 28-day specimens. Across the three mixtures, CC30 exhibited the most consistent overall residual mechanical performance, particularly under prolonged elevated-temperature exposure. These findings indicate that 30% GGBS replacement provides a promising balance between fresh-state performance and resistance to elevated-temperature exposure, supporting its potential for producing more sustainable lightweight mortar with improved thermal resistance.

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RiverCare: A Community-Based Digital Platform for River Monitoring ‘Observe - Report - Protect’

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Abstract

Rivers play an important role in supporting ecosystems, public health, and local communities. Effective river monitoring is therefore essential to ensure that river issues can be identified and addressed at an early stage. RiverCare is introduced as a conceptual digital platform that encourages community participation in river monitoring through a simple QR code reporting system. The objective of this innovation is to provide an accessible and affordable platform that allows members of the public to report river issues and helps the relevant authorities receive information more quickly. Users are expected to scan a QR code, upload a photograph, share their GPS location, and submit a short report using a smartphone without installing a mobile application. The submitted information is intended to be organised in a central monitoring portal for review by the relevant authorities. The conceptual platform is expected to improve river issue reporting, increase public awareness, and strengthen collaboration between local communities and the relevant authorities. Future development may include GIS mapping, notification features, report tracking, and data analysis tools to support more effective river monitoring and better decision making.

Keywords: River monitoring; Community participation; Digital platform; QR code; Sustainable river management.

1. INTRODUCTION

Rivers play an important role in supporting ecosystems, public health, economic activities, and local communities. However, increasing urban development and human activities continue to place pressure on river environments. Problems such as water pollution, improper waste disposal, riverbank erosion, blocked drainage, and fallen trees may affect river health and increase environmental and flood risks if they are not identified and addressed early. Regular monitoring is therefore important for effective and sustainable river management.

Conventional river monitoring commonly relies on field inspections, scheduled surveys, and public complaints. Although these methods remain important, they depend on the availability of staff, time, and resources. Community participation can complement existing monitoring by providing observations from different locations and at different times. Shao and Bishop (2025) highlighted the growing role of citizen science in river monitoring, while Blanco Ramírez et al. (2023) showed that public participation can provide useful additional information for water quality monitoring.

The use of smartphones and web technologies has created more opportunities for community involvement in environmental monitoring. Jovanovic et al. (2019) showed that mobile and web technologies can simplify the collection and management of environmental data, while Malthus et al. (2020) demonstrated the potential of smartphone applications for inland water monitoring. Win et al. (2019) also showed that a low cost participatory approach can improve monitoring coverage where conventional resources are limited. In addition, Carrion et al. (2021) and Sulistiyowati and Uyun (2024) demonstrated how mobile and web based platforms can support citizen observations and the management of water related information. Despite these developments, many existing systems focus mainly on water quality measurements, observations, or applications and supporting equipment. There is still a need for a simple reporting approach that allows the public to report river issues directly and easily.

To address this need, RiverCare is introduced as a conceptual digital platform for community based river monitoring. The platform allows users to scan a QR code, upload a photograph, share the GPS location, select the type of issue, and submit a short report using a smartphone without installing a application. The information is then organised through a central monitoring portal for review and follow up by the relevant authorities. RiverCare aims to support early identification of river issues, improve public participation, and strengthen collaboration between local communities and responsible authorities.

2. MATERIALS AND METHODS

2.1. Innovation Design

RiverCare is a conceptual digital platform designed to support community participation in river monitoring. The design focuses on a simple reporting process that can be accessed by the public without installing a mobile application. Users can report river issues by scanning a QR code using a smartphone and submitting the required information through an online form.

2.2. Platform Workflow

The conceptual RiverCare workflow consists of four main stages. First, a community member scans the QR code placed at a river location. Next, a photograph of the identified issue is uploaded together with the GPS location and a brief description. The report is then submitted to the RiverCare monitoring portal for review by the relevant authority. The final stage involves determining the appropriate action. Figure 1 illustrates the conceptual workflow of RiverCare.

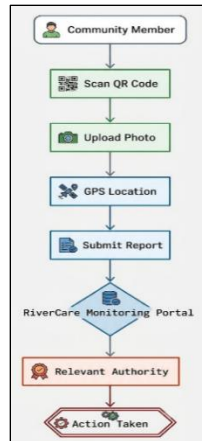


Figure 1. Conceptual workflow of RiverCare.

2.3 Materials

The conceptual RiverCare platform requires commonly available digital resources. A smartphone with a camera and internet connection is needed to access the reporting page through a QR code. The reporting form includes a photograph, GPS coordinates, issue category, a brief description, and the date and time of submission. The conceptual monitoring portal is included to organise the submitted information for review by the relevant authorities.

2.4 Development Method

The conceptual development of RiverCare consists of four stages. The first stage involves identifying common river management issues through a review of relevant literature and current monitoring practices. The second stage focuses on designing the reporting workflow and user interface. The third stage involves preparing the conceptual design of the reporting platform and monitoring portal. The final stage involves reviewing the conceptual workflow to ensure that the reporting process is simple, accessible, and suitable for community use.

2.5 Proposed System Architecture

The conceptual architecture of RiverCare follows a simple information flow. Members of the public submit reports through a QR code using a smartphone. The submitted information is directed to the RiverCare monitoring portal, where it can be organised and reviewed by the relevant authorities. This information flow is intended to support the identification of reported river issues and assist the relevant authorities in planning the appropriate response.

3. RESULTS AND DISCUSSION

3.1 RiverCare Reporting Interface

The RiverCare reporting interface is conceptually designed to provide a simple and clear reporting process for members of the public. The interface focuses on the essential information required for river monitoring, including photographs, GPS location, issue category, and a brief description.

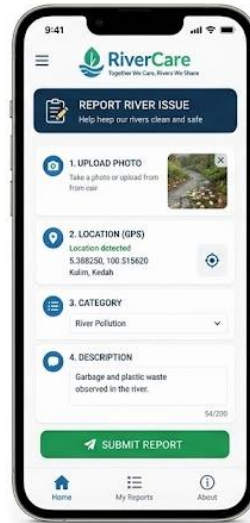


Figure 2. Conceptual design of the RiverCare Mobile Reporting Interface.

Figure 2 presents the conceptual design of the RiverCare mobile reporting interface. The interface illustrates how users can upload a photograph, share their current GPS location, select the issue category, and provide a brief description before submitting a report. The simple and user-friendly layout is intended to make the reporting process more accessible without requiring a dedicated mobile application.

3.2 RiverCare Monitoring Portal

The conceptual design of the RiverCare monitoring portal is intended to organise submitted reports in a central platform. The portal is designed to provide a clear overview of reported locations, issue categories, submission dates, and report status. Figure 3 presents the conceptual design of the monitoring portal, illustrating how reported information can be reviewed systematically to support the relevant authorities in identifying locations that require inspection or further action. The RiverCare monitoring portal was developed to organise all submitted reports in one central platform. The portal provides a clear overview of reported locations, issue categories, submission dates, and report status.



Figure 3. Conceptual design of the RiverCare Monitoring Portal.

Figure 3 presents the conceptual design of the RiverCare monitoring portal. The portal is designed to organise submitted reports, display their locations, and support the relevant authorities in reviewing and managing reported river issues systematically.

3.3 Comparison with Existing Practice

A comparison was made between conventional reporting practices and the RiverCare platform to highlight the main improvements introduced by the innovation. A comparison between conventional river monitoring and the proposed RiverCare platform was carried out to highlight the key improvements introduced by the innovation, as shown in Table 1.

Table 1. Comparison between Conventional River Monitoring and RiverCare.

Criteria	Conventional River Monitoring	RiverCare
Reporting Method	Public complaints, telephone calls, or field inspections	QR Code Reporting
User Access	Multiple reporting channels	Direct access through QR code
Reporting Interface	Manual reporting process	RiverCare Reporting Interface
Location Information	Location provided manually	GPS Location Sharing
Supporting Evidence	Limited photographs	Photograph Upload
Data Management	Records stored through different communication channels	RiverCare Monitoring Portal
Community Participation	Passive participation	Active community participation
Information Management	Manual review and record keeping	Central Monitoring Portal

Table 1 shows that RiverCare provides a simpler reporting process through direct QR code access. Photographs, location details, and report information are collected through one platform and organised in a central monitoring portal. The approach can improve information sharing between local communities and the relevant authorities.

4. CONCLUSION

RiverCare presents a conceptual digital platform that aims to improve community participation in river monitoring through a simple QR code reporting process. The proposed concept allows users to upload photographs, share GPS locations, and provide a brief description of river issues through a smartphone. The reported information is intended to be organised in a central monitoring portal to support systematic review by the relevant authorities. Compared with conventional reporting methods, the conceptual design of RiverCare offers a more accessible and organised approach to river issue reporting without requiring a mobile application. Future development may include notification features, data analysis tools, and integration with existing river management systems to further enhance monitoring and decision making.

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EcoSand: Enhanced Strength Sustainable Mortar

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Abstract

EcoSand is a sustainable mortar developed by incorporating Palm Oil Fuel Ash, POFA, as a partial replacement for natural sand. The innovation was developed to reduce the consumption of natural sand while improving the strength performance of conventional mortar. Mortar mixtures containing 0%, 1%, 3%, 5% and 7% POFA were prepared using a constant cement content, water cement ratio and superplasticizer dosage. Compressive strength tests were carried out at curing ages of 3, 14, 28 and 56 days to evaluate the influence of POFA replacement on strength development. The results showed that POFA affected mortar strength depending on the replacement percentage and curing age. At 28 days, the mortar containing 7% POFA achieved the highest compressive strength of 39.42 MPa compared with 33.78 MPa for the control mortar, representing an improvement of approximately 16.7%. The increase in strength may be due to the fine POFA particles that contribute to better particle packing and fill voids within the mortar matrix. EcoSand demonstrates the potential of palm oil industry waste to produce stronger and more sustainable mortar while reducing dependence on natural sand. Further work should focus on mix optimization, product quality improvement, and larger scale production for potential commercial application.

Keywords: Palm Oil Fuel Ash; Sustainable Mortar; Compressive Strength; Sand Replacement; Green Construction.

1. INTRODUCTION

Mortar is one of the most widely used materials in construction, particularly for masonry, plastering, rendering and repair works. Its performance is strongly influenced by the properties of cement, water and fine aggregate, where natural sand remains the main material used as fine aggregate. However, the growing demand for construction materials has increased the consumption of natural sand and raised concerns over excessive extraction, resource depletion and environmental degradation. Wan Ahmad et al. (2020) highlighted that increasing sand mining activities can contribute to environmental impacts and reduce the availability of natural sand resources.

The use of alternative materials from industrial and agricultural waste has therefore gained greater attention as part of sustainable construction practices. Palm Oil Fuel Ash (POFA), is one of the agricultural by products generated from the combustion of palm oil fibres and shells in palm oil mills. Large quantities of POFA are produced in palm oil producing countries, and much of this material is still treated as waste. Its

incorporation into construction materials offers an opportunity to reduce waste disposal while reducing the dependency on raw materials (Amran et al., 2021; Hamada et al., 2018).

Previous studies have shown that POFA has characteristics that can improve the performance of cement based materials when used at suitable proportions. Fine POFA particles can fill voids between larger particles and improve particle packing within the mortar matrix. Jaturapitakkul et al. (2011) reported that finely ground POFA contributes through both filler effects and pozzolanic reactions, which can enhance the development of compact mortar structure. Similar findings were reported by Saffuan et al. (2017), where POFA used as a fine aggregate replacement showed potential to improve the performance of cement based materials.

The effect of POFA on mortar performance is also influenced by its particle size, replacement level and curing period. Hamada et al. (2019) noted that the incorporation of POFA in mortar can provide beneficial effects when a suitable replacement level is used. More recently, Zaimi et al. (2023) reported that POFA used as partial fine aggregate replacement has the potential to improve fresh and hardened mortar properties. Liew et al. (2024) further showed that POFA particle fineness plays an important role in its reactivity and strength development.

Despite these good findings, the use of POFA as a partial replacement for natural sand in mortar is still less explored compared with its application as a cement replacement material. Therefore, EcoSand was developed as a sustainable mortar incorporating POFA as partial sand replacement. This study focuses on evaluating the effect of different POFA replacement levels on compressive strength and identifying a suitable percentage that can improve strength performance while reducing the use of natural sand. EcoSand was developed to transform palm oil waste into a value added mortar with enhanced strength performance and reduced dependence on natural sand.

2. MATERIALS AND METHODS

Ordinary Portland Cement, natural river sand, Palm Oil Fuel Ash, water and superplasticizer were used in the preparation of EcoSand mortar. The POFA was obtained from United Palm Oil Mill in Nibong Tebal, Pulau Pinang.

Five mortar mixtures were prepared using POFA as a partial replacement for natural sand at replacement levels of 0%, 1%, 3%, 5% and 7%. The 0% POFA mixture was used as the control mortar. A mortar mix ratio of 1:3 was adopted, while the water cement ratio and superplasticizer dosage were maintained consistently for all mixtures to provide comparable testing conditions. A total of 60 mortar cubes measuring 50 mm × 50 mm × 50 mm were prepared for compressive strength evaluation. After casting, the specimens were demoulded after 24 hours and subsequently water cured until the required testing age.

Compressive strength testing was conducted at 3, 14, 28 and 56 days in accordance with ASTM C109. Three specimens from each mixture were tested at each curing age, and the average compressive strength was used to evaluate the effect of POFA replacement. The original experimental programme also included physical characterization, workability, water absorption, density, porosity and microstructural assessment. However, this innovation focuses specifically on compressive strength as the main performance indicator for EcoSand. All materials and methods that have been used in the work must be stated clearly and subtitles should be used when necessary.

3. RESULTS AND DISCUSSION

3.1. Compressive Strength Performance

The compressive strength results showed that the incorporation of POFA influenced the strength development of mortar at different curing ages. The effect varied with both POFA replacement level and curing period, indicating that increasing the amount of POFA did not necessarily result in a continuous increase in strength.

Figure 1 presents the compressive strength development of mortar containing different POFA replacement levels at various curing ages. At Day 28, the 7% POFA mixture achieved the highest compressive strength of 39.42 MPa, compared with 33.78 MPa for the control mortar. This represents an improvement of approximately 16.7%, indicating that POFA can enhance mortar strength when used at an appropriate replacement level. The improvement may be attributed to the finer POFA particles, which can fill spaces between larger particles and improve particle packing within the mortar matrix. This behaviour is consistent with the filler effect and pozzolanic contribution of POFA reported in previous studies (Jaturapitakkul et al., 2011; Hamada et al., 2018).

Strength development was also observed at later curing ages. At Day 56, the 5% POFA mixture recorded the highest compressive strength of 40.97 MPa, followed by the 3% POFA mixture at 38.51 MPa. This suggests that the contribution of POFA to mortar strength depends not only on the replacement level but also on the curing period.

Overall, the results demonstrate the potential of POFA as a partial sand replacement in mortar. Among the mixtures investigated, 7% POFA provided the most promising strength performance at Day 28, supporting its potential use in EcoSand as a sustainable mortar with enhancement of the strength performance.

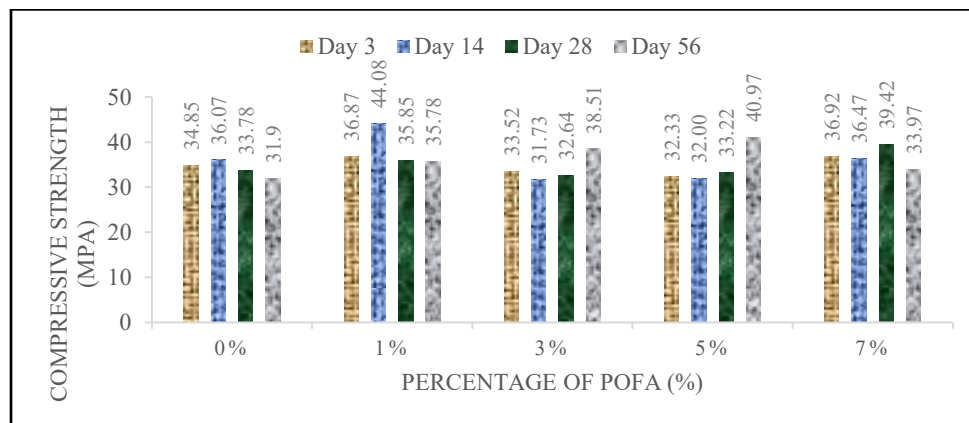


Figure 1. Compressive Strength of Mortar with Different POFA Replacement Levels at Various Curing Ages.

3.2. Innovation and Commercial Potential

The main innovation of EcoSand lies in the use of POFA as a partial replacement for sand rather than treating the material only as an industrial waste product. By incorporating POFA into mortar production, EcoSand addresses two issues, which are the increasing consumption of natural sand and the disposal of palm oil industry waste.

From a performance, 7% POFA mixture showed that part of the natural sand can be replaced without reducing mortar strength. In fact, it achieved a higher 28 day compressive strength than the control mortar.

EcoSand also has potential as a commercial mortar for masonry, plastering and general construction works. POFA can be added as part of the fine aggregate without major changes to the conventional mortar production process. Future commercialization should include further mix optimization, quality control of POFA, product standardization, larger scale production and actual site application.

4. CONCLUSION

EcoSand demonstrates the potential of Palm Oil Fuel Ash as a partial replacement for natural sand in sustainable mortar production. The compressive strength results showed that the effect of POFA depends on both the replacement level and curing age.

At Day 28, the 7% POFA mixture achieved the highest compressive strength of 39.42 MPa compared with 33.78 MPa for the control mortar, representing an improvement of approximately 16.7%. This improvement suggests that POFA replacement level can enhance the mortar strength, due to improvement in particle packing and the contribution of finer POFA particles within the mortar matrix.

The findings also indicate that higher POFA content does not necessarily result in higher strength, therefore a suitable replacement level should be selected. At the same time, the use of POFA reduces the demand for natural sand and provides a beneficial use for palm oil industry waste.

Overall, EcoSand shows strong potential as a sustainable mortar with improved strength performance. Further studies should focus on mix optimization, product development, site application performance and large scale production to support future commercialization.

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EcoMask Binder: Sustainable Bitumen Modification Using Recycled Face Masks

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Abstract

The increasing accumulation of disposable face mask (DFM) waste following the COVID-19 pandemic presents a significant environmental challenge due to its non-biodegradable polypropylene content, while the road construction industry continues to rely on costly petroleum-based and polymer-modified bitumen. This study introduces an innovative circular economy solution by transforming discarded face masks into a sustainable bitumen modifier for pavement applications. Unlike conventional polymer modifiers, which are expensive and derived from virgin materials, EcoMask Binder is not merely a modified bitumen but a scalable waste-to-infrastructure technology that converts post-pandemic medical waste into high-performance pavement material without relying on these costly virgin resources. DFM fibres were incorporated into Penetration Grade (PEN) 60/70 bitumen at 3%, 6%, and 9% by weight of binder and evaluated through penetration, softening point, and Dynamic Shear Rheometer (DSR) tests. Response Surface Methodology (RSM) identified 6% DFM as the optimum modifier content. The optimized binder exhibited enhanced stiffness, improved rutting resistance, and desirable viscoelastic properties, achieving performance comparable to high-grade PG76 binder while outperforming conventional PEN 60/70 bitumen. Beyond technical performance, this innovation offers a cost-effective and environmentally sustainable alternative for asphalt production by reducing medical waste disposal, promoting resource circularity, and decreasing dependence on virgin polymer modifiers like Styrene-Butadiene-Styrene (SBS). The technology demonstrates strong commercialization potential for road authorities, asphalt manufacturers, and the pavement industry, contributing to sustainable infrastructure development and supporting the transition towards a circular economy.

Keywords: Disposable Face Mask; Bitumen Modification; Circular Economy; Sustainable Pavement; Asphalt Innovation.

1. INTRODUCTION

The rapid proliferation of disposable face mask (DFM) usage has generated a substantial volume of polypropylene-based plastic waste, posing severe, long-term environmental challenges due to its non-biodegradable nature (Patricio Silva et al., 2020). In Malaysia alone, SWCorp data indicates that approximately 86 tons of face masks are discarded daily, accounting for 0.2% of the 38,000 tons of national daily waste (Waste Management Association of Malaysia [WMAM], 2021). Globally, the impact is even more alarming, with projections estimating that between 0.15 and 0.39 million tons of DFM waste enter the oceans annually (Aragaw, 2023).

Concurrently, the road construction sector remains heavily dependent on petroleum-derived bitumen—a non-renewable resource subject to the price and supply volatilities of the global crude oil market. While existing literature confirms that polypropylene waste can enhance asphalt properties, this research introduces a highly distinct and novel approach. Crucially, this is the first study to repurpose locally sourced, disinfected medical face masks in Malaysia as a direct, sustainable modifier for Penetration Grade (PEN) 60/70 bitumen. To achieve optimal material performance, this study distinctively applies Response Surface Methodology (RSM) to rigorously calibrate the DFM fibre dosage.

Furthermore, instead of evaluating the modified bitumen in isolation, this research conducts a comprehensive performance comparative analysis against a premium commercial benchmark: Performance Grade (PG) 76 binder. By upcycling plastic-based medical waste into a value-added, high-performance pavement material, this innovation transcends theoretical boundaries. It offers a practical, scalable technology primed for industrial implementation, actively advancing circular economy principles and sustainable infrastructure development.

2. MATERIALS AND METHODS

2.1 Materials

This study utilized Penetration Grade (PEN) 60/70 bitumen as the base binder and Performance Grade (PG) 76 bitumen as the benchmark binder. Disposable face masks (DFMs), primarily composed of polypropylene fibres, were collected from the UiTM Permatang Pauh Health Unit and used as the sustainable modifier. Prior to mixing, the masks were disinfected, air-dried, and processed into fibres approximately 6 mm in length before being incorporated into the bitumen at 3%, 6%, and 9% by weight of the binder. The cleaning process must comply with the requirements and guidelines established by the Solid Waste and Public Cleansing Management Corporation (SWCorp) Malaysia. Figure 1 shows preparation process of Disposable Face Mask (DFM) fibres.



Figure 1. Preparation Process of Disposable Face Mask (DFM) Fibres.

2.2 Preparation of DFM-Modified Bitumen

The collected disposable face masks underwent a preparation process involving disinfection, removal of ear loops and nose strips, and cutting of the polypropylene layers into fibres. The prepared fibres were blended with heated PEN 60/70 bitumen under controlled laboratory conditions to produce modified binders with varying DFM contents. A control sample of unmodified PEN 60/70 and a PG76 binder were also prepared for comparison.

2.3 Laboratory Testing and Optimization

The engineering performance of the modified binders was evaluated through penetration, softening point, and Dynamic Shear Rheometer (DSR) tests in accordance with relevant ASTM standards. Response Surface Methodology (RSM) using Design-Expert software was applied to determine the optimum DFM content. The optimized binder was subsequently compared with conventional PEN 60/70 and PG76 binders to evaluate improvements in physical and rheological performance. Figure 2 illustrates the step-by-step procedure in conducting DSR tests.

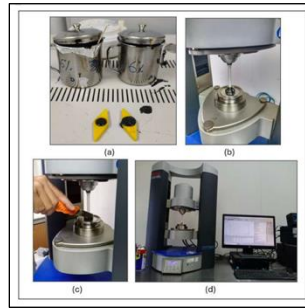


Figure 2. DSR Test Flow.

3. RESULTS AND DISCUSSION

The incorporation of disposable face mask (DFM) fibers into PEN 60/70 bitumen demonstrated significant improvements in both physical and rheological properties. Based on the Response Surface Methodology (RSM) optimization, the optimum DFM content was identified at 6% by weight of bitumen.

3.1. Physical Properties Enhancement

At 6% DFM content, the modified binder exhibited:

1. Reduced penetration value, indicating increased stiffness and improved load-bearing capacity.
2. Higher softening point, suggesting enhanced resistance to deformation at elevated temperatures.

These results indicate that the incorporation of DFM fibres effectively improves the thermal susceptibility and durability of conventional bitumen while complying with the PWD Standard Specification for Road Works.

3.2. Rheological Properties (DSR Analysis)

Dynamic Shear Rheometer (DSR) results showed that the 6% DFM-modified binder:

1. Achieved higher complex shear modulus (G^*).
2. Exhibited lower phase angle (δ), indicating improved elastic behaviour.
3. Demonstrated superior resistance to rutting under high-temperature conditions.

The viscoelastic behaviour remained stable, confirming that the modified binder can withstand repeated traffic loading while maintaining structural integrity.

3.3. Quantitative Evidence

Table 1 presents quantitative evidence for both the physical and rheological properties.

Table 1. Quantative Evidence For Both The Physical And Rheological Properties.

Property	PEN 60/70 (Conventional)	6% DFM added into PEN 60/70	PG 76 (Higher Grade)
Penetration	67 dmm	63 dmm	53 dmm
Softening Point	55.5°C	53.9°C	60°C
$G^*/\sin\delta$	29,333	260,500	83,940

3.4. Comparative Performance

To evaluate performance enhancement, the optimized 6% DFM-modified binder was compared with conventional PEN 60/70 and Performance Grade PG76 binders. The findings revealed that:

1. The modified binder significantly outperformed the original PEN 60/70 in terms of stiffness and high-temperature resistance.
2. It exhibited superior rheological properties compared to PG76, particularly in terms of complex shear modulus (G^*) and rutting parameter ($G^*/\sin\delta$) across the tested temperature range.
3. The enhanced performance is attributed to the reinforcing effect of polypropylene fibres, which improve resistance to shear deformation and permanent deformation.

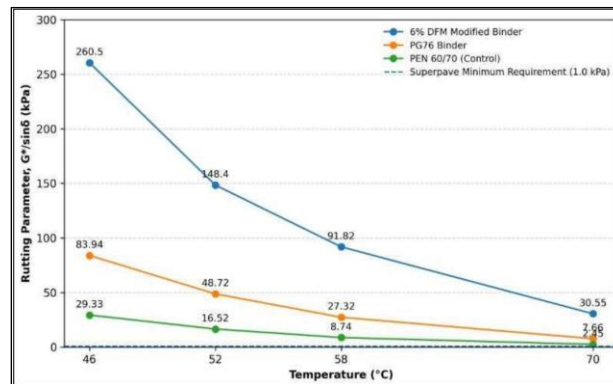


Figure 3. Comparison of rutting factors ($G^*/\sin\delta$) for PEN 60/70, PG76, and 6% DFM-modified binder.

These results indicate strong potential for DFM-modified bitumen to serve as an effective alternative to conventional and polymer-modified binders for high-temperature pavement applications. However, it should be noted that this comparison is based on binder-level rheological properties, and further evaluation at the mixture level is required for comprehensive performance validation.

3.5. Sustainability

The utilization of waste disposable face masks (DFMs) in bitumen modification offers profound sustainability and practical implications, significantly advancing circular economy practices within the road construction industry. At the optimized modification rate of 6% by weight, approximately 60 kilograms of polypropylene waste is repurposed per metric tonne of binder, which translates to recycling an estimated 20,000 disposable face masks per tonne of modified bitumen produced. This scalable approach drives a substantial reduction in environmental plastic waste by actively diverting persistent, non-biodegradable materials away from long-term landfill disposal. Table 2 presents a cost analysis to support sustainability.

Table 2. Cost Analysis.

Item	SBS Modified Bitumen	EcoMask Binder
Polymer cost	High	Very Low
Waste disposal	None	Reduces waste
Raw material	Virgin polymer	Recycled mask
Sustainability	Moderate	High

Furthermore, this eco-engineered material demonstrates strong synergy with the United Nations Sustainable Development Goals (SDGs). By decreasing reliance on volatile, non-renewable petroleum resources and fostering resilient pavement technologies, it directly supports SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities). The upcycling of daily medical plastic waste into high-value infrastructure materials champions SDG 12 (Responsible Consumption and Production), while mitigating environmental pollution to advance SDG 13 (Climate Action). Emphasizing these broad socio-environmental impacts is strategically advantageous for future implementation and funding, as innovation competitions value alignment with SDGs.

3.6. Commercialisation

The EcoMask Binder demonstrates high commercial viability as a cost-effective alternative to conventional modified bitumens, substantially lowering production costs by utilizing abundant, low-cost plastic waste materials instead of expensive virgin polymers like Styrene-Butadiene-Styrene (SBS). Primary market deployment targets key public and private pavement infrastructure stakeholders, including the Public Works Department (JKR), highway concessionaires, local municipal councils, asphalt batching plants, and road construction contractors seeking high-performance, sustainable asphalt modifiers.

4. CONCLUSION

This study demonstrates that recycled disposable face mask (DFM) fibres can be successfully utilised as a sustainable modifier for conventional PEN 60/70 bitumen. At the optimum dosage of 6%, the modified binder exhibited improved stiffness, thermal stability, and rutting resistance, achieving performance comparable to commercially available PG76 binder. Beyond enhancing pavement performance, this innovation provides a practical solution for recycling medical waste into a value-added construction material, supporting circular economy principles and sustainable infrastructure development. The technology shows strong potential for commercialization by road authorities and asphalt producers seeking environmentally friendly and cost-effective pavement materials. Future work will focus on mixture-level evaluation, long-term durability studies, and field trials to further validate its practical application.

ACKNOWLEDGEMENT

The authors wish to extend their profound appreciation to the dedicated laboratory personnel at UiTM Permatang Pauh and UiTM Shah Alam. Their exceptional technical expertise, diligent assistance, and unwavering support throughout the experimental phases were instrumental to the successful execution of this research.

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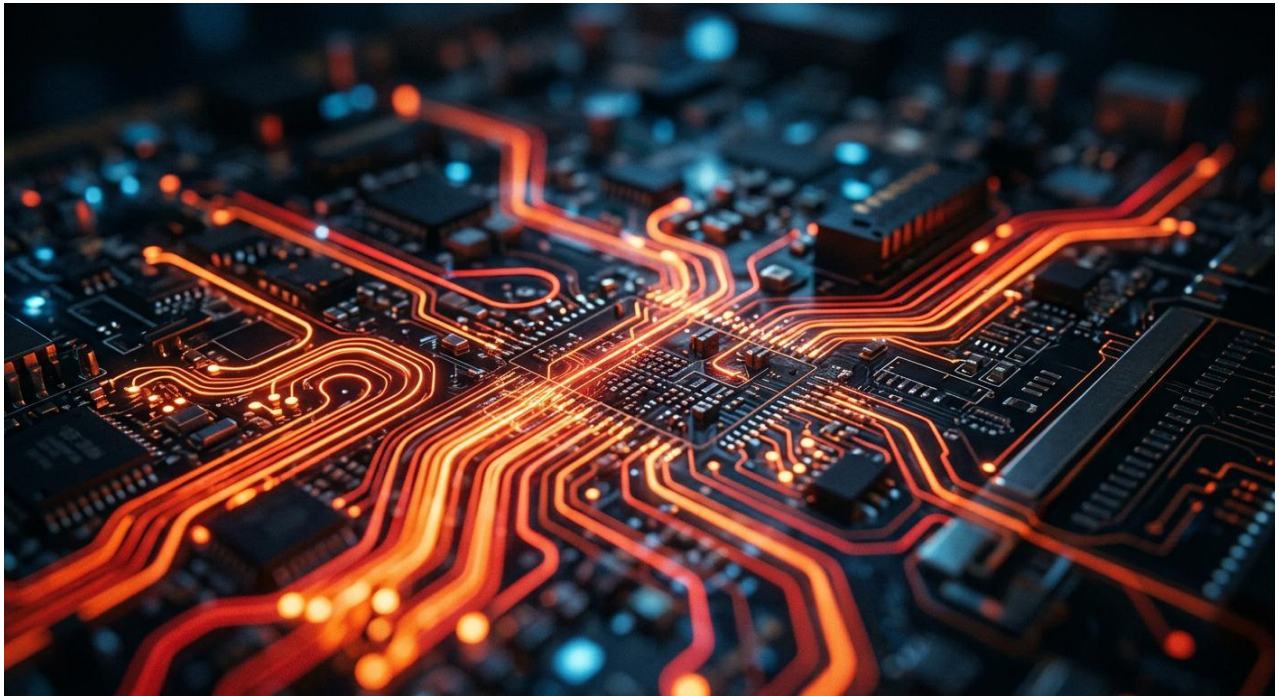
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SECTION 2

ELECTRICAL ENGINEERING



Powering innovation through intelligent technology.

Motoguard+: Centralized Smart Motorcycle Parking with Secure QR Access

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Abstract

Urban and commercial motorcycle parking faces severe challenges from rising vehicle volumes and inadequate security, leading to high theft rates and inefficient management. To address this, Motoguard+ has been introduced as an automated, centralized smart parking system designed to maximize security and operational efficiency. The system leverages a dynamically refreshed QR code access mechanism integrated with a Raspberry Pi terminal to strictly regulate entry and exit, eliminating credential duplication. Physically, Motoguard+ deploys an innovative dual-locking mechanism featuring an automated entry gate paired with individual physical wheel locks. Embedded infrared (IR) and position sensors continuously verify motorcycle presence and locking alignment, ensuring foolproof operation. Built for scalability, the architecture seamlessly manages multiple independent parking zones under a single centralized control unit. Laboratory experimental demonstrates that Motoguard+ successfully prevents unauthorized access, reduces manual oversight costs, and optimizes vehicle throughput. By combining touchless digital credentials with robust physical barriers, Motoguard+ delivers a highly secure, low-cost, IoT-driven solution ideal for campuses, residential complexes, and public hubs looking to future-proof parking infrastructure.

Keywords: Centralized parking system; motorcycle; security.

1. INTRODUCTION

Motorcycles are widely used as a convenient and affordable mode of transportation, resulting in an increasing demand for suitable and secure motorcycle parking facilities, particularly in institutional and urban environments. However, many existing motorcycle parking areas still rely on conventional approaches, such as open parking spaces and manual monitoring, which provide limited security and system control. These approaches may increase the risk of motorcycle theft, unauthorized access, and inefficient parking management (Long, 2023). Moreover previous works on motorcycle security systems studied to enhance motorcycle safety through individual locking system such as in (Supriatna, 2022) & (Godoy, 2021) and motorcycle tracking system (Fernandez, 2022) & (Abukari, 2024).

With the advancement of digital technologies, QR code-based access control has emerged as a practical and cost-effective approach for user authentication and parking activity management (Buian, 2024). QR codes can be easily generated and scanned using smartphones or dedicated scanning devices, while integration with authentication and database systems enables authorized access verification and digital record keeping. Therefore, the integration of QR code authentication with automated security mechanisms has the potential to improve the security, efficiency, and reliability of motorcycle parking systems.

Despite the increasing demand for motorcycle parking facilities, conventional parking systems often lack effective access control and automated security mechanisms. The absence of appropriate access control increases the risk of theft, vandalism, and unauthorized access to parked motorcycles. In addition, manual parking management commonly relies on parking tickets or logbooks to record vehicle entry and exit information, which may result in lost tickets, incomplete data, and inaccurate records. These limitations make it difficult for administrators to monitor parking activities and manage security-related incidents efficiently. Furthermore, paper-based records are less efficient for long-term data storage and retrieval. As the number of motorcycle users continues to increase, these weaknesses highlight the need for a secure and digital automated motorcycle parking system that can provide reliable user authentication, improve parking management, and reduce dependence on manual record keeping. Previous studies showed that digital parking systems enhance accuracy and efficiency by keeping human intervention minimal (Li, 2020). The administrators are also able to view the parking status, the entry and exit activities, and prepare reports based on these activities.

To overcome these limitations, this paper proposes Motoguard+, a centralized smart motorcycle parking system that combines dynamic QR code authentication with a Raspberry Pi-based control unit, infrared (IR) sensor verification, and a dual mechanical locking mechanism. Unlike conventional QR code parking systems, Motoguard+ generates a unique QR code for every parking session, ensuring one-time authentication and preventing code duplication or replay attacks. The system further enhances security by integrating sensor-assisted verification with automatic wheel locking, ensuring that only authenticated users can access or retrieve their motorcycles. A centralized architecture enables multiple parking bays to operate simultaneously while maintaining independent authentication and access control for each parking space.

2. MATERIALS AND METHODS

2.1. System Overview

Motoguard+ was developed using a system integration approach that combines hardware and software components to provide a secure and centralized motorcycle parking system. The system utilizes QR code authentication, a Raspberry Pi-based terminal unit, dual locking mechanisms, infrared (IR) sensors, and a centralized database to automate motorcycle entry and exit. Each parking session is assigned a unique, dynamically refreshed QR code to prevent duplication and unauthorized access. The proposed system supports two independent parking lots operating simultaneously under a centralized control framework, ensuring reliable and secure parking management.

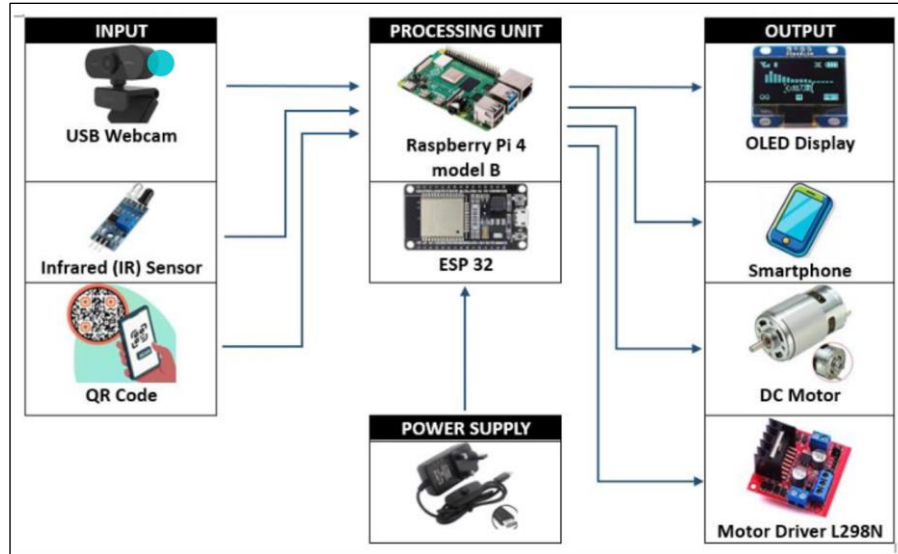


Figure 1. Block Diagram of Motoguard+.

2.2. Hardware and Software Integration

The hardware configuration consists of a Raspberry Pi 4 Model B as the central controller, a USB webcam for QR code scanning, infrared (IR) sensors for motorcycle and lock position detection, an OLED display for system status, and a dual-locking mechanism comprising an entry gate lock and a wheel locking system. These components operate together to provide secure access control and continuous monitoring of parking operations. The software was developed using Python to manage QR code generation, authentication, database communication, and hardware control. A web-based interface was also implemented to facilitate user interaction and system monitoring.

2.3. System Operation

The system operation begins when a user selects an available parking slot through the web interface. A unique QR code is generated and associated with the selected parking session. The QR code is scanned at the terminal using the webcam, and the Raspberry Pi verifies its validity through the database. Upon successful authentication, the entry gate unlocks automatically, allowing the motorcycle to enter the parking area. The IR sensors detect the motorcycle position before activating the wheel locking mechanism. During exit, the user scans the assigned QR code again to release the wheel lock and open the entry gate. The QR code is invalidated immediately after use to prevent reuse.

2.4. Experimental Validation

The developed prototype was evaluated under laboratory conditions to verify the functionality of the QR authentication process, locking mechanism, sensor feedback, and centralized control. Multiple parking sessions were conducted to evaluate simultaneous operation of two parking lots. The experiments focused on verifying unique QR code generation, accurate sensor detection, reliable lock operation, and secure parking management under normal operating conditions.

3. RESULTS AND DISCUSSION

3.1. Results and Analysis

The first part of the system evaluation focuses on the performance of the QR code generation and uniqueness mechanism. During testing, multiple parking requests were simulated to occur at the same time. The system was observed to generate different QR codes for each user session, with no duplication detected throughout the testing process. Even when two users attempted to access separate parking lots simultaneously, each user received a unique, time-based QR code. This result confirms that the QR refresh mechanism works effectively and successfully resolves the duplication issue encountered in earlier system designs.

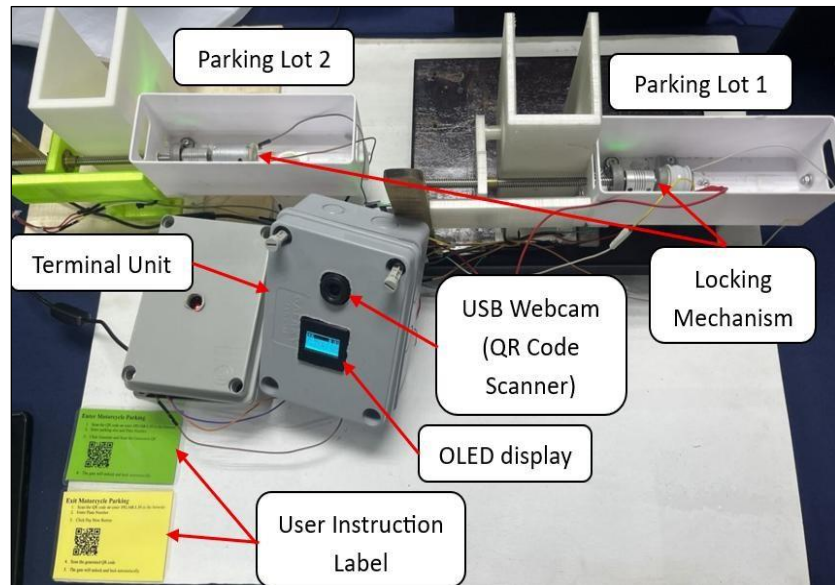


Figure 2. Overall Prototype Setup of the Motoguard+ System Showing Terminal Unit, QR Scanning Interface, and Dual Parking Lots.

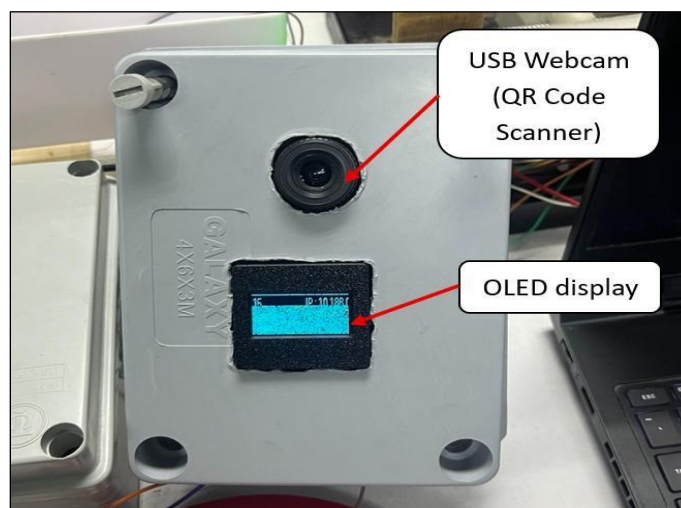


Figure 3. Terminal Unit of the Motoguard+ System.

The next evaluation examines the operation of the dual locking mechanism. Based on the test results, the entry lock responded correctly after a valid QR code was scanned, allowing the motorcycle to enter the parking space. Once the motorcycle was inside, the entry lock automatically closed to prevent unauthorized access. The wheel locking mechanism was then activated only after the wheel detection sensor confirmed the presence of the motorcycle. During the exit process, the system reliably released the wheel lock and reopened the entry lock after QR verification, indicating smooth and consistent lock control.

Sensor performance was also evaluated to ensure safe and reliable operation. Throughout the testing phase, both the position sensor and the wheel detection sensor provided accurate feedback to the controller. When the motorcycle was not positioned correctly, the system did not activate the wheel lock, preventing improper locking. In addition, if any abnormal condition was detected, such as incomplete lock movement, the system stopped further actions. These observations show that sensor feedback plays an important role in preventing system errors and improving overall safety.

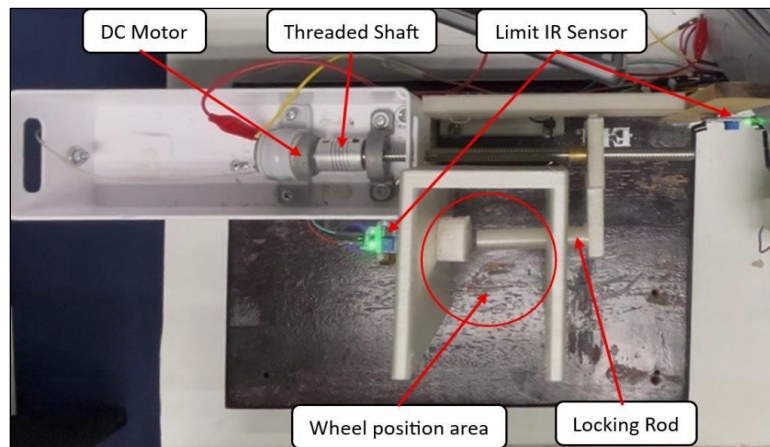


Figure 4. Wheel Locking Mechanism (Locked State).

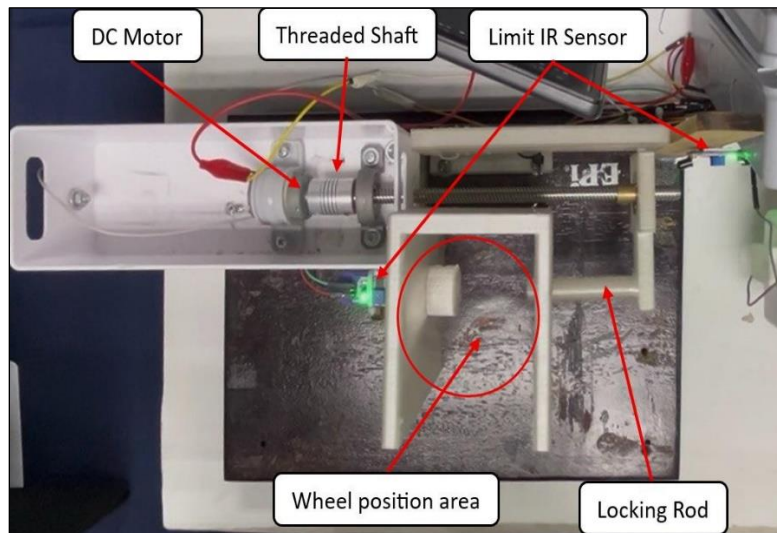


Figure 5. Wheel Locking Mechanism (Unlocked State).

The ability of the system to support two parking lots operating at the same time was evaluated. The results show that both parking lots functioned independently without interfering with each other. QR codes assigned to one parking lot were not accepted by the other, ensuring correct access control and parking slot assignment. This confirms that the centralized control system is capable of managing multiple parking

spaces efficiently while maintaining secure operation.

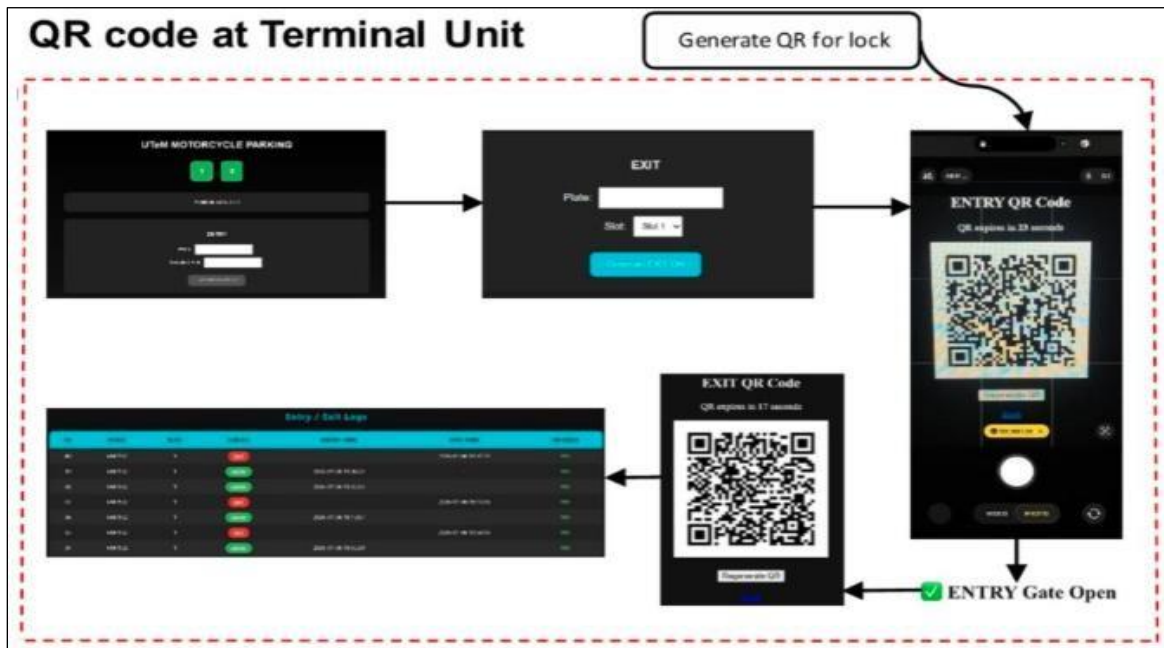


Figure 6. QR code at Terminal Unit.

Figure 6 presents the functioning of the QR Code at the Terminal Unit, which is a form of access control for the entry and exit process. At the terminal unit, the individual is asked to enter all the necessary information, including the car plate number or ID. Once the information has been verified, a unique QR code is produced. The QR code therefore acts as a form of virtual access.

For the entry procedure, the generated QR code is displayed on the terminal screen and scanned at the entry gate. The code is verified through the database, and once it is verified, a signal is received at the gate controller to open the entry gate automatically. This procedure ensures that only authenticated users enter the specified region.

In the case of the exit process, the exit QR code is created in the terminal unit. The QR code is then scanned at the exit gate. The system verifies the entry details in the database to access the corresponding entry record. After the confirmation is completed, the exit gate is opened automatically, and the exit record is updated. In summary, the integration of the QR code in the terminal unit can increase system security, minimize the involvement of humans, and therefore increase the reliability of the system.

4. CONCLUSION

Motoguard+ successfully demonstrates the feasibility of integrating dynamic QR code authentication, a Raspberry Pi-based controller, and a dual-locking mechanism into a centralized motorcycle parking system. The developed prototype effectively enhances parking security by preventing unauthorized access, reducing QR code duplication, and automating the parking entry and exit processes. Experimental evaluation confirmed the reliable operation of the authentication, sensor, and locking mechanisms under laboratory conditions. The proposed system offers a practical, scalable, and cost-effective solution for improving motorcycle parking management in universities, residential areas, and other public facilities. Future work will focus on expanding the system to support larger parking capacities, cloud-based monitoring, and mobile application integration for enhanced user convenience.

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Design And Analysis Of A Linear Electromagnetic Propulsion System For Internal Logistics Transport In Smart Compounds

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Abstract

Smart compounds show limited innovation in their internal logistics transportation, resulting in inefficient materials transportation, weather and manual handling dependency, limited payload and users' dissatisfaction. This project aims to propose, design, and validate an electromagnetic propulsion system for smart compound internal logistics. An analytical design procedure was developed for a target duty of a 200 kg payload at 3 m/s over a 1 km route, producing an 8-pole, 48-slot primary at 25 Hz, with a rated thrust requirement of 218.7 N. Two-dimensional transient finite-element analysis was used to size the winding at 26 turns per coil, giving a mean thrust of 219 N against that requirement and a mean normal attraction force of 816 N. A 4-pole scaled prototype preserving the pole pitch, slip, synchronous speed and per-area magnetic loading of the full-scale machine was fabricated and tested. Despite operating at twice the design frequency owing to laboratory supply limitations, it produced a standstill thrust of 2.26 N at 3.5 A, 75 percent of the finite-element prediction obtained at the same 50 Hz standstill operating point, and transported its full 2 kg payload drawing 3.0 A. The results validate the design methodology and identify the two-dimensional model as an upper bound on the achievable thrust and demonstrate the technical feasibility of linear induction motor propulsion for smart compound intralogistics.

Keywords: linear induction motor; finite element analysis; intralogistics; smart compound; prototype validation.

1. INTRODUCTION AND OBJECTIVE

Interconnected infrastructure is used by smart cities to increase efficiency, sustainability and improve living standards, and intelligent transportation and logistics are regarded as the cornerstones of this architectural concept (Silva et al., 2018). In a smart city, a separate facility such as campus, hospitals, airport and residential complex becomes a smart compound, where advanced technology solutions are implemented in order to provide additional services within the facility (Dong et al., 2020).

Moving goods internally is one such service, and there already exist a few dedicated solutions for that purpose: an autonomous delivery robot like Starship, having delivered millions of last-mile shipments but operating at speeds of up to 6 km/h, having small capacity and being limited to outdoor operation depending on weather conditions (Starship Technologies, n.d.); warehouse transport robots such as the Amazon Titan, which can operate only on structured indoor surfaces (Greenawalt, 2025); pneumatic tubes, currently serving as the main system of intralogistics in hospitals, but still limited to moving light canisters (Weinmeyer, 2023); and underground transport systems like Cargo Sous Terrain (Cargo Sous Terrain, n.d.). All of them share common limitations such as small payload capacity, low speed, weather sensitivity or costly maintenance, which make a dedicated transport system necessary.

Linear electric machines (LEMs) generate thrust directly, without rotary-to-linear conversion, and therefore offer adhesion-free propulsion, an absence of gearing and backlash, high reliability and precise motion control (Boldea et al., 2018). The linear induction motor (LIM) combines a simple wound primary with an entirely passive conductive secondary, giving the lowest track cost, a single power supply and straightforward manufacture over long distances (Palka & Woronowicz, 2021). For a short-distance, low-speed indoor application in which track length dominates the system cost, the LIM is the appropriate choice.

Published LIM research has concentrated on large-scale rail transit and electromagnetic launch systems, while design studies of low-speed machines have addressed efficiency and power-factor optimization (Isfahani et al., 2008) and secondary topology improvement (Lv et al., 2018). The application of a compact LIM propulsion system to internal logistics transportation within smart compounds, however, remains largely unexplored. This project addresses that gap with a fully electric, zero direct emission, low-maintenance propulsion system running over a passive track, in direct support of the OpIIC 2026 aim of open international innovation for a sustainable future.

The objectives of this work are: (1) to design and analyze an electromagnetic propulsion system as a transportation channel for a smart compound logistics network; and (2) to develop a small scale 1–1.5 m long track proof-of-concept prototype of the proposed system.

2. MATERIALS AND METHODS

The project adopts a deductive and experimental approach, focusing on literature mainly based on IEEE, design using AutoCAD, simulation in Ansys Maxwell, and the prototype development for performance validation through quantitative and qualitative analysis.

2.1. Target Specifications and Machine Topology

The propulsion system specifications are given for a track-guided cart that delivers the loads to various points at an indoor or sheltered passageway of a length of up to 1 km. The load capacity of 200 kg is sufficient for consolidation of residential orders, medical supplies, and lightweight industrial items in one go. A maximum speed of 3 m/s is adequate for movement in a confined environment where pedestrians can also be nearby, giving satisfactory transit times. Table 1 gives the design criteria.

Table 1. Target Specifications Of The Propulsion System.

Parameter	Value
Payload per trip	200 kg
Vehicle mass	130 kg
Rated / maximum speed	3 / 5 m/s
Acceleration	0.5 m/s ²
Route length	1 km (or longer)
Guidance	Profiled linear guideway
Power transfer	Conductor bars + collector shoes

The machine will be a short-primary, slotted, heteropolar, single-sided, and longitudinal-flux LIM using forced-air cooling. A short primary relative to the passive reaction rail will reduce the cost of the long guideway and the longitudinal flux structure is easier to construct and has a better power factor compared to its transverse counterpart. As the reaction rail, a ladder-slit aluminum sheet backed by a solid steel back iron will be used: compared to a simple flat sheet, the ladder slit design will confine the eddy current effects in the active zone to their productive transverse components leading to an improvement of about 15% in thrust and 6% in efficiency and this is specifically recommended for short range applications (Lv et al.,

2018). Figure 1 shows the resulting machine concept.

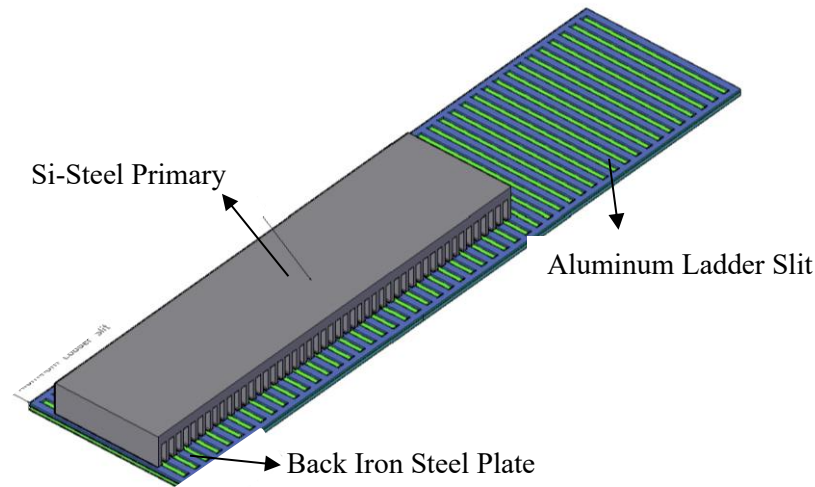


Figure 1. Three-Dimensional View Of The Full-Scale Single-Sided LIM: Slotted Short Primary Above The Ladder-Slit Aluminium Secondary With Solid Steel Back Iron.

2.2. Analytical Design of the Full-Scale Machine

Because the carriage runs on recirculating bearing blocks, the resistance to motion is rolling friction. For the total mass $m = 330 \text{ kg}$, $W = 3237 \text{ N}$; the normal force follows from the air-gap magnetic pressure as $F_n = 10.19 \text{ kN}$, giving a bearing load of 13.43 kN and $F_{rr} = 53.7 \text{ N}$. Adding the inertial force for the specified acceleration, the rated thrust requirement is $F_{th} = F_{rr} + mT a = 218.7 \text{ N}$ (Eq. 1). The corresponding mechanical power is 656 W during acceleration at 3 m/s , so the rated output power is set to 1 kW . A rated slip of $s = 0.25$ places the synchronous speed at 4 m/s ; 25 Hz with a pole pitch of 80 mm is selected as the best compromise between primary length and iron utilization. Eight poles suppress the longitudinal end effect, fixing the active length at 640 mm with a stack width of 160 mm . The number of turns per coil is left to be fixed by the finite-element model, since the analytical estimate of the air-gap flux density proves optimistic.

2.3. Scaled Prototype Design and Fabrication

The prototype validates the propulsion concept and the design chain at benchtop cost rather than reproducing full-scale performance. The guiding principle is to conserve every parameter that governs the electromagnetic analysis, including pole pitch, slip, synchronous speed and per-area magnetic loading, while freely reducing the parameters that only add size and cost. The primary core is stacked from 0.5 mm non-oriented M19 silicon-steel laminations, wound with enamelled copper in Nomex-lined slots and wye-connected through brass binding posts. The secondary is an aluminium plate on a mild-steel back iron. Table 2 contrasts the two machines, and Figure 2 shows the completed shuttle.

Table 2. Prototype Versus Full-Scale Machine.

Parameter	Full scale	Prototype
Poles	8	4
Primary length	640 mm	320 mm
Stack width	160 mm	100 mm
Slots ($q = 2$)	48	24
Turns per coil	26	40
Back iron	15 mm	10 mm
Pole pitch	80 mm	80 mm
Design frequency	25 Hz	25 Hz
Rated excitation	18 A	3.54 A rms
Design payload	200 kg	2 kg



Figure 2. Fabricated Prototype Shuttle: Hand-Wound 4-Pole Primary In The PETG Carriage On Polyurethane Wheels Over The Aluminium Reaction Plate.

3. RESULTS AND DISCUSSION

This work makes four key contributions. The first is an analysis-based design of a single-sided LIM based on requirements for a 200 kg, 3 m/s indoor logistics shuttle using ladder slit secondary. The second contribution is the verification of the design through two-dimensional transient FEA, where the winding is sized from the simulated thrust and the normal attraction force is quantified. The third contribution is a cost-based scaling procedure which retains the electromagnetic operating condition of the full-scale machine in a benchtop prototype. The fourth contribution is building and testing of the prototype including the frequency derating due to laboratory power limitations.

Two-dimensional transient finite-element analysis was used to size the winding rather than only to check the design. An initial iteration with the analytically derived 20 turns per coil gave a mean thrust of only 130 N, below the 218.7 N requirement, because the model places the peak air-gap flux density at 168 mT rather than the 0.5 T assumed analytically; the winding was therefore raised to 26 turns per coil. The model then predicts a mean thrust of 219 N at the rated slip of 0.25, meeting the requirement, together with a mean normal attraction force of 816 N, a ratio of 3.7 : 1 against the thrust. Figure 3 shows the simulated thrust: a start-up overshoot of 267 N at 20 ms settles after about 60 ms into a steady state oscillating between 200 N and 248 N. Although an order of magnitude below the analytical estimate, the normal force still governs the specification of a profiled linear guideway.

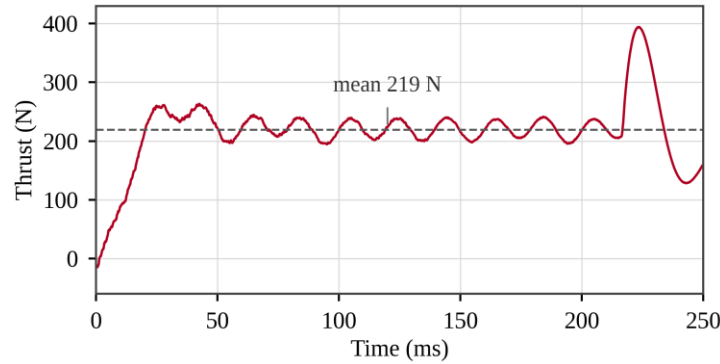


Figure 3. Simulated Thrust Of The Full-Scale Machine At The Rated Operating Point (25 Hz, 18 A rms, 3 m/s).

Only a 50 Hz three-phase supply (a 0–300 V variac) was available for testing, twice the design frequency. The standstill thrust was therefore chosen as the primary measurement, because it is independent of the synchronous speed and can be compared directly against a model solved at the same frequency. The standstill thrust was measured with a spring balance and follows the expected quadratic law $F = kI^2$ with no sign of saturation up to 3.7 A: 1.08 N at 2.0 A and 2.26 N at 3.5 A. The key result, 2.26 N at 3.5 A, is 75 percent of the 3.0 N predicted by a finite-element model solved at the same 50 Hz standstill operating point with the same 3.54 A rms excitation. The shortfall is consistent with the transverse edge effect, which a two-dimensional model cannot represent, and with an effective air gap larger than the 2 mm assumed. The design chain is thereby confirmed as an upper bound on the delivered thrust.

In free running over 0.5 m, the shuttle reached an average speed of 0.32 m/s at 4 A, with an acceleration of about 0.4 m/s². Under load, the shuttle transported its full 2 kg design payload at 0.128 m/s drawing 3.0 A, below the 3.54 A rating and at twice the design frequency, thereby meeting the primary objective of the prototype with margin. The rolling resistance back-calculated from these runs is only 0.3–0.4 N, several times below the conservative 1.7 N budget.

The prototype has clear limitations. It could only be driven at 50 Hz instead of its 25 Hz design point, the variac supply was unstable above about 2 A, and deformation of the polyurethane wheels under load closed the air gap, which together with the transverse edge effect explains the 25 percent shortfall against simulation. Thrust was read from a spring balance, limiting accuracy to a few tenths of a newton. Future work should retest the shuttle at 25 Hz on a variable-frequency drive fed from a stable inverter supply, add closed-loop control with soft-start ramping, stiffen the guidance to hold the air gap, and validate the forced-air cooling under continuous duty.

Consolidating the analysis, the complete transport system is proposed as nine subsystems: the primary (mover), the secondary reaction track, the carriage, the guidance system, the power-transfer system, the carrier, the corridor, thermal management and safety. The intent is a simple and compact installation suited to a smart compound rather than a large-scale transit system, with each component selected on a performance-versus-cost basis. Figure 4 shows the resulting system.

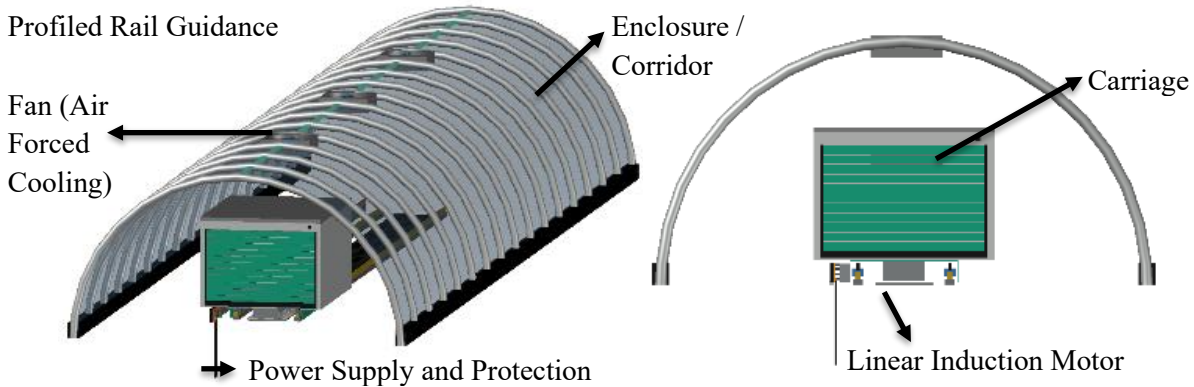


Figure 4. Complete Drawing Of The Proposed Full-Scale System, Integrating The Linear Motor, Reaction Track, Carriage, Guideway, Power-Transfer Bars, Carrier And Covered Corridor.

The novelty of the work lies in translating a technology so far reserved for large-scale rail transit into a compact, requirement-driven intralogistics machine, validated end-to-end from analytical sizing through finite-element simulation to a working hardware prototype. Because the guideway is entirely passive, the incremental cost of extending the route is limited to an aluminium sheet and a steel back iron, giving the system strong commercial value for hospitals, university campuses, airports and warehouse complexes where frequent, repetitive point-to-point deliveries are required. Its fully electric, zero direct emission, low-noise and low-maintenance operation contributes towards a sustainable and resilient future, in line with Sustainable Development Goal 9 (Industry, Innovation and Infrastructure) and Goal 11 (Sustainable Cities and Communities).

4. CONCLUSION

Through a structured deductive approach from literature review to analytical design and later to simulation, a single-sided, short-primary, slotted, heteropolar, longitudinal-flux linear induction motor with air-forced cooling, ladder-type conductive secondary and a steel back iron was proposed for the electromagnetic propulsion system for internal logistics transportation in smart compounds. These results validate the complete design chain, from analytical sizing through finite-element simulation to hardware, and confirm that the two-dimensional model constitutes an upper bound on machine performance, with the measured thrust falling within the margin expected of a two-dimensional analysis. The project therefore demonstrates that linear induction motor propulsion is a technically feasible, low-maintenance and scalable alternative to autonomous mobile robots and pneumatic tube systems for internal logistics transportation in smart compounds, and it provides a validated design methodology and a working proof-of-concept upon which a full-scale system can be developed. This work contributes a complete, experimentally validated design chain for low-speed linear induction motor propulsion in an application domain, smart compound intralogistics, where published research has so far concentrated on large-scale rail transit and electromagnetic launch systems. Economically, the passive-track architecture means route extension costs are limited to aluminium sheet and steel back iron, giving the system strong potential as a scalable, cost-effective installation for smart compounds.

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SECTION 3

FINANCE AND ACCOUNTING



Transforming financial knowledge into sustainable value.

Accounting Launchpad

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Abstract

Accounting Launchpad is an innovative Padlet-based digital learning platform developed to enhance students' understanding of Introduction to Financial Accounting (ACC117), a foundational course covering basic accounting concepts, the accounting equation, principles of double-entry bookkeeping, and the preparation of financial records. Many students experience difficulties in mastering these interconnected concepts when relying solely on conventional lecture notes. To address this challenge, Accounting Launchpad integrates structured lecture materials, interactive mind maps, visual learning resources, and self-directed learning activities within a single, user-friendly platform. The innovation adopts a student-centred approach that encourages active learning, improves accessibility to learning materials, and supports independent revision beyond the classroom. By presenting complex accounting concepts through visual and interactive formats, the platform aims to improve conceptual understanding, knowledge retention, and student engagement. Accounting Launchpad also promotes flexible learning by enabling students to access resources anytime and anywhere using digital devices. This innovation demonstrates the effective integration of educational technology into accounting education to create a more engaging, accessible, and meaningful learning experience.

Keywords: Financial Accounting Education, Padlet, Digital Learning, Mind Mapping, Student Engagement.

1. INTRODUCTION

Education systems are increasingly confronted with challenges associated with the rapid digitalisation of education (Dancsa et al., 2023). To improve and implement a modern education system, a holistic approach involving various stakeholders, including students, parents, policymakers, and educators, is essential (Ninad et al., 2023). Furthermore, the utilisation of digital technologies enables students to actively engage in the learning process while enhancing their problem-solving skills and critical thinking abilities (Dancsa et al., 2023). However, students enrolled in Introduction to Financial Accounting (ACC117) at Universiti Teknologi MARA specifically, often encounter difficulties in understanding fundamental accounting concepts, particularly the accounting equation and the double-entry system, when relying solely on conventional lecture notes. Therefore, this project introduces Accounting Launchpad, a Padlet-based digital learning platform that integrates concise lecture notes with visual mind maps into a comprehensive learning environment. The platform is designed to support effective teaching, enhance students' conceptual understanding, and promote independent and flexible learning.

2. RESEARCH OBJECTIVES

To enhance students' comprehension of the Introduction to Financial Accounting (ACC117) course, this project aims to develop a user-friendly Padlet platform known as Accounting Launchpad as an alternative digital learning platform. The primary objectives are:

1. To simplify the learning process by providing students with an accessible and effective digital learning platform through Accounting Launchpad.
2. To simplify complex accounting concepts by presenting colourful visual mind maps alongside concise lecture notes, thereby improving students' understanding and knowledge retention.
3. To enhance students' engagement and motivation by creating an interactive and innovative digital learning environment that incorporates visual learning strategies and interactive learning materials

3. METHODOLOGY

This project adopted a design and development approach to create an interactive Padlet platform known as Accounting Launchpad as a supplementary teaching and learning resource for the Introduction to Financial Accounting (ACC117) course. The development process consisted of two main stages.

The first stage involved developing instructional materials based on the ACC117 course syllabus. Concise lecture notes were prepared by summarising the fundamental accounting concepts, including accounting principles, the accounting equation, and the course learning outcomes.

The second stage involved designing visually engaging mind maps for each topic to facilitate students' understanding of complex accounting concepts. The mind maps incorporated colour coding, icons, diagrams, and hierarchical structures to improve knowledge organisation and retention.

Finally, all learning resources, including lecture notes and visual mind maps, were integrated into the Accounting Launchpad platform using Padlet. As an online platform, Accounting Launchpad enables students to access learning materials anytime and anywhere using computers, tablets, or smartphones, thereby supporting blended learning, flexible learning, and self-directed learning.

4. RESULTS AND DISCUSSION

The completed innovation, Accounting Launchpad, integrates lecture notes and visual mind maps into a single interactive digital learning platform for the Introduction to Financial Accounting (ACC117) course. The platform supports both classroom teaching and independent learning by providing organised and easily accessible learning resources.

The key features of Accounting Launchpad include comprehensive and well-structured lecture notes, colourful visual mind maps, and an interactive learning environment that simplifies complex accounting concepts. These features encourage active student engagement while improving students' understanding of fundamental accounting principles.

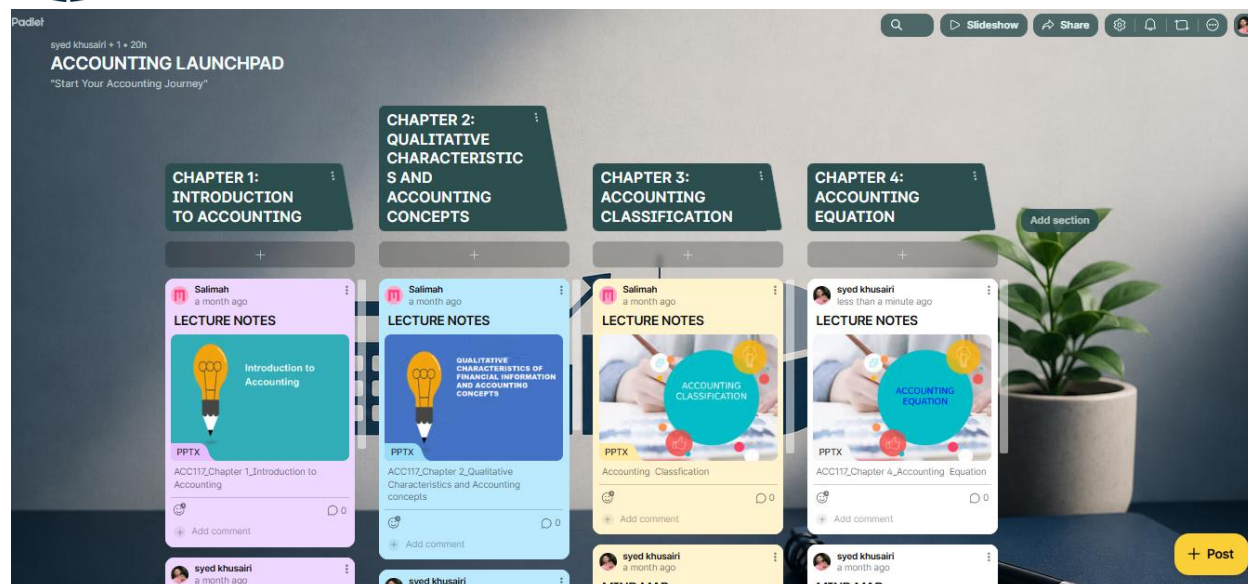


Figure 1: Accounting Launchpad

Accounting Launchpad demonstrates that the integration of digital learning platforms can enhance both teaching quality and students' learning experiences, particularly in challenging subjects such as Introduction to Financial Accounting (ACC117). The use of visual mind maps together with concise lecture notes enables students to understand complex accounting concepts more effectively while reducing cognitive burden. The platform also supports formative learning by allowing students to identify gaps in their understanding before formal assessments. Furthermore, because Accounting Launchpad is accessible via the internet, students can conveniently access learning materials using computers, tablets, or smartphones at any time and from any location. This flexibility promotes blended learning, self-directed learning, and continuous revision beyond the classroom.

5. CONCLUSION

Accounting Launchpad serves as an innovative digital learning platform for the Introduction to Financial Accounting (ACC117) course by integrating educational technology with interactive learning strategies within a student-centred learning environment. The platform enhances students' engagement, improves their understanding of fundamental accounting concepts, and supports independent learning through flexible access to digital learning resources. Overall, Accounting Launchpad represents an effective supplementary teaching and learning tool that contributes to improving the quality of accounting education.

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SECTION 4

GAMIFICATION



Engaging ideas. Interactive experiences. Meaningful innovation

MathBrain: The Geometry Adventure

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Abstract

MathBrain: The Geometry Adventure is an interactive educational puzzle game developed to enhance learners' understanding of geometric concepts through shape-and-formula matching challenges. The objective of this innovation is to create a fun and engaging learning experience that improves problem-solving skills, pattern recognition, creativity, and critical thinking. The game can be accessed through a webpage created using Google Sites, while the interactive puzzles were generated using Interacty. The development method involved integrating geometry-based puzzles into a digital gaming platform that encourages active participation and cognitive engagement. The game promotes enjoyable learning while helping users strengthen their knowledge of geometry, concentration, patience, and analytical skills. The interactive gameplay also increases learners' motivation and sense of achievement after solving each puzzle. For future improvements, additional levels, animations, and wider mathematics topics can be incorporated to further enhance the educational value and user experience of the game.

Keywords: Educational Puzzle Game; Geometry Learning; Interactive Mathematics; Pattern Recognition, Problem-Solving Skills.

1. INTRODUCTION

MathBrain: The Geometry Adventure is an innovative educational puzzle game designed to transform the learning of geometry into an engaging and interactive experience. The game challenges players to match geometric shapes with their corresponding formulas, promoting active learning through gameplay rather than conventional memorisation. Accessible via a webpage built with Google Sites, the interactive puzzles are created with Interacty, allowing learners to play anytime, anywhere on internet-connected devices.

Recent studies have highlighted the effectiveness of game-based learning (GBL) in mathematics education. A systematic review by Marzuki et al. (2025) found that GBL positively influences students' motivation, engagement, confidence, problem-solving skills, conceptual understanding, and academic achievement in mathematics. Similarly, a review by Vankúš (2021) reported that game-based learning promotes active participation and enhances students' attitudes towards mathematics by making learning more enjoyable and meaningful. Yulianto et al. (2025) reported that digital game-based learning promotes higher-order thinking skills by encouraging learners to analyse, evaluate, and apply mathematical concepts in meaningful contexts.

Furthermore, recent research indicates that gamification and game-based approaches can support the development of higher-order thinking skills, including critical thinking, creativity, and analytical reasoning, while increasing learner engagement in mathematics classrooms. The visual matching activities implemented in MathBrain support these findings by enabling learners to associate geometric shapes with mathematical formulas through interactive exploration rather than rote memorisation.

2. MATERIALS AND METHODS

The design of MathBrain is supported by Constructivist Learning Theory, which emphasises that learners construct knowledge through active engagement and meaningful experiences rather than passive information reception (Piaget, 1972). By actively matching shapes with formulas, learners apply existing knowledge, identify misconceptions through immediate feedback, and strengthen conceptual understanding through repeated practice.

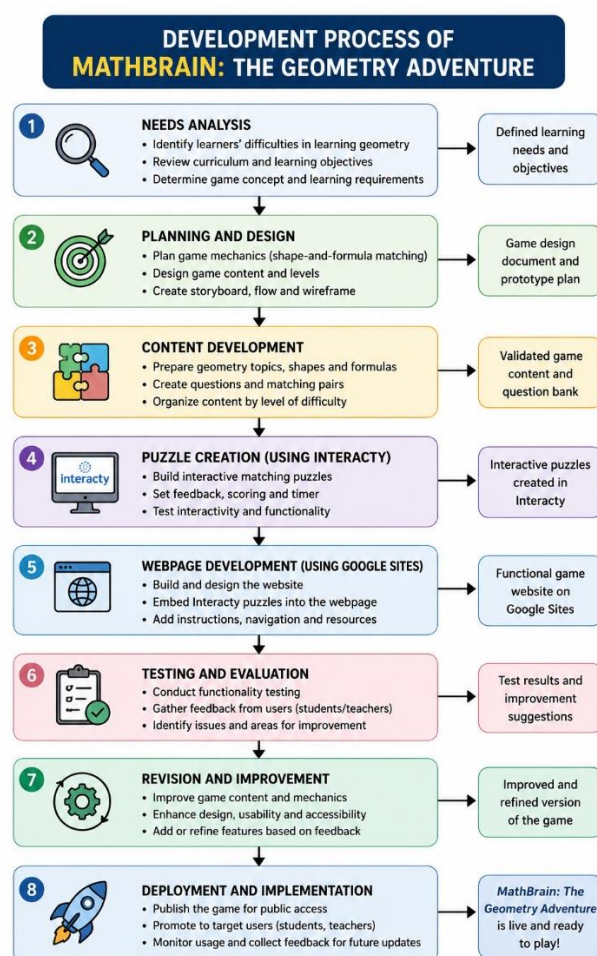


Figure 1. The Development Process of MathBrain

Figure 1 shows the development process of MathBrain. The innovation adopts a gamification approach by integrating geometry learning with interactive puzzle-solving mechanics to create an engaging learning experience. The game is hosted on a webpage developed using Google Sites, while the interactive shape-and-formula matching puzzles are created using Interactivity. Players are challenged to match geometric shapes with their corresponding formulas, promoting active learning, critical thinking, and problem-solving rather than rote memorisation. The web-based platform enables users to access the game through any modern web browser on computers, tablets, or smartphones, making it suitable for classroom instruction,

home learning, and self-directed learning environments. This development approach provides a cost-effective, user-friendly, and easily maintainable educational solution that supports flexible digital learning. MathBrain can be accessed via the link <https://sites.google.com/uitm.edu.my/mathsbrain/home>.

3. RESULTS AND DISCUSSION

The MathBrain webpage includes a reference table as shown in Figure 2, containing the basic formulas for the area and perimeter of common two-dimensional geometric shapes. This feature serves as a quick learning resource that learners can consult before or during gameplay.

SHAPE	NAME	AREA	PERIMETER
	RECTANGLE	$h \times b$	$2 \times (h + b)$
	SQUARE	$a \times a$	$4 \times a$
	TRIANGLE	$\frac{1}{2} \times h \times b$	$2a + b$
	CIRCLE	$\pi \times r^2$	$2 \times \pi \times r$
	PARALLELOGRAM	$h \times b$	$2 \times (a + b)$

Figure 2. Reference Table of The Basic Formulas for The Area and Perimeter

The integration of a geometry formula reference table with interactive puzzle-solving distinguishes MathBrain from conventional educational games. Rather than requiring learners to memorise formulas before playing, the game allows them to refer to the formula table while completing the matching activities. Figures 3 and 4 show the shape-and-formula matching puzzles. These games encourage meaningful learning by helping learners associate each geometric shape with its corresponding area and perimeter formulas through repeated exposure and application. Over time, frequent interaction with the reference table and puzzle activities can improve formula retention and reduce reliance on memorisation alone.

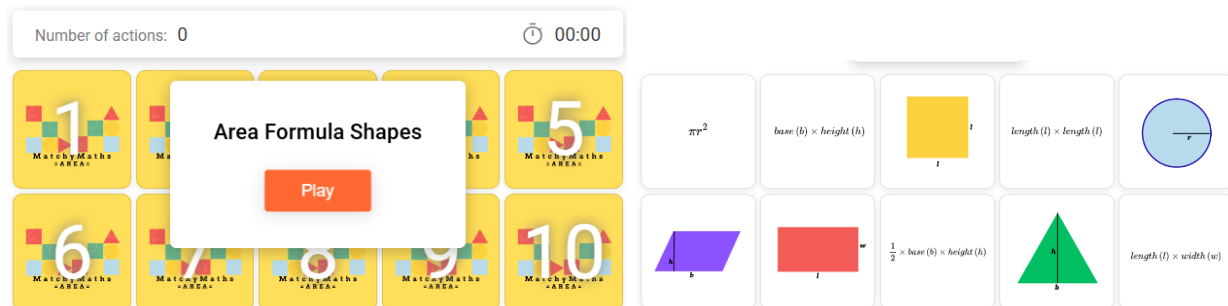


Figure 3. Interactive Shape-And-Formula Matching Puzzles for The Area

Unlike conventional worksheets or static digital content, the game incorporates multiple interactive components, including matching challenges, visual representations of geometric shapes, scoring, and progressive puzzle completion. Through repeated gameplay, users strengthen their understanding of

geometric concepts while developing concentration, patience, analytical thinking, and pattern-recognition abilities. These features encourage active participation rather than passive memorisation.

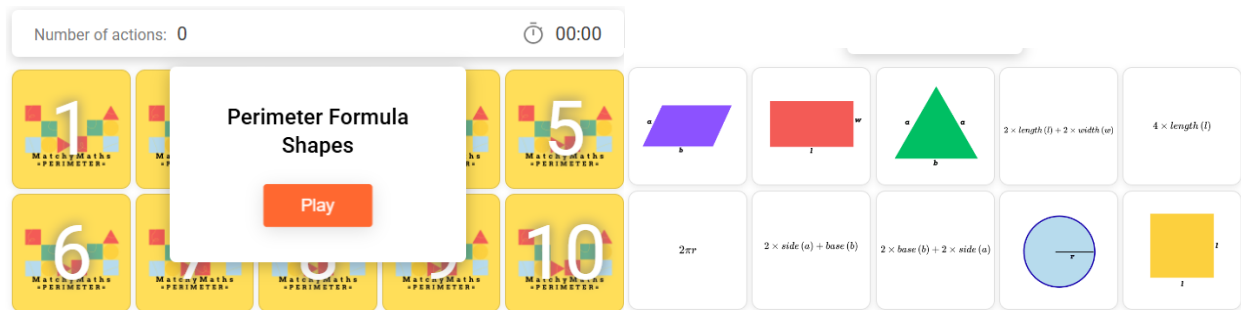


Figure 4. Interactive Shape-And-Formula Matching Puzzles for The Perimeter

MathBrain demonstrates originality by combining web-based technology, interactive puzzle mechanics, and geometry education into a single digital learning platform. Unlike conventional mathematics websites that mainly provide notes or exercises, MathBrain transforms geometry learning into an enjoyable gaming experience that promotes self-directed learning. The use of Google Sites provides a cost-effective and easily maintainable platform, while Interacty enhances user engagement through interactive game elements. Consequently, the innovation has strong potential for implementation in schools, higher education institutions, tuition centres, and online learning environments.

Furthermore, the visual nature of MathBrain aligns with Dual Coding Theory (Paivio, 1986), which suggests that combining visual and verbal information enhances learning and memory. Presenting geometric shapes alongside their corresponding formulas enables learners to process information through both visual and verbal channels, making abstract mathematical concepts easier to understand and recall. Mayer's Cognitive Theory of Multimedia Learning (2009) similarly argues that well-designed multimedia learning environments improve understanding by integrating words, images, and interactive elements while reducing unnecessary cognitive load.

The innovation benefits multiple stakeholders. Students gain a more enjoyable learning experience, educators receive an engaging supplementary teaching tool, and educational institutions can support digital learning initiatives. The web-based design ensures accessibility and ease of use without requiring specialized hardware or software.

From a commercialization perspective, the product is marketable due to its user-friendly interface, scalability, and low deployment cost. It has potential applications in schools, tuition centres, educational exhibitions, and online learning platforms. Additional premium modules and curriculum-aligned content can further enhance its commercial value. The originality of MathBrain lies in its integration of geometry education with interactive puzzle gaming. The combination of visual shape recognition and formula matching creates an engaging learning environment that differs from conventional mathematics teaching approaches. The innovation was independently developed and has not previously received awards in other innovation competitions. The product is currently available and can be accessed and played online. The core game mechanics, geometry content, and interactive features have been successfully implemented and tested.

4. CONCLUSION

MathBrain: The Geometry Adventure demonstrates the potential of educational game innovation to improve geometry learning through engagement, interactivity, and gamification. The game supports cognitive skill development while making mathematics more enjoyable and accessible for learners. Future enhancements include additional levels of difficulty, more geometry topics, multilingual support,

animations, learner performance analytics, and mobile application development. These improvements will strengthen both the educational impact and commercialization potential of the innovation.

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SAY IT! V2: Upgrading Proverb Learning Through Competitive Card-Based Gameplay

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Abstract

The card-based educational game SAY IT! V2 Select and Answer Your Idioms Tactfully enables primary students to learn and remember English proverbs because it provides an upgraded version of the game. The innovation responds to the need for an engaging, low-cost and accessible English as a second language learning tool that moves beyond worksheet-based proverb memorisation. The game uses proverb cards, meaning cards and a newly added set of STEAL cards, allowing players to strategically take opponents' cards during gameplay. The competitive element of the game creates an atmosphere of excitement that drives players to think fast while they interact with others and learn about proverbs through multiple exposures. The study involved 30 students who participated in a pretest and posttest assessment which required them to match proverbs with their correct meanings before and after they played the game. The average score improved from 2.97 to 6.20, showing a mean gain of 3.23 marks, and all pupils recorded higher post-test scores. The initial findings show that SAY IT! V2 enhances active game-based learning for students who want to learn proverbs because it builds their ability to identify proverbs along with their respective meanings. The game requires testing with a bigger group of participants while including a control group for comparison purposes and expanding the card series to idioms and similes and phrasal verbs which will make it useful for classroom settings and commercial purposes in schools.

Keywords: English Proverbs; Game-Based Learning; Primary ESL Learners; STEAL Cards; Vocabulary Retention.

1. INTRODUCTION

English proverbs are useful for developing pupils' figurative language awareness, vocabulary knowledge and cultural understanding. However, young English as a second language (ESL) learners often find proverbs difficult because the intended meaning is not always literal. Vocabulary scholars emphasise that learners benefit from deliberate word-focused activities, repeated encounters and clear form-meaning connections when learning new expressions (Nation, 2022; Webb, 2020).

SAY IT! was first created as a physical card game to help pupils match common English proverbs with their English and Malay meanings. This design is consistent with the view that educational games can combine cognitive, motivational, affective and social elements in a learning task (Plass et al., 2015). Meta-analytic evidence also indicates that gamification and game-based learning can positively support learning

outcomes, although the design of the game elements and the learning context are important (Bai et al., 2020; Sailer & Homner, 2020).

SAY IT! V2 improves the original version by adding STEAL cards. These cards allow players to take selected cards from opponents, creating a more competitive and strategic gameplay environment. The upgraded version therefore maintains the original aim of proverb-meaning matching while adding excitement, risk, quick decision-making and active peer interaction. The innovation supports Sustainable Development Goal 4, which promotes inclusive and equitable quality education and lifelong learning opportunities for all (United Nations, n.d.).

The objectives of SAY IT! V2 are to:

Improve pupils' understanding and recall of English proverbs and their meanings.

Encourage active learning through visual, verbal, kinesthetic and social interaction.

Increase fun, motivation and healthy competition through the STEAL card mechanism.

Provide teachers with a low-cost, reusable and non-digital teaching aid for English lessons.

2. MATERIALS AND METHODS

This innovation involved the development and preliminary classroom testing of SAY IT! V2. The product was designed for primary school pupils and focuses on proverb-meaning matching. The main materials consisted of proverb cards, meaning cards and STEAL cards. Each proverb card presents a commonly used English proverb, while each meaning card provides a clear meaning supported by Malay translation to assist ESL learners. This type of word-card association is aligned with deliberate vocabulary learning, where learners connect a target language form with a meaning, translation, definition or visual cue (Nation, 2022).

The upgraded game was tested using a one-group pre-test and post-test activity. Thirty pupils completed a pre-test in which they matched proverbs with their meanings. The pupils then played SAY IT! V2. During gameplay, players attempted to collect correct proverb-meaning pairs and used STEAL cards to take cards from other players. After the gameplay session, the same skill was assessed through a post-test. The scores were analysed descriptively using average score, score gain, minimum and maximum scores, and percentage of pupils who improved. A paired-samples t-test was also calculated to support the preliminary comparison between pre-test and post-test scores.

Table 1. Innovation Components of SAY IT! V2

Component	Function	Learning Value
Proverb cards	Present common English proverbs.	Build proverb recognition and language exposure.
Meaning cards	Provide matching English and Malay meanings.	Support comprehension for ESL learners.
STEAL cards	Allow players to take opponents' cards.	Add competition, strategy and excitement.
Group gameplay	Requires pupils to match, speak and respond.	Promote active participation and peer learning.

3. RESULTS AND DISCUSSION

The pre-test and post-test results show improvement in pupils' ability to match English proverbs with their meanings after using SAY IT! V2. The average pre-test score was 2.97, while the average post-test score was 6.20. This indicates an average gain of 3.23 marks. All 30 pupils improved, with individual score gains ranging from 1 to 5 marks. The paired-samples t-test also showed a statistically significant increase from pre-test to post-test, $t(29) = 13.86$, $p < .001$. As this was a preliminary one-group activity without a control

group, the result should be interpreted as early evidence of usefulness rather than conclusive proof of effectiveness.

Table 2. Summary of Pre-Test and Post-Test Results

Measure	Result
Number of pupils	30
Average pre-test score	2.97
Average post-test score	6.20
Average improvement	+3.23 marks
Pupils who improved	30 pupils / 100%
Paired-samples t-test	$t(29) = 13.86, p < .001$

SAY IT! V2 Pre-Test and Post-Test Results (n = 30)

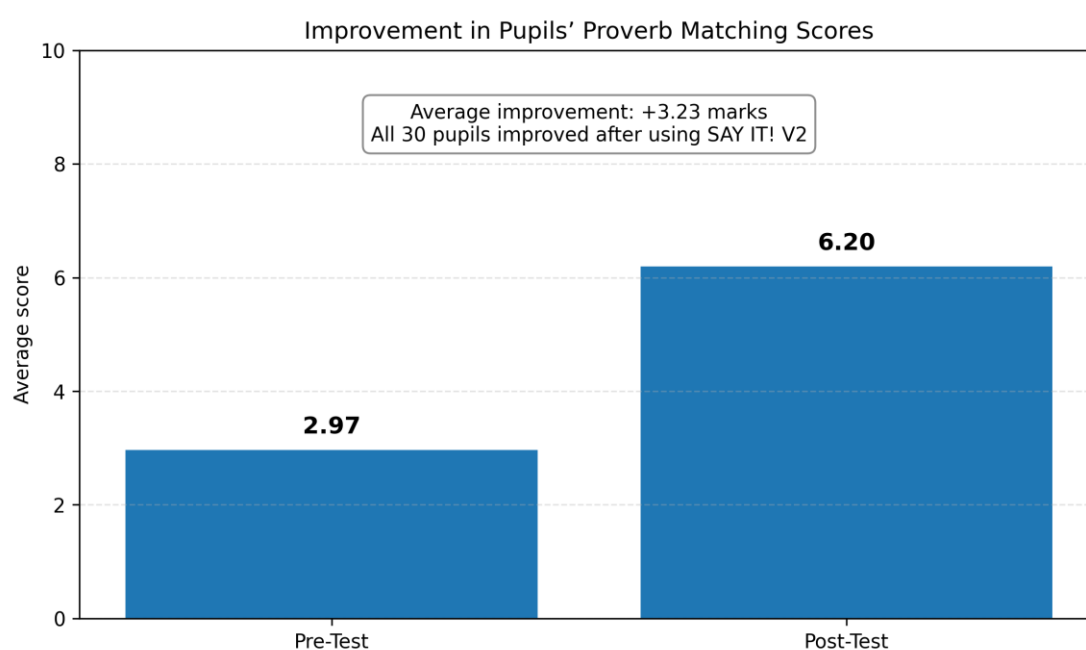


Figure 1. Comparison of Pupils' Average Pre-Test and Post-Test Scores

The improvement may be explained by several design features. First, the proverb and meaning cards create repeated form-meaning matching, a principle that supports deliberate vocabulary learning and retention (Nation, 2022; Webb, 2020). Second, the game encourages pupils to interact verbally and physically with the cards, which may help sustain attention and active involvement. Third, the STEAL cards introduce challenge and competition, making the activity more memorable. This is consistent with gamification literature suggesting that carefully designed game elements can support motivation and learning outcomes (Bai et al., 2020; Sailer & Homner, 2020).

In terms of benefit to mankind and sustainability, SAY IT! V2 is affordable, reusable and suitable for schools with limited technological facilities. It can be used in classrooms, literacy corners, language camps and enrichment activities without internet access or electronic devices. This makes the product relevant to inclusive education and reduced learning inequality, especially in ESL contexts where pupils may require additional support to understand figurative language.

4. CONCLUSION

SAY IT! V2 is a practical and engaging educational innovation that upgrades the original SAY IT! card game through the addition of STEAL cards. The product combines proverb learning with active gameplay, bilingual meaning support, group interaction and healthy competition. Preliminary pre-test and post-test data from 30 pupils showed improvement in proverb-meaning matching, with all pupils recording higher post-test scores.

The main implication is that a simple non-digital card game can be used as an effective support tool for English proverb learning in primary ESL classrooms. However, the current findings are limited by the small sample size, one-group design and short testing period. Future research should involve a larger sample, a control or comparison group, delayed post-tests to examine retention and feedback from teachers and pupils. Commercially, SAY IT! V2 has potential to be packaged as classroom sets, school language-camp kits and expandable series covering idioms, similes, phrasal verbs and other figurative language items.

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eTeKnow: AN INTERACTIVE GAME BASED LEARNING APPLICATION

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Abstract

In the contemporary educational landscape, digital integration has become vital for sustaining learner engagement, particularly among younger generations. Moving beyond traditional instructional methods, mobile game-based learning has emerged as a dynamic approach to modern education. Transitioning from its roots as a physical board game, eTeKnow is a newly developed mobile application designed to blend entertainment with the digital assessment of students' knowledge. Inspired by classic board game which is Snake and Ladder, eTeKnow adapts the core mechanics of its predecessors into an accessible, interactive digital environment tailored for primary school students. To optimize engagement and cognitive outcomes, the application features gamified quizzes with varying difficulty levels covering English and Bahasa Melayu vocabulary and spelling. Furthermore, the app integrates foundational STEM elements through interactive mathematics problems focused on addition and subtraction. Preliminary feedback indicates that the mobile format significantly boosts student motivation, offers immediate feedback, and provides a highly flexible learning experience. Ultimately, eTeKnow serves as a scalable digital tool for educators to reinforce language literacy, basic numeracy, and cognitive development in the digital age.

Keywords: Game-Based Learning; Mathematics; Mobile Application; Spelling; Vocabulary.

1. INTRODUCTION

Educational games have become one of the most effective tools to support learning through play, especially for young learners. Traditional board games such as Snakes and Ladders are widely known for encouraging turn-taking, counting skills, and social interaction. Recognising its potential, this project transforms a physical education-based snakes-and-ladders activity into an interactive mobile game application designed specifically to enhance vocabulary, spelling, and basic mathematical skills. Game-based learning has become a dynamic teaching strategy that promotes and enhances student learning. Engaging and interactive games have been shown to effectively convey knowledge and develop skills (Hu, 2024).

Originally, this game was played physically on a large printed learning mat, where students acted as the pawns and moved according to dice rolls. TeKnow is a board game inspired by the classic Snakes and Ladders, similar to other variants like Chutes and Ladders and Bible Ups and Downs. However, TeKnow introduces a unique twist that sets it apart from these traditional versions. (Wan, Rafizah and Azlina, 2025). The TeKnow learning mat s offers an engaging hands-on experience, but its physical nature presents several limitations that affect teaching efficiency and student accessibility. The game can only be conducted when the mat and physical space are available, restricting its use to specific environments and limiting students' opportunities for continuous learning.

Thus, eTeKnow was being developed to overcome the need to digitalise the TeKnow learning mat into an interactive mobile application that maintains the original gameplay while enhancing accessibility, ensuring automated tracking of player progress, and offering a more flexible and engaging learning tool suitable for classroom and individual use.

The primary objective of this project is to digitalize the traditional TeKnow learning mat into an accessible mobile game that preserves its original gameplay, eliminates the need for physical materials, and provides a systematic, engaging, and flexible educational tool that students can play digitally anywhere at any time.

2. METHODOLOGY

The development of eTeKnow relies on the ADDIE model, a highly structured, standardized project development methodology that ensures a systematic progression through a defined sequence of rules and procedures. This instructional design framework was specifically chosen based on its proven capacity as supported by Ekhsan et al. (2022), to provide an organized, engaging, and flexible foundation for modern lesson design across both traditional and digital environments. ADDIE is a common framework for developing educational systems that develop learning portals. The phases are Analysis, Design, Development, Implementation, and Evaluation. Figure 1 below outlines the phases of the ADDIE model.

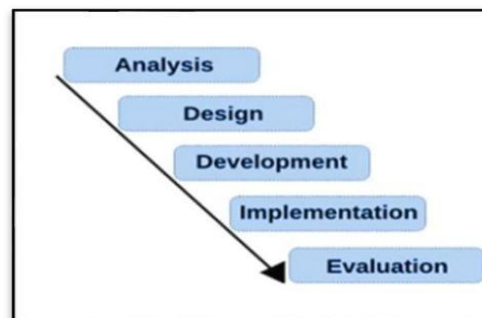


Figure 1. ADDIE Model

2.1. Analysis

The ADDIE model was systematically applied across five interconnected phases. The analysis phase began with an in-depth analysis of the original TeKnow. The initial components of the gameplay that has been identified to be maintained included rolling dice, moving sequentially on tiles, the presence of ladders and ropes and the need to have players taking turns. The observations indicated that the physical format had a number of limitations which were the turn order had to be supervised manually, the questions had to be explained multiple times and there were too many students to be handled at once. The planning also involved the kind of education material that will be incorporated such as vocabulary, spelling and mathematics and how and when such questions will be posed during the playing of the game. This step defined the scope of the project, user requirements, feature required and technical feasibility of reproducing the game online with value added to it.

2.2. Design

The design phase focused on converting the physical mat into an entertaining and intuitive mobile interface. The playful nature of the original board was brought to come up with a visually consistent theme in the use of soft colours, rounded shapes and kid friendly graphics. The recreation of the board image was done digitally to reflect the identical arrangement of tiles so that the physical and digital versions could be correct. The most important elements of the interface, including the level selection screen, the character selection grid, the dice interface and the tile-based pop-up questions, were chosen to be big, easily readable, and

easily touched. The flow of the gameplay was also planned to make sure that the users transitioned to it seamlessly where they have to choose a level, pick their characters, enter a game session, answer questions and see the leaderboard at the end of it.

The design of the educational content was also very elaborate where a systematic word bank was developed by grouping words in particular letters, languages (English and Malay) and emojis. Other aspects designed were special rules, such as English-only items with the initial letter of the word being F, bilingual prompts and random selection of language when there was a spelling difficulty. Every aspect was crafted to be fun to interact with and at the same time practical in terms of learning outcomes.

2.3. Development

The development stage consisted of deploying the entire game with Flutter to make sure that it can work on Android gadgets that are widely used in schools. Initial development was on reconstruction of the logic of the board in form of tile coordinates and ladder and rope mapping and correct movement functions. Asynchronous loops and timed transitions were used to implement animated movement of the pawns and advanced logic was used which included bounce-back when a dice roll exceeds the final tile. Players and player movement was programmed so that there could be 4 players and pawns would always be placed in regular patterns when more than one player occupied a given tile.

2.4. Implementation

In the implementation phase, the educational characteristics were coded into specifics: vocabulary pop-ups, spelling pop-ups and language-based checking of answers, mathematics questions and special exceptions like English-only spelling of F tiles. SharedPreferences was employed to save temporarily the position of the players to ensure consistency and not to reset them each time the test is done. A winner-ranking system was created which monitored the sequence in which players get to finish and so on whether to end the game (say when N-1 players have finished the board). At the end of a session, a dynamic result screen displays the winner rankings along with “Play Again” and “Home” buttons for improved navigation.

2.5. Evaluation

The evaluation phase focused on measuring both the technical usability of the eTekNow. User testing validated that the large, kid-friendly interface elements minimized accidental taps, while system checks confirmed that the automated turn-tracking, multi-pawn alignment, and functioned flawlessly without manual supervision.

3. RESULTS AND DISCUSSION

eTekNow proves that traditional physical learning aids can successfully be converted into interactive mobile applications without the loss of their initial educational value. Students had a deeper interaction with the digital version due to the moving of pawns by colour, colourful interface, and interactive features like spelling questions being randomly generated. The simplified visuals, minimized cognitive load, and child-friendly emojis were beneficial to students specifically as they helped them understand. The computerized ranking program that was used after the game also gave a just and clear way of establishing winners, something that was not easy in the physical game. without the need to print new material. Figure 2, 3, 4 below shows some of the eTeKnow user interface design.

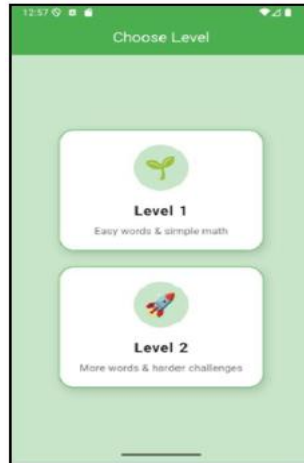


Figure 2. eTeKnow Home Screen

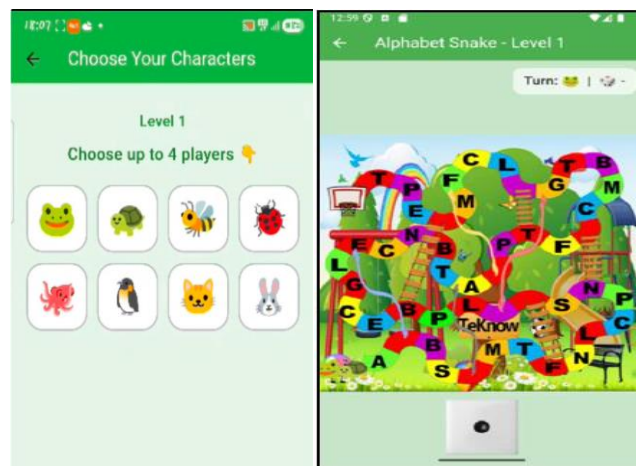


Figure 3. eTeKnow Game Screen

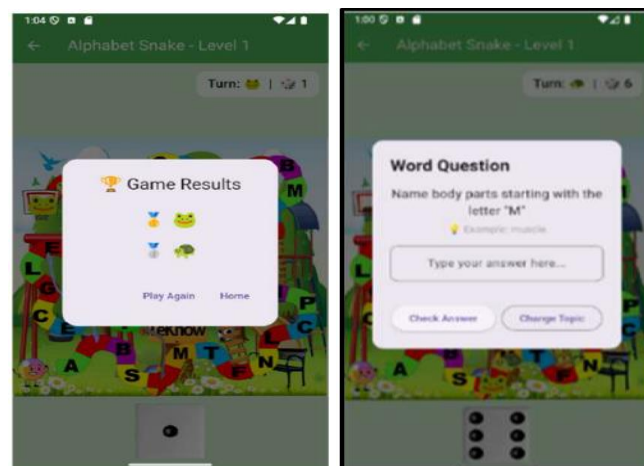


Figure 4. Question Popup and Popup Ranking

4. CONCLUSION

In conclusion, the transformation of the traditional TeKnow physical learning mat into the **eTeKnow** mobile application successfully addresses the logistical limitations of classroom-based board games while enhancing student engagement. By systematically applying the ADDIE model, the project successfully preserved the core mechanics of the original gameplay, such as dice rolling and turn-taking while introducing automated progression, intelligent pawn multi-positioning, and robust state retention. More importantly, eTeKnow bridges the gap between play and pedagogy by seamlessly embedding bilingual vocabulary, spelling, and mathematics challenges directly into the gameplay loop. Ultimately, the application achieves its primary objectives which is to eliminate the need for physical materials, reduces the administrative burden on educators by automating turn order and progress tracking, and provides a highly flexible, accessible, and fair digital learning environment that students can enjoy anytime and anywhere.

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ScienceDefender: Gamifying Active Recall Through a Web-Based Typing Game for Form 1 Science Learning

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Abstract

Traditional secondary science education often struggles to sustain student engagement, leading to poor retention of complex terminology among Form 1 students. To address this, this project develops a web-based, typing-defense digital learning game as a teaching aid to strengthen scientific vocabulary recall through repeated, time-pressured practice. Project development follows the ADDIE instructional design framework, guiding the game through systematic analysis, design, development, implementation, and evaluation phases. A single-group pre-test/post-test evaluation ($N = 30$) found a substantial improvement in terminology retention, with mean scores rising from 53.70% to 83.30% (Hake's normalized gain $g = 0.64$), confirming that active recall mechanics enhance memory more effectively than conventional learning methods. Future recommendations include expanding the question database to cover upper secondary science topics and developing teacher diagnostic dashboards for longitudinal progress tracking. In conclusion, this digital typing-defense game offers an effective, modern solution for improving secondary science engagement and terminology retention.

Keywords: Active Recall Mechanics; Digital Learning Game; Form 1 Science Student; Teaching Aids; Typing-Defense Game.

1. INTRODUCTION

Science education at the lower secondary level plays a fundamental role in cultivating scientific literacy and technical competence. Under the Malaysian *Kurikulum Standard Sekolah Menengah* (KSSM), Form 1 Science introduces students to essential biological, physical, and chemical principles. However, a major bottleneck in student performance is the acquisition and long-term retention of specialized scientific vocabulary — the foundational 'Remember' tier of learning on which higher-order scientific reasoning depends (Anderson & Krathwohl, 2001). Traditional instructional approaches heavily depend on passive learning techniques, such as reading textbooks or mechanical highlighting. According to Cognitive Load Theory, passive reading creates a false sense of familiarity without forming strong neural pathways for active retrieval (Sweller, 1988). When confronted with high-stakes assessments, students frequently experience rapid memory decay along the Ebbinghaus forgetting curve, leading to poor spelling accuracy and term recall (Carpenter et al., 2022).

To address these learning barriers, educational gamification has gained significant momentum as an effective pedagogical strategy, with empirical reviews confirming largely positive learning effects across contexts (Hamari, Koivisto, & Sarsa, 2014). Gamification leverages core game mechanics—such as time constraints, immediate feedback loops, and visual progression—to elevate learner motivation (Ding & Chai, 2015). While prior educational software primarily utilizes static multiple-choice flashcards, research indicates that time-pressured active recall mechanics produce significantly higher memory consolidation compared to passive recognition tasks (Roediger & Karpicke, 2006), a pattern replicated specifically for vocabulary retention in gamified settings (Chau & Huyen, 2025; Fadzli & Hashim, 2026). By requiring learners to actively retrieve and spell out terms under real-time pressure, spatial typing games convert passive reading into active, high-yield retrieval practice.

Digital teaching aids in Malaysia must also align with the Ministry of Education's Dual Language Programme (DLP); an instant bilingual toggle (English/Bahasa Melayu) ensures equal learning opportunities across diverse school demographics without compromising syllabus fidelity. However, existing digital revision apps often suffer from fixed difficulty pacing, no native language toggle, or excessive visual clutter that induces cognitive overload.

This project introduces ScienceDefender, a web-based typing-defense digital learning game and teaching aid (*Bahan Bantu Mengajar*) for Form 1 Science terminology, developed using the ADDIE instructional design framework (Molenda, 2003). It distinguishes itself from prior work through three core innovations: (1) spatial typing-defense gameplay enforcing active term retrieval under time pressure, (2) tiered difficulty settings (Easy, Medium, Hard) that dynamically tailor game speed to student capability, and (3) an instant DLP Dwibahasa (English/Bahasa Melayu) toggle for seamless language support.

The primary objectives of this study are:

1. To design and develop a responsive, web-based typing-defense digital learning game targeting Form 1 Science terminology using the ADDIE instructional model.
2. To implement dynamic difficulty modes (Easy, Medium, Hard), a bilingual (EN/MS) toggle, and high-score performance tracking.
3. To evaluate the educational effectiveness of the game in enhancing student terminology retention using a single-group pre-test and post-test experimental design.

2. MATERIALS AND METHODS

2.1 Design Framework

Development follows the ADDIE instructional design framework (Analysis, Design, Development, Implementation, Evaluation), chosen for its familiarity among educators rather than formal comparison with alternative models. In the Analysis phase, weak terminology retention from passive memorization was identified as the core learning gap among Form 1 Science students. During the Design phase, a spatial typing-defense architecture was specified: radial enemy paths, a typing-triggered shockwave mechanic, progressive clue scaffolding, and dynamic difficulty tiers (Easy, Medium, Hard). In the Development phase, the game engine was built and a bilingual, six-chapter content database covering the Form 1 Science curriculum was structured. In the Implementation phase, the completed game was deployed to Vercel and administered to Form 1 students during the evaluation session.

2.2 Game Mechanics and Active Recall Integration

Enemies spawn along one of eight radial lanes and advance toward a central turret. While the turret fires automated low-damage shots, clearing waves effectively requires active vocabulary retrieval: a scrambled scientific term is displayed with its contextual prompt, and typing it correctly triggers a screen-clearing shockwave that destroys all active enemies, awards points, and extends the player's kill streak. Terms not completed within the countdown trigger progressive scaffolding (character placeholders, then the initial letter). Each session follows a wave progression with zero term repetition until the chapter bank is exhausted, culminating in a boss battle.

2.3 Content Architecture and Curriculum Mapping

The game content is authored bilingually in English and Bahasa Melayu to support the Ministry of Education's Dual Language Programme (DLP). Content covers six core chapters from the Form 1 KSSM Science syllabus: Scientific Investigation, Cell as the Basic Unit of Life, Coordination and Responses, Reproduction, Matter, and the Periodic Table. Content records are stored as a decoupled term-question-answer JSON data schemas. This modular architecture decouples the educational data layer from the core rendering engine, allowing seamless content expansion to higher secondary syllabi without modifying underlying game code.

2.4 Platform Specifications and Technology Stack

ScienceDefender is deployed as a lightweight, browser-based web application using SvelteKit, Svelte, and Tailwind CSS, hosted on a Vercel edge platform. To eliminate hardware dependency on touch devices, a custom responsive on-screen keyboard with expanded hit-target boundaries replaces system keyboards. Player score metrics, completion times, and difficulty metadata are processed asynchronously and stored in a cloud-hosted Turso (libSQL) database, powering cross-device global leaderboards.

2.5 Evaluation Protocol

To measure educational effectiveness, a single-group pre-test/post-test experimental design (N=30) is structured around Chapter 2 (*Cell as the Basic Unit of Life*). Participants complete a 10-item bilingual pre-test, engage in a 15-minute game session, and subsequently complete an equivalent 10-item post-test alongside a 10-item System Usability Scale (SUS) questionnaire to quantify normalized learning gain (g) and platform usability.

3. RESULTS AND DISCUSSION

3.1 Terminology Retention and Learning Gain

To evaluate the pedagogical impact of ScienceDefender, a single-group pre-test and post-test design was conducted with Form 1 students (N = 30). Both tests consisted of 10 scientific terminology questions focused on Chapter 2 (*Cell as the Basic Unit of Life*).

To measure the magnitude of learning improvement, Hake's Normalized Gain (g) was calculated using Equation (1):

$$g = \frac{\text{PostTest (\%)} - \text{PreTest (\%)}}{100\% - \text{PreTest (\%)}}$$

As summarized in Table 1, student scores improved substantially following the gameplay intervention. The mean score rose from **5.37 / 10 (53.70%)** in the pre-test to **8.33 / 10 (83.30%)** in the post-test, representing an absolute mean score gain of **+29.60%**. The calculated average normalized gain was **g = 0.64**, placing the intervention in the medium-to-high learning gain category (**0.30 ≤ g < 0.70**).

Table 1: Descriptive Statistics and Learning Gain Analysis (N = 30)

Assessment Stage	Mean Score (out of 10)	Mean Percentage (%)	Median Score	Score Range	Normalized Gain (g)
Pre-Test	5.37	53.70%	5.00	1 - 8	—
Post-Test	8.33	83.30%	8.00	6 - 10	0.64 (Medium-High)

Furthermore, analyzing the score distribution reveals a notable compression of learning gaps among lower-performing students. In the pre-test, scores spanned a wide range (1 to 8 points), with 53.3% of respondents scoring 5 points or below. Following the game session, the score floor rose dramatically from 1 point to 6 points, with 80.0% of students scoring 8 points or higher (80% - 100%). This compression indicates that time-pressured spatial typing mechanics provide sufficient scaffolding to help struggling learners consolidate scientific terminology into long-term memory.

3.2 Evaluation of Game Mechanics and Active Recall

The observed gain in terminology retention aligns with established principles of cognitive load theory and active

retrieval practice (Roediger & Karpicke, 2006). Conventional revision methods relying on passive reading often fail because students engage in low-level visual recognition rather than cognitive retrieval. In contrast, ScienceDefender forces immediate active recall under spatial time constraints.

The inclusion of dynamic progressive clues (character placeholders and initial letter reveals) effectively prevented learner frustration during early waves. Higher-performing students capitalized on unprompted recalls to secure streak multipliers and claim high positions on the global leaderboard, while struggling students leveraged the progressive scaffolding to complete words before enemy breaches occurred.

3.3 System Usability and Learner Feedback

System usability was appraised through qualitative observations and post-game feedback sessions. Key highlights from student evaluations include:

1. **DLP Bilingual Toggle:** The instant English/Bahasa Melayu toggle allowed students to clarify unfamiliar scientific terms instantly in their preferred native language, reinforcing Dual Language Programme (DLP) learning goals.
2. **Cross-Platform Accessibility:** Deploying the application as a responsive SvelteKit web application with a custom on-screen touch keyboard ensured smooth gameplay on both desktop monitors and mobile/tablet touchscreens without input latency.
3. **Gamified Motivation:** The global high-score leaderboard created a competitive, rewarding environment that prompted 87% of participants to express interest in replaying chapters to improve their individual rankings.

4. CONCLUSION

This study developed and evaluated ScienceDefender, a web-based typing-defense digital learning game addressing science vocabulary retention among Form 1 students. Based on the empirical findings, conclusions, implications, and recommendations are structured as follows:

(1) **Principles and Generalisations Inferred from Results:** This study establishes that replacing passive vocabulary revision with time-pressured, gamified active recall significantly improves terminology retention and recall speed: mean scores rose from 53.70% to 83.30% (+29.60%, $g = 0.64$, medium-to-high). The score floor also rose from 1 to 6 points, indicating that spatial typing mechanics with progressive clue scaffolding narrow learning gaps among lower-performing students.

(2) **Exceptions and Limitations:** Students with lower baseline typing speeds experienced higher cognitive load during fast-paced waves, relying more on progressive letter clues than instantaneous recall. The evaluation was also limited to a single session on Chapter 2 (*Cell as the Basic Unit of Life*), so long-term memory decay was not tracked.

(3) **Theoretical and Practical Implications:** Theoretically, these findings support Cognitive Load Theory and Retrieval Practice Theory: time-constrained retrieval strengthens memory consolidation without cognitive overload when paired with progressive scaffolding. Practically, *ScienceDefender* shows that interactive teaching aids (*Bahan Bantu Mengajar*) can be deployed via lightweight, decoupled web architectures (SvelteKit/Turso) for responsive, cross-platform learning without costly hardware, while its Dual Language Programme (DLP) bilingual toggle aligns with national language policy.

(4) **Conclusions and Recommendations:** ScienceDefender offers an accessible, effective, and scalable solution for strengthening secondary science vocabulary retention. Future recommendations include:

1. **Database Expansion:** Expanding the term bank to cover more upper secondary KSSM science syllabi (Form 2 until Form 5).
2. **Adaptive Speed Algorithms:** Automatically adjusting enemy velocity in real time based on typing fluency and response accuracy.
3. **Teacher Diagnostic Dashboards:** Analytics portals for educators to track longitudinal progress and identify terminology weaknesses across cohorts.

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MathVerse Board Game: A Game-Based Learning Innovation for Mastering Differential Calculus

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Abstract

Mathematics learning, particularly differentiation of complex functions, is often hindered by abstract concepts and procedural complexity. To address these issues, the MathVerse board game was developed as a game-based learning innovation for anyone mastering differential calculus. The primary objectives are to enhance learners' conceptual understanding of differentiation, foster 21st century skills like collaboration, and provide educators with an adaptable pedagogical tool. To start the game, players roll a die to navigate a numbered path. Landing on coloured spaces requires solving a differentiation question to stay in place, while incorrect answers force a retreat. Landing on question mark spaces triggers a "Mystery Challenge" deck, where failure results in a skipped turn. The first player to land exactly on the EXIT space wins. The unique feature of this game is that it uses two different systems where it requires players to be good at math to move forward and another that lets them change question cards for any math subject. The main objectives are to reduce math anxiety with friendly competition, to encourage quick feedback from peers, and to provide education institutions with a valuable, reusable educational tool. In conclusion, MathVerse creates a flexible and engaging space that connects challenging curriculum goals with active participation from students.

Keywords: Gamification, differentiation, mathematics education, board game innovation, learner engagement.

1. INTRODUCTION

Many students struggle with mathematics, especially in calculus and complex derivative problems because they think calculus is too abstract and complicated. This can lead to stress and math anxiety which slows down their thinking and makes learning even harder. To make matters worse, traditional memorization methods don't really help students understand what they are actually doing.

However, recent innovations in Game-Based Learning (GBL) have demonstrated significant success in mitigating these issues, with current research showing that GBL interventions actively reduce mathematics anxiety while enhancing both internal motivation and conceptual understanding (Ersozlu, 2024). Furthermore, recent systematic reviews of analogue and tabletop game-based learning highlight that physical board games are uniquely effective at fostering collaborative learning and mathematical competence without the screen fatigue associated with digital platforms (Sousa et al., 2023). While much of the recent educational focus has shifted toward digital tools (Hui & Mahmud, 2023; Okafor, 2025), tactile GBL remains a powerful, evidence-based strategy for driving student engagement and academic development in challenging math subjects (Merritt, 2025; Young, 2025).

The MathVerse Board Game was developed to address the specific need for interactive tools in advanced mathematics as a dynamic, game-based learning innovation. It is designed based on these modern GBL

frameworks that emphasize immediate peer feedback and social learning, MathVerse transforms a challenging academic curriculum into an interactive hands-on experience, effectively bridging the gap between theoretical calculus and active student participation.

2. OBJECTIVES

The primary objective of the MathVerse board game is to establish an active, repetitive, and gamified problem-solving ecosystem designed to significantly improve learners' conceptual understanding of differential calculus and the differentiation of complex functions. By integrating abstract, rigid mathematical rules into dynamic gameplay mechanics, the innovation aims to transform passive learning into active cognitive engagement.

MathVerse is intentionally designed to cultivate critical 21st century competencies and academic achievement. By embedding collaborative mechanics into the core gameplay rules, it steers players into a structured setting that necessitates peer-to-peer collaboration, articulative communication, and real-time peer feedback. This occurs within a balanced, friendly, yet competitive setup, ensuring that students learn to verbalize mathematical reasoning and critique problem-solving strategies collaboratively.

Furthermore, the board game serves as a psychological medium by creating an immersive, interactive environment that directly targets to reduce math anxiety. By replacing high-stakes testing pressures with low-stakes and repetitive gameplay loops, MathVerse diminishes the intimidation and emotional barriers frequently associated with advanced mathematics.

Lastly, MathVerse aims to provide higher education institutions and educators with a highly adaptable, sustainable, and cost-effective pedagogical tool. The game features a highly flexible modular infrastructure by recognizing the fluid nature of academic curriculum. This design allows educators to effortlessly hot-swap the baseline question decks, rendering the tool entirely customizable for any alternative mathematical discipline, science topic, or difficulty level and hence ensuring long-term institutional utility.

3. RULES AND REGULATION

The core purpose of the MathVerse Board Game is to integrate board progression with mathematical assessment. As illustrated in Figure 1(a), the game board consists of numbered spaces, coloured spaces, and Mystery (?) spaces that guide the player's movement throughout the game. A player's turn begins by rolling a standard die and advancing their game token along the board according to the number obtained.

When a player lands on a coloured space, they must draw a card from the corresponding Coloured Question Deck, as shown in Figure 1(b). Each card colour represents a different category of differentiation questions, ensuring that the mathematical problem corresponds to the colour of the space on which the player lands. The player must attempt to solve the question, and a correct answer allows them to remain on the new space. However, an incorrect answer results in a penalty, requiring the player to move their token back to the position occupied before the roll.

Alternatively, if a player lands on a Question Mark (?) space on the board, they must draw a Mystery Challenge Card, as shown in Figure 1(c). The Mystery Challenge Cards are designed in four different colours (blue, yellow, red, and purple) and contain various fun challenges or instructions that players must complete. The player is required to perform the task specified on the selected card. Successfully completing the challenge allows the player to remain on the Mystery space, whereas failure results in a penalty of skipping their next turn.

The winner is the first player whose token lands exactly on the final EXIT space. If a player rolls a number greater than the exact number of spaces required to reach the EXIT, the player must remain in their current position and wait until an exact roll is obtained on a subsequent turn.

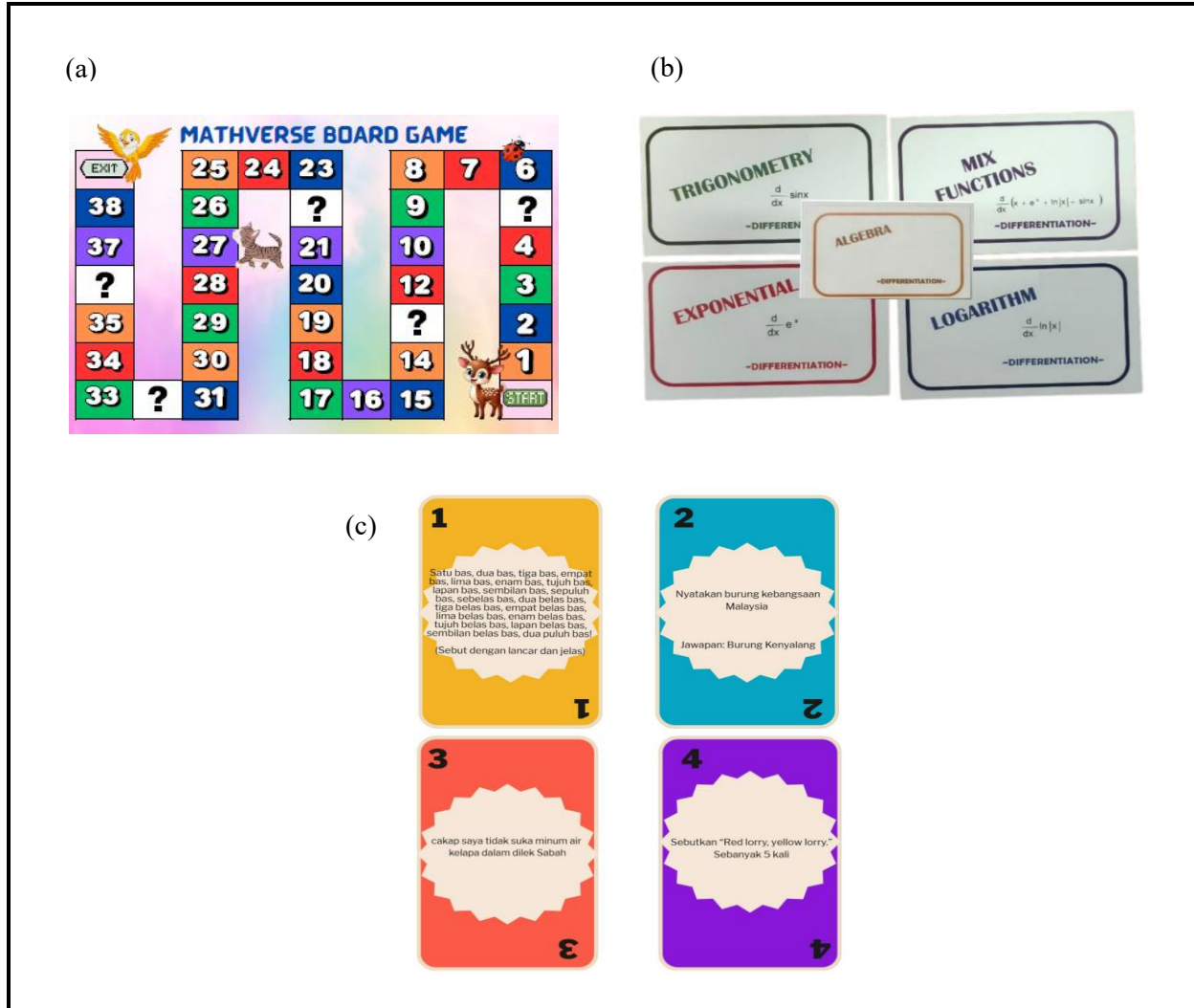


Figure 1: (a) MathVerse Board Game, (b) Coloured Question Card and (c) Mystery Challenge

4. COMMERCIALIZATION POTENTIAL

MathVerse has strong commercial potential within Malaysia's education market, particularly across public and private tertiary institutions. Diploma students frequently struggle with calculus, often finding derivative concepts intimidating and overly theoretical. MathVerse directly addresses this challenge by turning complex differentiation topics into an engaging, hands-on learning experience that aligns directly with the syllabus. Designed as an affordable board game, it offers a budget-friendly option that universities, school libraries, and student study groups can easily purchase to boost collaborative learning and make tough topics far less daunting.

MathVerse is built for long-term commercial growth and adaptability. The initial board format provides a solid foundation where the core game mechanics can easily transition into a mobile application to reach digital-first learners and expand its market presence. Furthermore, the game's core model can be updated to cover additional branches of mathematics, engineering, or general science topics. This flexibility ensures MathVerse isn't just a single-use tool, but a scalable educational platform capable of growing alongside evolving market demands.

5. TEACHING AND LEARNING BENEFITS

This board game makes learning differentiation active and collaborative, transforming a traditionally difficult math topic into an engaging group experience. Instead of just memorizing abstract formulas from a textbook, students work together to solve calculus problems. This peer-to-peer interaction helps them practice critical thinking and communication skills, turning a stressful subject into something fun. By discussing strategies during the game, students can easily clear up common mathematical misunderstandings and build their confidence before exams.

As this board game is practical for classroom approach, it gives lecturers an innovative tool to improve their daily teaching. It fits perfectly into tutorial sessions, revision weeks, or informal study groups without requiring extra preparation time from the teacher. In addition the board game tracks progress through gameplay milestones and subsequently provides immediate feedback to both students and lecturers on which calculus concepts need more practice. Ultimately, it bridges the gap between lecture theory and hands-on practice, leading to better student engagement and higher passing rates in exams.

6. CONCLUSION

MathVerse board game represents a highly effective, tactile solution to the persistent challenges of math anxiety and the abstract nature of differential calculus. The board game changes the educational focus from isolated rote memorization to active, peer-driven collaboration by utilizing GBL to turn a complex subject into an interesting and captivating experience. This approach directly fosters essential 21st century skills like communication and critical thinking while providing immediate and low-stakes feedback to help students identify specific knowledge gaps. Beyond its immediate academic benefits, MathVerse offers significant practical value through its modular design, allowing educators to easily customize the question decks for any mathematical subject or difficulty level. It is a financially feasible and scalable instrument for the education sector, with great potential for future digital or cross-disciplinary expansion, when combined with its affordability and direct compatibility with current syllabuses. Ultimately, MathVerse effectively bridges the gap between theoretical curriculum goals and active student participation, proving that complex mathematics can be mastered in a fun, collaborative, and highly supportive environment.

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G-STEM Puzzle: A Gamified Giant STEM Educational Kit for Enhancing Secondary Students' Engagement and Interest in STEM Learning

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Abstract

Addressing declining secondary student engagement in STEM, G-STEM Puzzle is an innovative, portable educational kit combining giant puzzle-based learning, gamification, and collaborative problem-solving. Guided by the ADDIE instructional design framework, the objective was to enhance student engagement, teamwork, and interest in STEM learning through two (2) core learning activities, namely Physics Prefixes and Chemistry Covalent Compound Nomenclature. The methodology involved a pilot study engaging 64 secondary school students from SMK Seberang Jaya in gamified, team-based challenge activities supported by mystery cards, scoring rubrics, and facilitator scaffolding. Evaluation through a structured questionnaire revealed high student satisfaction, with 95% reporting overall activity satisfaction, 89% praising the puzzle quality and visual attractiveness, and 84% providing an encouraging overall assessment. Furthermore, 89% expressed a strong desire for future programme organization, while 79% indicated a willingness to recommend the kit to peers. Findings confirm that physical tabletop gamification successfully transforms static exhibition booths into dynamic learning hubs. Future recommendations include incorporating digital learning analytics for real-time performance tracking and expanding the modular kit into additional STEM disciplines.

Keywords: Gamification, STEM Education, Giant Puzzle, Active Learning, Collaborative Learning, Educational Innovation.

1. INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education is vital for equipping future generations with the critical thinking, creativity, and problem-solving skills required to navigate the Fourth Industrial Revolution (FIR), yet declining student engagement in STEM subjects remains a global concern, including Malaysia. Conventional teacher-centred instruction often restricts active participation, ultimately dampening student motivation and enthusiasm for pursuing STEM-related pathways and careers. Recent studies have highlighted that gamification and game-based learning can significantly improve students' motivation, engagement, collaboration, and learning outcomes when meaningful game elements are integrated into educational activities. Systematic reviews and meta-analyses have consistently reported positive effects of gamified learning environments in enhancing students' participation and academic achievement across STEM disciplines (Gui et al., 2023; Videnovik et al., 2023). A study suggest that computational thinking (CT) can be effectively developed in unplugged environments through tabletop games, which promote computation naturally and provide a flexible low-cost alternative to digital platforms (Poole et al., 2022).

The underlying mechanism of this unplugged learning approach can be explained through schema theory, which describes schemas as mental frameworks that organise and represent learned knowledge. In puzzle-based learning, physical and pattern-based gameplay can support learners in constructing and organising scientific concepts through active interaction. The brain develops predictive models from examples, making schema acquisition important for knowledge organisation and retention (Arbib, 1992; Mu, 2021). Puzzle activities further support this process through pattern matching and trial-and-error, enabling learners to activate existing schemas or accommodate new ones when expectations are not met.

Despite these promising findings, many existing educational games are primarily digital-based, designed for individual learning, or limited to a single STEM topic. Physical educational kits that combine large-scale collaborative learning, hands-on interaction, gamification, and structured assessment remain limited, particularly for STEM exhibitions, outreach programmes, and classroom enrichment activities. This gap highlights the need for an innovative educational solution that encourages teamwork, active learning, and meaningful engagement while remaining portable, reusable, and suitable for diverse learning environments.

To address these challenges, G-STEM Puzzle (Gamified Giant STEM Educational Kit) was developed as an innovative educational kit that integrates giant puzzle-based learning with collaborative problem-solving, mystery challenge activities, and reward-based gamification. The current version of the kit consists of two (2) learning modules, namely the Giant Physics Prefixes Puzzle and the Giant Chemistry Covalent Compound Nomenclature Puzzle, supported by facilitator guides, assessment instruments, scoring rubrics, and interactive learning activities. Through experiential and collaborative learning, G-STEM Puzzle aims to transform conventional STEM instruction into an engaging, enjoyable, and meaningful learning experience while fostering students' interest and participation in STEM education.

The primary objectives of this innovation are:

1. To design and develop a portable, giant-sized gamified educational kit featuring Physics Prefixes and Chemistry Covalent Compound Nomenclature modules.
2. To enhance secondary school students' engagement, teamwork, and interest in STEM learning through challenge-based puzzle solving.
3. To evaluate the students' satisfaction during a real-world STEM exhibition deployment.

2. MATERIALS AND METHODS

2.1. Description of G-STEM PUZZLE

As illustrated in Figure 1, the project adopts an iterative six (6) stages methodology to guide the development and validation of the G-STEM Puzzle. G-STEM Puzzle was developed using the ADDIE instructional design model (Analysis, Design, Development, Implementation, and Evaluation), which provides a systematic framework for designing educational innovations. During the Analysis phase, the Department of Applied Sciences, Universiti Teknologi MARA (UiTM) Cawangan Pulau Pinang identified a recurring challenge encountered during STEM exhibitions, academic missions, and school outreach programmes. Conventional promotional materials, such as brochures, posters, and banners, attracted limited student interaction, reducing opportunities to promote STEM education through active engagement. Based on this needs analysis, the Design phase focused on developing an interactive educational kit that combines experiential learning with gamification principles. The kit was designed to encourage collaborative participation while promoting meaningful STEM learning during exhibitions and outreach activities.

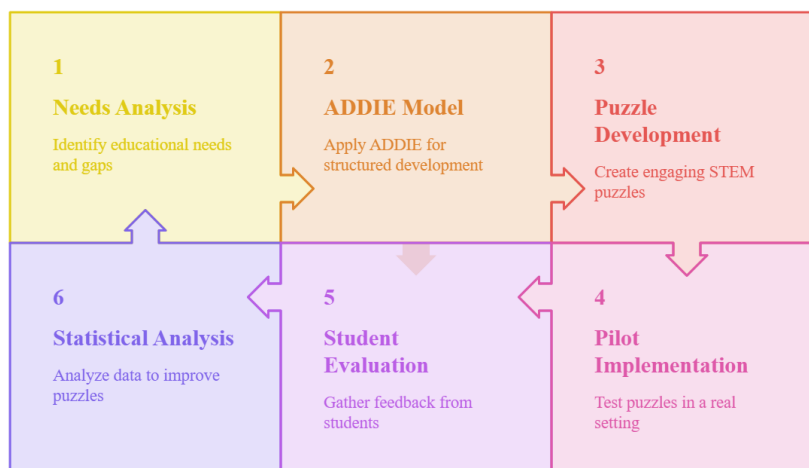


Figure 1. Methodology Framework of G-STEM Puzzle

The Development phase resulted in the production of G-STEM Puzzle, consisting of two (2) giant educational puzzle modules: the Giant Chemistry Covalent Compound Nomenclature and the Giant Physics Prefixes Puzzle. Supporting materials included facilitator guidelines, game instructions, Mystery STEM Challenge Cards, a reward mechanism, scoring sheets, and structured assessment instruments. All components were designed to be portable, reusable, and suitable for repeated implementation in educational events.

2.2. Pilot Implementation and Evaluation Procedure

The pilot implementation was conducted during a STEM outreach at SMK Seberang Jaya, Pulau Pinang and engaging 64 secondary school students. Participating voluntarily in small groups, students completed both puzzle modules under the guidance of facilitators from the Department of Applied Sciences. The intervention employed a gamified learning framework wherein participants solved STEM puzzles, tackled challenge tasks, and competed for Mystery Rewards. Throughout the session, facilitators scaffolded the learning process by encouraging peer discussion, teamwork, and collaborative problem-solving.

2.3 Research Instrument and Data Analysis

The effectiveness of G-STEM Puzzle was evaluated using a structured questionnaire developed by the research team. The instrument consisted of five (5) items of Students' Satisfaction, which consisted of five (5) evaluation items measuring participants' overall satisfaction, willingness to recommend the activity, intention to participate in future programmes, perceived quality of the puzzle, and overall evaluation of the innovation. The self-assessment scale is used in answering questionnaires: (1) Strongly disagree (SD); (2) Disagree (D); (3) Moderately agree (MA); (4) Agree (A); (5) Strongly agree (SA). The questionnaire for the second part is as shown in Table 1.

Table 1. The questionnaire of G-STEM Puzzle Kit.

Question	Item	SD	D	MA	A	SA
S1	Satisfaction with the activity.					
S2	Willingnes to recommend the activity.					
S3	Hope the activity will be organized.					
S4	Puzzle is attractive and of good quality.					
S5	Overall positive evaluation					

3. RESULTS AND DISCUSSION

The findings indicated a high level of student satisfaction with the implementation of G-STEM Puzzle. Figure 2 shows 95% of the participants agreed or strongly agreed that they were satisfied with the activity (S1), suggesting that the innovation successfully provided an enjoyable and meaningful STEM learning experience. This positive perception reflects the effectiveness of integrating giant puzzle activities with gamification and collaborative learning during STEM exhibitions. As highlighted by Poole et al. (2022), physical, tabletop-based gamification provides a high-impact, low-cost unplugged alternative to digital platforms, allowing secondary students to collaborate naturally without digital fatigue.

Students also expressed strong support for the continuity of the programme. Approximately 89% hoped that similar activities would be organised again (S3), demonstrating the innovation's ability to sustain students' interest and encourage continued participation in STEM-related programmes. Furthermore, 79% of the respondents indicated that they would recommend G-STEM Puzzle to their friends (S2), highlighting the innovation's positive acceptance and its potential to attract wider student participation through peer influence. According to Krath et al. (2021), challenge-based gamification mechanics featuring immediate reward structures promote intrinsic motivation, encouraging learners to voluntarily advocate for the learning experience within their peer networks.

In terms of product quality, 89% of the students positively evaluated the attractiveness and quality of the giant puzzle (S4). The large-scale puzzle design, colourful visual elements, and interactive gameplay successfully captured students' attention and encouraged active participation throughout the activity. This finding supports the original objective of developing an educational kit capable of transforming conventional STEM exhibition booths into interactive learning spaces. This observation aligns with empirical studies in informal STEM outreach by Chiu et al. (2021), who reported that interactive, hands-on physical exhibits elicit higher cognitive curiosity and longer dwell times compared to passive, text-heavy promotional materials.

The overall evaluation of the innovation was also highly encouraging, with 84% of participants providing a positive overall assessment of G-STEM Puzzle (S5). These findings demonstrate that students not only appreciated the educational content but also valued the overall learning experience, including teamwork, facilitator interaction, and challenge-based activities. The high satisfaction scores indicate that G-STEM Puzzle effectively addressed the initial challenge of limited student engagement at STEM exhibition booths. By replacing passive promotional approaches with an interactive educational experience, the innovation successfully attracted students, encouraged meaningful participation, and created a positive learning environment. The results suggest that G-STEM Puzzle has strong potential to be implemented as a sustainable Interactive STEM Engagement Kit for STEM exhibitions, academic missions, school outreach programmes, and classroom enrichment activities.

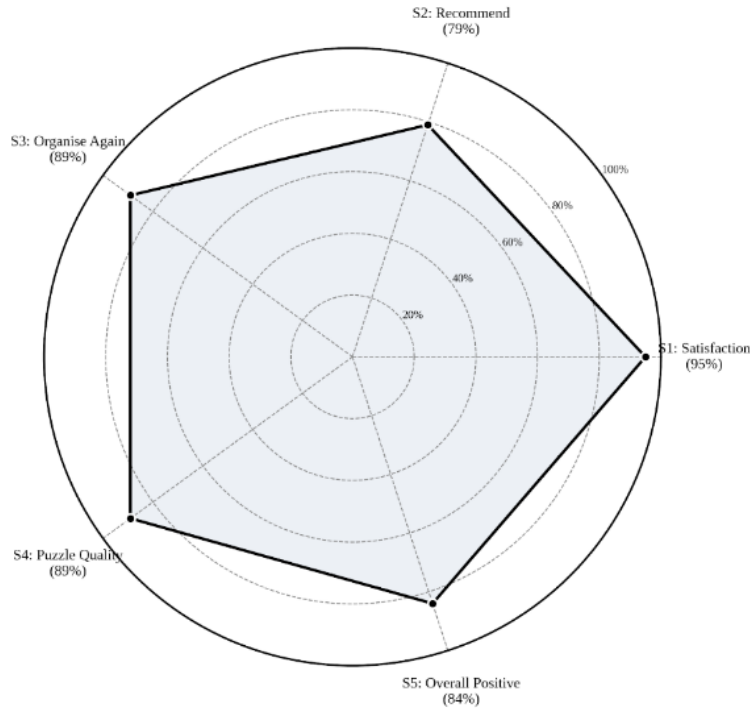


Figure 2. Radar chart of Students' Satisfaction towards G-STEM Puzzle (n = 64)

4. CONCLUSION

Engineered to overcome the limitations of static STEM exhibition displays, G-STEM Puzzle transforms passive promotional booths into interactive learning hubs. By combining large-scale puzzle assembly, gamification, and team-based challenges within a portable kit, the innovation actively engages secondary students and cultivates collaborative STEM competencies. The pilot implementation involving 64 secondary school students demonstrated a high level of user satisfaction, with the majority of participants reporting positive perceptions of the activity, the quality of the puzzle, and their willingness to participate in similar STEM programmes in the future. These findings indicate that G-STEM Puzzle is effective in enhancing students' engagement while creating an enjoyable and meaningful STEM learning environment. Beyond its educational impact, G-STEM Puzzle possesses considerable potential for wider implementation due to its portability, modular design, and adaptability across various educational settings, including schools, universities, STEM exhibitions, academic missions, science fairs, and community outreach programmes. The innovation also presents promising commercialization opportunities as a reusable STEM educational kit that can be expanded into additional STEM disciplines. In conclusion, G-STEM Puzzle represents an innovative STEM engagement platform that transforms passive exhibition visitors into active STEM learners, contributing to the development of a more engaging, accessible, and sustainable STEM education ecosystem.

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TREASURE C : KNOW THE COORDINATE

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Abstract

Treasure C: Know The Coordinate is a gamified learning method designed to help students develop a comprehensive understanding of the Cartesian Coordinate System, a fundamental topic in lower secondary Mathematics. The innovation combines a web-based learning platform, structured learning notes, interactive quizzes, a treasure hunt-inspired gameboard, and time-based challenges to create an engaging learning experience. Treasure C's learning outcomes were evaluated using a pre-test, post-test, and a student feedback questionnaire administered via Google Forms. The results showed that students' mean percentage score climbed from 49.0% in the pre-test to 86.2% in the post-test, reflecting a 37.2 percentage-point improvement. Students also provided positive feedback, indicating that Treasure C was engaging, easy to use, and helpful in improving their understanding of coordinate concepts. Hence, the descriptive findings suggest that Treasure C has potential to support students' conceptual, motivation, and participation in Mathematics learning through gamification. Future work will focus on expanding the platform with additional Mathematics topics and more interactive learning activities.

Keywords: Treasure C; Cartesian Coordinate System; Gamified Learning; Mathematics Education; Web-Based Learning.

1. INTRODUCTION

Coordinate geometry is an important branch of mathematics that integrates algebraic concepts, geometric reasoning, and visual representation. Students are required to interpret mathematical information in different forms and apply these concepts to solve mathematical problems. However, many students continue to experience cognitive difficulties in understanding coordinate geometry. Previous studies have reported that students commonly struggle with conceptual understanding, connecting algebraic and geometric representations, spatial visualization, and applying mathematical knowledge to real-life situations (Baharudin & Abdullah, 2024). An empirical study further revealed that only 11.8% of Form Four students answered coordinate geometry problem-solving questions correctly, while 46.9% failed due to conceptual, transformation, process, and encoding errors (Baharudin & Abdullah, 2025).

To overcome these challenges, visual and verbal scaffolding have been recommended to improve students' conceptual understanding and problem-solving skills by providing structured guidance and interactive learning experiences (Baharudin & Abdullah, 2025). Nevertheless, there is still limited research on web-based interactive learning platforms specifically designed for coordinate geometry in Malaysian educational context. Therefore, this study proposes Treasure C, a web-based interactive learning platform that integrates learning notes, board-game elements, interactive exercises, and time-based challenges. The platform aims to enhance students' understanding of the Cartesian coordinate system while increasing their engagement and motivation in learning coordinate geometry.

1.1 Problem Statement

The coordinate subject is an essential topic in mathematics, providing as the basis for geometry and graph concepts. However, many students continue to struggle with comprehending coordinate concepts such as finding the correct x and y-coordinates, effectively plotting points, and recognizing quadrants. These issues are frequently exacerbated by traditional teaching methods that prioritize memorization and repetitive activities over conceptual understanding. There are many digital learning tools accessible, the majority concentrate on a single learning medium and do not combine gamified exercises, interactive tests, and learning notes into a single platform. Treasure C was created to give an interactive web-based learning platform that includes a gameboard and time-based challenges to improve students' conceptual understanding, engagement, and motivation when studying the coordinate topics.

1.2 Objective

To develop Treasure C, a gamified learning platform that integrates a website, an interactive gameboard, and digital quizzes to enhance students' understanding of the coordinate topics. To achieve this project, three objectives must be met. The objectives of the project are:

- i. To develop a web-based learning platform that provides structured learning notes and interactive quizzes on the Cartesian coordinate system.
- ii. To design a treasure hunt-inspired gameboard that promotes active and collaborative learning.
- iii. To enhance students' conceptual understanding, engagement, and motivation in learning the Cartesian coordinate system through gamification.

2. METHODOLOGY

This study emphasized research on students' understanding of Coordinate topic in Mathematics by using a gamified teaching aid or instructional material which designed to attract students' interest in Mathematics and focus on easy topics to earn marks. Students tend not to be interested in Mathematics, causing them to lose confidence in Mathematics and think they wouldn't be able to score in any topics. In order to solve this situation, we developed and evaluated a gamified teaching method, Treasure C which focuses on coordinate, including how to read coordinates, the movements and some random questions to strengthen knowledge and skills in coordinate. This research was conducted in five phases, starting with:

- (1) Analysis and identification of learning problems
- (2) Design of problem-solving and development of Treasure C game
- (3) Implementation of Treasure C game among students
- (4) Testing by collecting data using pre-tests and post-tests
- (5) Evaluation of learning outcomes

2.1 Analysis And Identification Of Learning Problems

- Simple test covering key concepts in Coordinate
- Classroom observation by teacher (Interviewed teacher's perspective)

The findings indicated that traditional teaching approaches were insufficient in helping students develop a strong conceptual understanding of coordinates. By this information, we generate ideas informing the design of Treasure C, a gamified learning tool aimed at improving conceptual understanding, active participation, and learning motivation.

2.2 Design Of Problem-Solving And Development Of Treasure C Game

Based on the information analysis, we designed Treasure C as a gamified teaching method that integrates Mathematics learning with adventure-based gameplay to improve students' understanding of the Coordinate topic. We implement the idea from snake boardgame, monopoly gameboard and adding adventure-based from Jumanji where we change the theme to Sea Coordinate. The innovation combines game-based learning, collaborative learning, and experiential learning approaches by transforming abstract coordinate concepts into an interactive treasure-hunting activity. Students learn through exploration, problem-solving, and decision-making through this mission games.

2.3 Implementation Of Treasure C Game Among Students

After we generated the Treasure C game, we conducted the game among Form 1 students, involving 209 students in the implementation. By introducing the rules of the games, how games works and objective of the games to students, students participated in Treasure C game collaboratively in group to complete treasure-hunting missions using coordinate maps, challenge cards, and reward mechanisms (Reward and Punishment Theory).

The effectiveness of Treasure C was evaluated through pre-test and post-test comparisons, classroom observations, students' involvement in games and student perception questionnaires. The implementation process demonstrated that Treasure C provides an engaging, interactive, and student-centered approach to improve in coordinate.

2.4 Testing By Collecting Data Using Pre-Tests And Post-Tests

The testing phase was conducted to evaluate the effectiveness of Treasure C in improving students' understanding of the Coordinate topic and to determine students' acceptance towards the innovation. Data were collected using pre-test and post-test.

Pre-test

- A diagnostic test was administered before using Treasure C.
- The test measured students' initial understanding on simple coordinate concepts [ordered pairs (x,y), coordinate movement]

Post-test

- A post-test was conducted after the implementation of Treasure C.
- Students' results were compared with the pre-test to identify and measure improvement in learning achievement or outcomes.
- Collect data on feedback evaluation from the students [attractiveness, ease of use, enjoyment, effectiveness]

The testing phase evaluated the effectiveness and usability of Treasure C through pre-test and post-test assessments. Students' engagement and learning behaviors were observed during gameplay, and questionnaires were used to evaluate their perceptions towards the innovation. The collected data were analysed to determine the impact of Treasure C on students.

2.5 Evaluation Of Learning Outcomes

To evaluate the learning outcomes of using Treasure C in improving students' understanding of Coordinate concepts, evaluation phase intended to identify the potential that Treasure C had as an innovative teaching aid or learning methods. The improvement in students' coordinate understanding was analysed (pre-test and post-test) based on score improvement. This phase also examined the potential of Treasure C as an

innovative teaching aid that support Mathematics learning through an interactive, collaborative, and student-centered approach and enabled continuous improvement of the learning tool for future implementation. This structured methodology ensured that the development and application of Treasure C were carried out systematically, allowing the innovation to effectively support students' conceptual understanding, motivation, and engagement in learning the coordinate topic in Mathematics.

3. RESULTS AND DISCUSSION

3.1. Pre And Post Test Result

As the same set of questions was used for both the pre-test and post-test, a testing or recall effect may have contributed to the observed improvement. This should therefore be considered when interpreting the descriptive pre-test and post-test comparison. No separate statistical analysis was conducted to isolate the effect of prior exposure to the questions.

To evaluate the effectiveness of Treasure C, a pre-test and post-test were administered to secondary school pupils via Google Form. The pre-test was given before students used Treasure C to assess their basic understanding of the Coordinate Topic. After completing the learning activities on the Treasure C website, gameboard, and interactive quizzes, students took a post-test with the same set of questions.

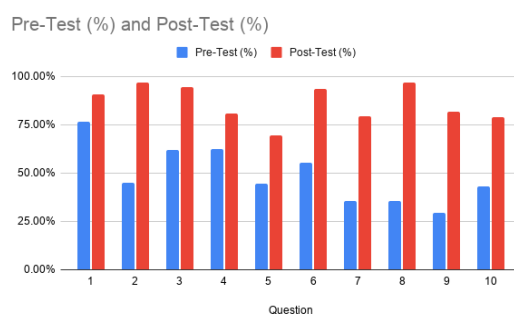


Figure 1. Pre-Test (%) and Post-Test (%)

Based on Figure 1, the percentage of correct replies in the post-test was consistently higher than in the pre-test on all ten questions among the 209 participating students. The pre-test results ranged between 30% and 75%, showing that many students struggled to understand the Cartesian Coordinate System before using a Treasure C. Lower percentage were found in Questions 7, 8, and 9, indicating that students had difficulty identifying coordinates, recognizing quadrants and applying coordinate concepts. After using Treasure C, student performance showed a descriptive improvement. The post-test results ranged from 80% to 95% for the majority of questions. Higher percentages of correct answers can be seen in Questions 2, 6, 8, and 9, indicating descriptive improvement from the pre-test.

Table 1. Summary of Pre-Test and Post-Test Result

<i>Assesment</i>	<i>Percentage (%)</i>
<i>Pre-Test</i>	49
<i>Post-Test</i>	86.2
<i>Improvement</i>	37.2

The increase in students' post-test scores suggests an improvement in their understanding of the Cartesian Coordinate System. The combination of learning notes, quizzes, and a treasure hunt-based gameboard provided students with opportunities for active and interactive learning. The higher post-test scores compared with the pre-test suggest an improvement in students' understanding in coordinate-related concepts after using Treasure C.

3.2. Students Feedback On Treasure C

A feedback questionnaire was conducted to evaluate students' perceptions of Treasure C. The results showed that students were satisfied with the innovation, particularly in terms of usability, learning materials, and interactive features. Students agreed that the gameboard made learning more enjoyable and the time-based activities increased their motivation. Some suggestions were provided, such as adding more practice questions, visual examples, and additional game levels. These recommendations will be considered for future improvements to enhance the effectiveness of Treasure C.

4. CONCLUSION

The findings suggest that Treasure C has a potential as a gamified learning innovation to support students' understanding of the Coordinate System. The descriptive comparison showed an improvement in students' learning achievement, increased engagement, and positive learning experiences. By integrating interactive digital learning with game-based activities, Treasure C provides an engaging and student-centered approach to Mathematics education. This innovation has strong potential to be implemented in classrooms and further expanded to support the learning of other Mathematics topics.

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PahlawanIQ: Gamifikasi Tokoh Pahlawan Islam

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Abstrak

Pahlawan Islam telah banyak berjasa dalam mempertahankan agama, namun generasi muda kini semakin kurang mengenali jasa dan pengorbanan mereka. Kajian ini bertujuan untuk mengenali latar belakang pahlawan Islam serta nilai-nilai murni yang ditunjukkan oleh mereka seperti keberanian, pengorbanan dan kepimpinan. Bagi mencapai tujuan tersebut, satu gamifikasi bertajuk “PahlawanIQ: Gamifikasi Tokoh Pahlawan Islam” telah dibangunkan sebagai medium pembelajaran yang interaktif. Kajian ini dijalankan melalui kaedah rujukan buku, laman sesawang yang dipercayai dan artikel berkaitan. Hasil kajian ini diharapkan dapat meningkatkan pengetahuan masyarakat tentang jasa pahlawan Islam serta memupuk nilai keberanian, kepimpinan dan pengorbanan dalam kalangan generasi muda supaya menjadikan mereka sebagai teladan.

Kata kunci: Pahlawan Islam; Gamifikasi; Generasi Muda

1. PENGENALAN DAN OBJEKTIF

Sejarah Islam dipenuhi dengan tokoh pahlawan yang memberi sumbangan besar dalam mempertahankan agama dan membela umat. Nama seperti Khalid bin al-Walid, Hamzah bin Abdul Muttalib dan Salahuddin al-Ayyubi bukan sekadar catatan sejarah, tetapi lambang keberanian dan keikhlasan yang membentuk peradaban Islam. Sungguhpun begitu, pengenalan generasi muda terhadap tokoh-tokoh ini semakin menipis. Ramai remaja lebih mengenali watak hiburan popular berbanding pahlawan yang pernah mengagadai nyawa demi menegakkan kebenaran.

Keadaan ini menimbulkan kebimbangan kerana nilai keberanian, pengorbanan dan semangat perjuangan yang ditinggalkan oleh para pahlawan semakin kurang dihayati. Kaedah penyampaian sejarah yang bersifat satu hala, seperti pembacaan teks yang panjang, sering dianggap membosankan oleh golongan muda yang membesar dalam persekitaran digital. Pendekatan pembelajaran berasaskan permainan atau gamifikasi dilihat mampu menangani jurang ini, kerana ia menukarkan bahan pembelajaran kepada pengalaman yang lebih menarik dan mudah diingati (Deterding et al., 2011).

Kajian ini bertujuan untuk mengenali latar belakang serta jasa pahlawan Islam, dan memahami nilai-nilai murni yang mereka tunjukkan seperti keberanian, pengorbanan dan kepimpinan. Selain itu, kajian ini turut bermatlamat untuk membangunkan satu produk gamifikasi yang dapat memperkenalkan tokoh pahlawan Islam kepada masyarakat, khususnya golongan muda, dengan cara yang lebih menyeronokkan dan berkesan berbanding kaedah konvensional.

2. BAHAN DAN KAEDAH

Kajian ini dijalankan menggunakan gabungan kaedah pengumpulan maklumat dan pembangunan produk. Peringkat pertama melibatkan rujukan terhadap sumber yang dipercayai, iaitu buku sejarah Islam, laman sesawang berwibawa dan artikel ilmiah berkaitan tokoh pahlawan Islam. Maklumat yang diperoleh dikumpulkan, diteliti dan disusun bagi memastikan setiap fakta yang dimasukkan ke dalam gamifikasi adalah tepat dan sahih.

2.1. Pembangunan Produk Gamifikasi

PahlawanIQ dibangunkan dalam bentuk kuiz interaktif yang menguji pengetahuan pemain tentang tokoh pahlawan Islam. Setiap soalan disertakan dengan pilihan jawapan dan had masa tertentu bagi menambah unsur cabaran. Sebagai contoh, pemain dikehendaki mengenal pasti tokoh yang mendapat gelaran “Singa Allah” dalam tempoh masa yang ditetapkan. Elemen permainan seperti pemasa, mata dan maklum balas segera digunakan untuk mengekalkan tumpuan pemain sepanjang sesi pembelajaran (Sailer & Homner, 2020).

Produk ini disusun mengikut tiga fasa utama, iaitu skrin permulaan yang memaparkan tajuk dan butang mula, skrin permainan yang mengandungi soalan berserta pilihan jawapan, dan skrin penghabisan yang mengesahkan misi telah berjaya diselesaikan. Reka bentuk yang ringkas ini dipilih supaya pengguna daripada pelbagai peringkat umur dapat menggunakannya dengan mudah tanpa memerlukan panduan yang rumit.

3. DAPATAN DAN PERBINCANGAN KAJIAN

Hasil pembangunan menunjukkan bahawa PahlawanIQ berjaya menyampaikan maklumat tokoh pahlawan Islam dalam format yang lebih menarik berbanding pembacaan teks biasa. Struktur permainan yang berperingkat membolehkan pengguna belajar sambil menguji kefahaman mereka secara langsung. Susunan tiga fasa produk ini dirumuskan dalam Jadual 1.

Jadual 1. Struktur Fasa Permainan PahlawanIQ

Fasa	Fungsi
Permulaan	Memaparkan tajuk permainan dan butang mula untuk memulakan sesi.
Cara Main	Memaparkan soalan berserta pilihan jawapan dan pemasa bagi menguji pengetahuan pemain.
Penghabisan	Mengesahkan misi telah berjaya diselesaikan dan membenarkan pemain kembali ke laman utama.

Antara paparan sebenar produk yang dibangunkan ini dalam Rajah 1 hingga Rajah 4, dan keseluruhan gamifikasi ini boleh diakses secara talian melalui pautan <https://view.genially.com/6a58562ff4c1e52429dee9eb>.

Rajah 1 menunjukkan skrin permulaan yang memaparkan tajuk permainan bersama butang “MULA”, direka dengan tema bom dan warna merah yang berani bagi menarik perhatian pemain sebaik sahaja aplikasi dibuka.



Rajah 1. Skrin permulaan gamifikasi PahlawanIQ

Rajah 2 memaparkan fasa cara main, iaitu contoh soalan kuiz yang menguji pengetahuan pemain tentang gelaran tokoh pahlawan Islam. Setiap soalan disertakan pemasa berbentuk bom berdetik dan empat pilihan jawapan berwarna, iaitu biru, kuning, hijau dan jingga, yang perlu dijawab sebelum masa tamat.



Rajah 2. Fasa cara main dengan soalan bertema bom berdetik

Rajah 3 (a) – (c) menunjukkan variasi soalan lain yang menguji pengetahuan pemain tentang tokoh yang bergelar Pedang Allah. Susunan soalan yang pelbagai ini memastikan pemain terus teruja untuk meneruskan misi sehingga selesai.



(a)



(b)



(c)

Rajah 3. Variasi soalan mengenai gelaran tokoh pahlawan Islam

Rajah 4 pula memaparkan skrin penghabisan yang muncul apabila pemain berjaya menamatkan keseluruhan misi. Paparan ini memberikan rasa pencapaian kepada pemain dan menyediakan butang untuk kembali ke laman utama.



Rajah 4. Skrin penghabisan yang mengesahkan misi berjaya diselesaikan

Penggunaan had masa dan maklum balas segera dalam produk ini selari dengan prinsip pembelajaran berasaskan permainan, yang menunjukkan bahawa penglibatan aktif meningkatkan pengekalan maklumat dalam kalangan pelajar (Sailer & Homner, 2020). Berbanding kaedah tradisional yang bergantung pada hafalan pasif, pendekatan ini menggalakkan pengguna berfikir dan bertindak balas dengan pantas. Hal ini secara tidak langsung membantu menyemai semangat cinta akan agama serta memupuk nilai keberanian, kepimpinan dan pengorbanan yang menjadi teras perjuangan pahlawan Islam.

Perbezaan utama kajian ini berbanding usaha terdahulu ialah penumpuannya terhadap tokoh pahlawan Islam secara khusus, dan bukan sekadar topik sejarah umum. Dengan menggabungkan ketepatan fakta dan elemen permainan yang menghiburkan, PahlawanIQ menawarkan medium pembelajaran yang bukan sahaja informatif tetapi juga relevan dengan citarasa generasi digital masa kini.

4. KESIMPULAN

Kajian ini menunjukkan bahawa gamifikasi berpotensi menjadi medium yang berkesan untuk memperkenalkan tokoh pahlawan Islam kepada generasi muda. Produk PahlawanIQ berjaya menggabungkan maklumat sejarah yang sahih dengan elemen permainan interaktif, sekali gus menjadikan proses pembelajaran lebih menarik dan mudah dihayati. Melalui pendekatan ini, nilai keberanian, pengorbanan dan kepimpinan yang ditunjukkan oleh para pahlawan dapat disampaikan dengan cara yang lebih bermakna.

Untuk penambahbaikan pada masa hadapan, disarankan agar bilangan soalan dan tokoh yang dipaparkan diperluaskan supaya liputan sejarah menjadi lebih menyeluruh. Penambahan sistem mata dan papan pendahulu juga boleh dipertimbangkan bagi meningkatkan motivasi pengguna. Selain itu, kajian penilaian terhadap keberkesanan produk dalam kalangan pelajar sebenar wajar dijalankan bagi mengukur impaknya terhadap peningkatan pengetahuan dan penghayatan nilai murni.

PENGHARGAAN

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MISSION: SAVE THE DATA! A Web-Based Gamified Learning Tool for Correcting Statistical Misinterpretations

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Abstract

Statistical misinterpretations involving p-values, test selection, correlation, and confidence intervals can weaken students' reasoning and data-based decisions. This project introduces MISSION: SAVE THE DATA! a web-based gamified learning tool designed to reinforce four foundational concepts in inferential statistics through a mission narrative. The prototype was developed using HTML, CSS, and JavaScript and deployed through Netlify for installation-free access on mobile devices. Learners assume the role of secret agents confronting the Misinterpretation 2.0 virus. For each challenge, a selected answer produces one digit; the four digits must then be combined into a recovery code to deactivate the virus. Functional testing confirmed answer selection, automatic code compilation, code validation, responsive presentation, and unrestricted public access without user login. The key novelty is its concept-linked recovery-code mechanism: every statistical decision contributes directly to a cumulative mission outcome, integrating conceptual diagnosis, immediate feedback, narrative progression, and self-correction within one lightweight activity. Unlike conventional quizzes that treat questions as independent items, the tool makes all four interpretations interdependent and gives learners a purpose for reviewing incorrect choices. The prototype is suitable for lectures, tutorials, revision, and self-directed learning. Future evaluation will compare pre- and post-test performance and examine usability, engagement, and retention among students.

Keywords: Gamification; Statistical Misinterpretation; Inferential Statistics; Web-Based Learning; Educational Technology.

1. INTRODUCTION

Sound statistical reasoning is essential for interpreting evidence and making data-informed decisions. Nevertheless, learners frequently confuse the meaning of p-values, the conditions for selecting inferential tests, association with causation, and the interpretation of confidence intervals. The American Statistical Association has specifically highlighted the widespread misuse and misinterpretation of p-values and the need to improve statistical practice and education (Wasserstein & Lazar, 2016). These difficulties suggest a need for short learning activities that require students to make and review conceptual decisions rather than merely repeat definitions.

Gamification applies selected game-design elements to non-game contexts (Deterding et al., 2011). In higher education, well-aligned gamified activities can support engagement, active participation, and purposeful practice, although outcomes depend on the instructional design rather than the mere presence of points or rewards (Khaldi et al., 2023; Pelizzari, 2024). Challenge-based gamification has also shown

potential specifically in statistics education (Legaki et al., 2020). These findings provide the pedagogical basis for an activity in which game progression is tied directly to correct statistical interpretation.

The developed project MISSION: SAVE THE DATA!, is a lightweight web-based game reinforcing four foundational ideas in inferential statistics. Its objectives are to: (i) prompt learners to distinguish correct from incorrect statistical interpretations; (ii) connect four conceptual decisions through a single mission outcome; (iii) provide immediate, low-stakes opportunities for self-correction; and (iv) offer an installation-free resource suitable for lectures, tutorials, revision, and independent learning.

2. MATERIALS AND METHODS

2.1 Development Platform

The prototype was authored as a single responsive web page using HTML for content structure, CSS for visual presentation, and JavaScript for interaction and code validation. The final version was deployed through Netlify and can be opened in a standard web browser without installation or account registration. The interface uses a high-contrast mission-control theme and a responsive two-column card layout that reflows on smaller screens.

2.2 Learning Content and Game Flow

The content was organized into four challenges representing common interpretation decisions. Each challenge presents two alternatives. Selecting an option highlights the response and contributes a digit to an automatically compiled four-digit recovery code. Learners submit the assembled code to deactivate the fictional Misinterpretation 2.0 virus. A correct code produces a success message; an incorrect code prompts the learner to review the four decisions. Table 1 summarizes the concept-to-code design.

Table 1. Statistical Concepts and Recovery-Code Design

Challenge	Conceptual focus	Correct decision	Digit
1	p-value decision at $\alpha = 0.05$	Reject H_0 when $p = 0.021$	8
2	Test selection	Use a t-test for a small sample when population variance is unknown	7
3	Correlation and causation	A strong relationship alone does not establish causation	9
4	Confidence interval	A 95% interval from 4.10 to 4.60 lies above the neutral value of 3	5

2.3 Novelty of the Innovation

The principal novelty is the concept-linked recovery-code mechanism. Conventional online quizzes typically score independent questions and reveal a total at the end. In this innovation, every statistical decision generates one component of a shared mission code which consequently become interdependent and are necessary to complete the objective. The mechanism combines conceptual diagnosis, automatic code assembly, immediate visual feedback, narrative progression, and self-correction without relying on external quiz platforms, user accounts, paid licences, or software installation. The tool is therefore both pedagogically distinctive and technically lightweight.

2.4 Prototype Verification

Functional verification was conducted by testing both answer options in every challenge, the automatic assembly of selected digits, the correct recovery code (8795), representative incorrect codes, and public access through the deployment URL. The interface was also checked at desktop and reduced browser widths to verify responsive presentation. This stage assessed prototype functionality only; it did not constitute a student learning-effectiveness study.

3. RESULTS AND DISCUSSION

3.1 Functional Outcomes

The completed prototype met all predefined functional requirements. Answer buttons registered and highlighted the most recent selection, the corresponding digits were compiled in challenge order, and the validation routine correctly distinguished the recovery code 8795 from incorrect entries. The published version opened directly without requiring a JSFiddle or Netlify login. Table 2 reports the functional checks.

Table 2. Prototype Functional Verification

No.	Requirement	Observed outcome	Status
1	Option selection	Selected response is visibly highlighted	Passed
2	Digit assignment	Each option supplies its programmed digit	Passed
3	Code compilation	Digits are assembled in challenge order	Passed
4	Correct-code validation	Code 8795 triggers the success response	Passed
5	Incorrect-code validation	Other codes trigger a review prompt	Passed
6	Public deployment	Game opens through a browser without user login	Passed



MISSION: SAVE THE DATA!
Prof. Data vs. the Misinterpretation 2.0 Virus

MISSION BRIEF: You are a secret agent from JSKM. The Misinterpretation 2.0 virus has attacked the statistics laboratory! Complete four challenges to obtain the four-digit Recovery Code.

CHALLENGE 1: p-Value Panic!

Given $\alpha = 0.05$ and p-value of 0.021, what is the correct decision?

A. Fail to reject H_0 (Code = 2)

B. Reject H_0 (Code = 8)

CHALLENGE 2: Test Trouble

The sample is small ($n = 12$), and the population variance is unknown. Which statistical test is appropriate?

A. Z-test (Code = 1)

B. t-test (Code = 7)

CHALLENGE 3: Correlation Confusion!

A graph shows a strong positive relationship. A student claims, "X causes Y." Is this statement true or false?

A. True (Code = 3)

B. False (Code = 9)

CHALLENGE 4: Confidence Crisis

The 95% confidence interval is $4.10 \leq \mu \leq 4.60$. The neutral value is 3. What can be concluded?

A. The population mean is above the neutral value (Code = 6)

B. No conclusion can be made (Code = 4)

DATA RECOVERY SYSTEM

Enter the Final Code (4 Digits):

8 7 9 5

DEACTIVATE THE VIRUS

CONGRATULATIONS! Code [8795] is correct. The virus has been successfully eliminated, and the laboratory is stable again!

Figure 1. Published Interface of MISSION: SAVE THE DATA!

3.2 Educational Value and Limitations

The prototype converts four short conceptual checks into a coherent task with a visible purpose. This alignment is important because educational gamification is most useful when game mechanics support the learning objective rather than distract from it. The recovery-code structure encourages learners to revisit all four interpretations after an unsuccessful attempt, while the concise format allows the activity to be used as a lesson opener, formative check, tutorial station, or revision exercise. Its browser-based design also supports reuse across disciplines that teach introductory inferential statistics.

The current prototype has deliberate limitations. It contains four binary-choice challenges, does not store learner analytics, and provides outcome-level rather than item-specific explanatory feedback. Most importantly, no claim of improved achievement is made at this prototype stage. A future evaluation should administer matched pre- and post-tests, collect usability and engagement ratings, examine delayed retention, and record error patterns. Additional question banks, randomised codes, difficulty levels, bilingual options, and accessible audio support may then be developed based on user evidence.

4. CONCLUSION

MISSION: SAVE THE DATA! demonstrates how a small, open-web prototype can integrate statistical reasoning with meaningful game progression. The innovation links decisions about p-values, test selection, correlation, and confidence intervals to a single recovery code and thereby turns four isolated questions into one coherent mission. Functional verification confirmed that answer selection, code assembly, validation, responsive display, and public access operated as intended. The tool is ready for classroom pilot testing, but evidence of learning effectiveness must be established through systematic student evaluation.

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Kembara Sejarah: Cabaran Tahun 6

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Abstrak

Pembelajaran sejarah, terutamanya topik penubuhan Malaysia, kerap dianggap pasif dan sukar dikuasai oleh pelajar generasi digital berikutan kebergantungan kepada teks konvensional. Banyak fakta seperti tarikh dan nama-nama tokoh perlu diingat secara tepat. Keadaan ini menyebabkan pelajar sukar mengingat kronologi, tokoh, serta iktibar sejarah secara berkesan. Kembara Sejarah: Cabaran Tahun 6 adalah sebuah papan permainan pendidikan berkonsepkan pusingan spiral berterusan yang diilhamkan daripada struktur *Ghost Board*, direka khas untuk menyokong kurikulum subjek Sejarah Tahun 6 KSSR. Permainan ini menggabungkan elemen geografi, kronologi, dan pengetahuan tentang Malaysia melalui satu laluan tunggal yang mengalir pada era awal penubuhan Malaysia. Pemain menavigasi dengan membaling dadu serta perlu menjawab kuiz fakta sejarah. Permainan ini direka untuk menggalakkan kolaborasi, kemahiran berfikir kritis, dan penguasaan subjek melalui pengalaman pembelajaran berasaskan permainan yang dinamik. Keunikan permainan ini ialah membolehkan pembelajaran sendiri (*self-paced learning*) berlaku tanpa perlu memuat turun sebarang aplikasi. Selain itu, pemain boleh menggunakan permainan ini sebagai latihan tubi kepada subjek sejarah kerana permainan ini boleh dimainkan secara individu juga sesuai untuk bilik darjah atau aktiviti rumah. Kesimpulannya, inovasi ini memodenkan pengajaran Sejarah menerusi integrasi teknologi digital, sekali gus melahirkan generasi yang menghayati warisan sejarah dengan cara yang berkesan dan bermakna.

Keywords: Gamifikasi Digital, Genially, Sejarah Malaysia, pembelajaran sendiri.

1. PENGENALAN

Pendidikan Sejarah dalam Kurikulum Standard Sekolah Rendah (KSSR) memainkan peranan penting dalam memupuk semangat patriotisme, pemahaman susur alur negara, serta pembentukan jati diri murid. Walau bagaimanapun, proses Pengajaran dan Pembelajaran (PdP) Sejarah, terutamanya bagi topik penubuhan Malaysia dalam sukatan Tahun 6, kerap kali dilaksanakan secara pasif dengan kebergantungan yang tinggi terhadap buku teks konvensional (Kurniawan & Sholeh, 2023). Pendekatan berpusatkan guru dan teks ini didapati kurang memberi daya tarikan kepada murid generasi digital yang lebih terdedah kepada persekitaran visual dan interaktif (Rahman et al., 2020).

Isu utama yang timbul dalam PdP Sejarah konvensional ialah kesukaran murid untuk menguasai dan mengingat fakta-fakta penting secara berkesan. Topik penubuhan Malaysia menuntut murid memahami kronologi peristiwa, tarikh-tarikh kritikal, lokasi geografi, serta nama-nama tokoh yang terlibat secara tepat. Keadaan ini menyebabkan murid berasa terbeban dengan hafalan tegar, cepat merasa bosan, dan sukar menghubungkan iktibar sejarah dalam kehidupan seharian, yang seterusnya menjejaskan pencapaian serta minat mereka terhadap subjek ini (Aziz et al., 2024).

Bagi menangani cabaran tersebut, integrasi pendekatan gamifikasi digital dilihat sebagai penyelesaian pedagogi yang inovatif dan berimpak tinggi (Martdana & Atno, 2025). Inovasi Kembara Sejarah: Cabaran

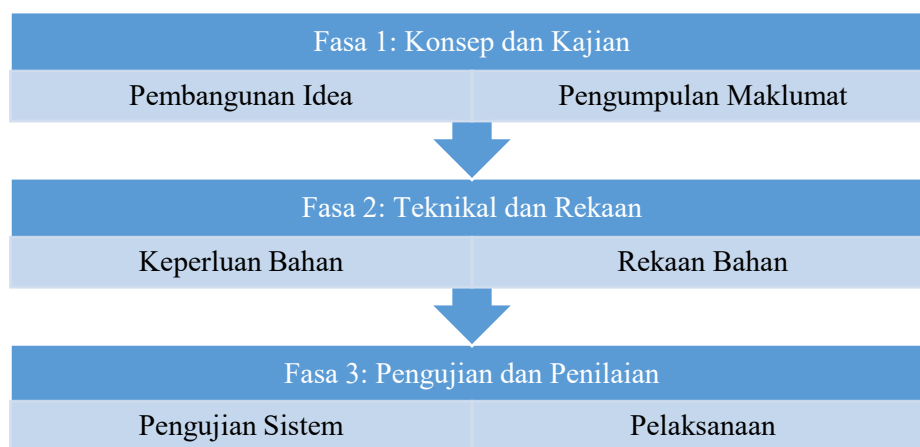
Tahun 6 dibangunkan sebagai bahan bantu mengajar interaktif berasaskan platform Genially bagi mentransformasikan kaedah pembelajaran Sejarah. Melalui gabungan elemen permainan, visual menarik, dan cabaran kuiz interaktif, inovasi ini berupaya memodenkan pengajaran Sejarah, meningkatkan keterlibatan murid, serta menyokong pembelajaran sendiri (*self-paced learning*) secara lebih menyeronokkan dan bermakna (Fauzi & Kumara, 2025).

Objektif utama pembangunan inovasi ini adalah untuk memodenkan kaedah Pengajaran dan Pembelajaran (PdP) Sejarah Tahun 6 KSSR menerusi integrasi teknologi gamifikasi digital berasaskan platform Genially. Secara khususnya, inovasi ini bertujuan untuk memudahkan pemahaman murid terhadap kronologi, fakta geografi, dan peristiwa pembentukan Malaysia melalui pengalaman pembelajaran berasaskan permainan yang interaktif dan dinamik. Di samping itu, inovasi ini beraspirasi menyediakan bahan bantu mengajar yang fleksibel dan mudah diakses bagi menyokong pembelajaran sendiri serta aktiviti latih tubi, baik untuk kegunaan kolaboratif di dalam bilik darjah mahupun secara individu di rumah tanpa kekangan muat turun aplikasi.

2. METODOLOGI

2.1. Fasa Pembangunan Kembara Sejarah

Proses pembangunan inovasi ini melalui fasa analisis keperluan, reka bentuk perisian, dan penilaian kebolehgunaan bagi memastikan bahan yang dihasilkan memenuhi standard kurikulum Sejarah Tahun 6 KSSR. Rangka kerja perancangan ini memberi tumpuan kepada pemetaan topik penubuhan Malaysia ke dalam bentuk elemen permainan yang mampu merangsang kemahiran berfikir aras tinggi (KBAT) dan minat murid. Pendekatan ini turut mengintegrasikan prinsip-prinsip pedagogi berasaskan permainan untuk mewujudkan persekitaran pembelajaran yang inklusif, fleksibel, dan bermakna. Rajah 1 menunjukkan tiga fasa bagi penghasilan inovasi ini.



Rajah 1. Tiga fasa penghasilan inovasi papan permainan Kembara Sejarah

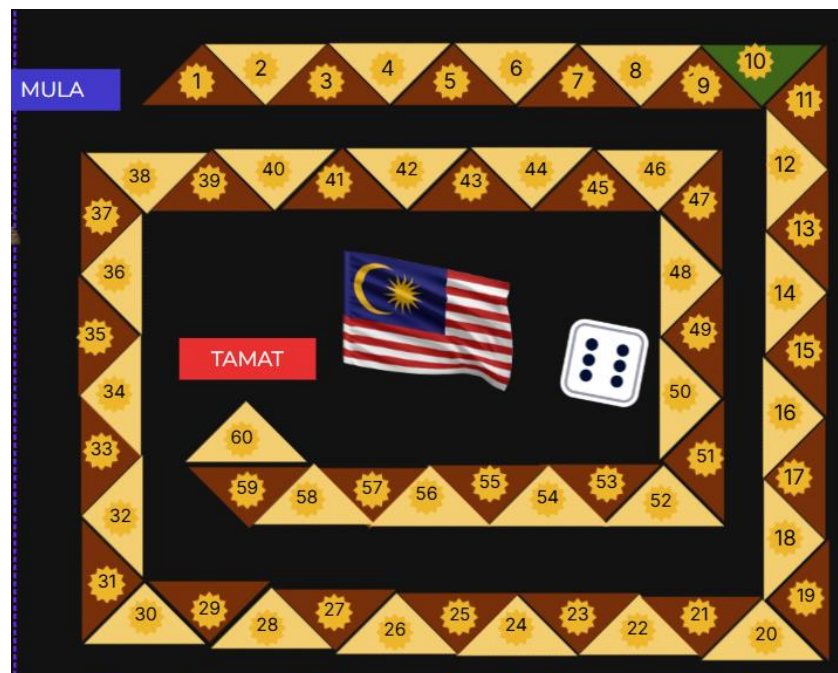
Fokus utama fasa pertama adalah pada pembangunan idea untuk mengatasi masalah subjek pembelajaran yang sering dianggap membosankan dan kurang melibatkan murid. Sebagai penyelesaian, elemen gamifikasi (*gamification*) telah diintegrasikan ke dalam projek ini. Fasa ini turut melibatkan proses pengumpulan maklumat, di mana silibus yang memfokuskan kepada tiga unit pertama subjek Sejarah Tahun 6 telah dikumpulkan.

Seterusnya, fasa kedua memberi tumpuan kepada aspek teknikal dan reka bentuk permainan digital. Bagi memenuhi keperluan bahan, platform Genially telah digunakan sepenuhnya untuk membina papan permainan digital berkonsepkan pusingan melingkar (*spiral*). Selain itu, rekaan ini mampu menarik minat murid melalui penggabungan elemen permainan dam dan kuiz interaktif.

Akhir sekali, fasa ketiga bertujuan untuk memastikan sistem permainan dapat berfungsi dengan lancar. Pengujian sistem dilaksanakan melalui semakan kelancaran interaktif merentas pelbagai peranti yang mungkin digunakan oleh murid, termasuk telefon pintar, tablet, dan komputer. Setelah proses pengujian selesai, pelaksanaan diteruskan kepada pengguna akhir melalui perkongsian kod QR bagi memudahkan akses.

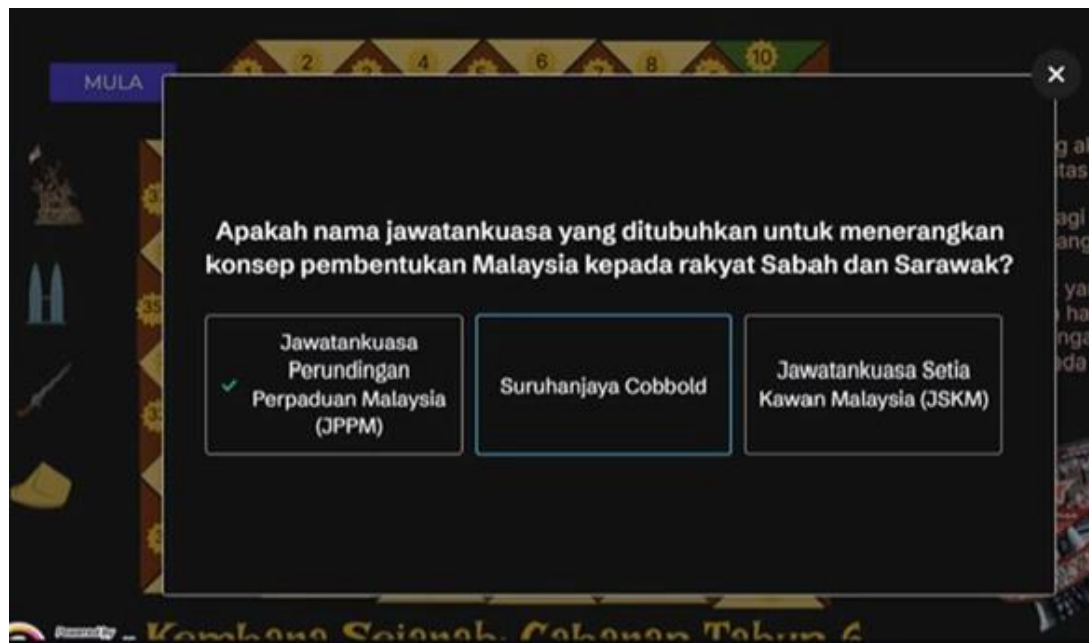
2.2. Aplikasi Genially

Inovasi Kembara Sejarah: Cabaran Tahun 6 dibangunkan berasaskan platform interaktif Genially dengan mengintegrasikan struktur reka bentuk papan permainan *Ghost Board*. Papan permainan ini menampilkan laluan spiral berterusan yang mengandungi 60 petak cabaran interaktif, bermula dari petak **MULA** (Petak 1) hingga **TAMAT** (Petak 60) (Rajah 2).



Rajah 2. Papan permainan Kembara Sejarah: Cabaran Tahun 6

Dari segi mekanisme permainan, murid menavigasi laluan dengan memilih token, membaling dadu digital terbina (built-in digital dice), dan menggerakkan token mengikut bilangan langkah yang dipaparkan. Apabila mendarat di petak-petak tertentu, murid perlu menjawab kuiz fakta sejarah berkaitan penubuhan Malaysia untuk meneruskan pergerakan atau mengukuhkan markah (Rajah 3). Pendekatan ini menggalakkan kemahiran berfikir kritis dan kolaborasi berasaskan pengalaman pembelajaran yang dinamik.



Rajah 3. Cara bermain papan permainan Kembara Sejarah: Cabaran Tahun 6

Inovasi ini direka secara berasaskan web (web-based), membolehkan akses terus menerusi penyemak imbas pada pelbagai peranti seperti telefon pintar, tablet, atau komputer tanpa perlu memuat turun sebarang aplikasi. Ciri ini memberikan fleksibiliti tinggi di mana ia sesuai digunakan sebagai aktiviti kolaboratif di dalam bilik darjah mahupun sebagai alat latihan tubi sendiri (self-paced learning) secara individu di rumah.

3. PERBINCANGAN DAN IMPAK

Pelaksanaan inovasi Kembara Sejarah: Cabaran Tahun 6 secara keseluruhannya menunjukkan impak positif terhadap proses pengajaran dan pembelajaran (PdP) Sejarah. Dari aspek pengukuhan ingatan, struktur papan permainan berbentuk laluan spiral berterusan dengan 60 petak cabaran terbukti membantu murid memetakan kronologi peristiwa penubuhan Malaysia secara berperingkat dan visual. Integrasi soalan kuiz

fakta di petak-petak cabaran membolehkan pengukuhan ingatan (*retention rate*) berlaku secara aktif, sekali gus mengurangkan kebergantungan kepada kaedah hafalan tegar berasaskan buku teks konvensional (Rosdi & Ahmad, 2025).

Dari sudut kebolegunaan dan fleksibiliti pedagogi, keunikan inovasi ini yang berasaskan platform *web-based* tanpa keperluan memuat turun aplikasi membolehkan pembelajaran sendiri (*self-paced learning*) dilaksanakan secara berkesan (Awang, 2026). Murid boleh mengulang tayang permainan sebagai aktiviti latihan tubi mengikut kadar keupayaan masing-masing, sama ada secara individu di rumah atau secara berpasukan di dalam bilik darjah. Keadaan ini mewujudkan suasana pembelajaran yang dinamik, menggalakkan kolaborasi sesama rakan sebaya, serta meningkatkan motivasi murid untuk meneroka fakta sejarah.

Selain itu, penggabungan elemen gamifikasi digital dengan motif warisan kebudayaan seperti Tugu Negara, Keris, dan Wau Bulan secara tidak langsung berjaya memupuk nilai patriotisme dan kebanggaan terhadap identiti negara. Inovasi ini membuktikan bahawa integrasi teknologi dalam subjek Sejarah bukan sahaja memodenkan pendekatan pengajaran guru, malah berupaya mentransformasikan persepsi murid terhadap subjek Sejarah, daripada satu subjek yang pasif dan membosankan kepada satu pengalaman pembelajaran yang interaktif, berkesan, dan bermakna.

4. KESIMPULAN

Secara keseluruhannya, inovasi Kembara Sejarah: Cabaran Tahun 6 berjaya mentransformasikan kaedah Pengajaran dan Pembelajaran (PdP) Sejarah daripada pendekatan konvensional yang pasif kepada pengalaman digital yang interaktif dan berimpak tinggi. Integrasi gamifikasi menerusi platform Genially bukan sahaja meningkatkan minat dan pemahaman murid terhadap kronologi serta fakta pembentukan Malaysia, malah menyokong kemahiran berfikir kritis dan pembelajaran sendiri secara fleksibel. Berdasarkan keberkesanan dan sifatnya yang mudah diakses tanpa kekangan aplikasi, inovasi ini berpotensi besar untuk diperluas ke topik-topik Sejarah yang lain serta dijadikan model PdP abad ke-21 yang relevan dengan keperluan generasi digital.

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SwatchSpace (Penang Style Edition): A Physical–Digital Hybrid Pedagogy for Heritage Materiality and Generative AI

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Abstract

Traditional lecture-based pedagogical methods often do not provide dynamic, tactile, and experiential problem-solving environments. To bridge this gap, this product introduces SwatchSpace (Penang Style Edition), an innovative card-based educational game integrated with generative AI perspective visualisation for tertiary interior design classrooms. The game is played in 4-player teams over a 30-minute session using a structured physical A3 isometric base board, specialised material decks (96 floor and wall finish cards), regional Penang style decks (6 different categories) and dynamic SWAT challenge modifier cards. Students are tasked with matching tactile material selections to the hidden style and space scenario cards in a strategic manner, while negotiating unpredictable design constraints. After finishing a layout, players shout “Swatch!”, capture the physical isometric assembly with a mobile device, and create a photorealistic interior perspective with context-appropriate lighting using AI models, and deliver an analytical oral presentation. The findings show that SwatchSpace greatly increases psychomotor engagement, speeds up visual-spatial reasoning, and strengthens the knowledge retention of regional materiality and surface finishes through gamified experiential learning

Keywords: Gamified Learning; Interior Design Education; Penang Heritage Materials; Generative AI Visualization; Experiential Pedagogy

1. INTRODUCTION

Interior architecture and design education is studio based and relies on visual synthesis and spatial reasoning. However, the delivery of material technology and specifications is often relegated to static lectures and passive swatch board creation, without interactive feedback, peer collaboration and active problem solving (Babacan Çörekci, 2023). Students often struggle to understand the synthesis of discrete raw materials into cohesive interior styles that are specific to a given context such as the regional vernacular and heritage aesthetics common in George Town, Penang, Malaysia. The traditional lecture format and static mood boards embody a linear and predictable learning paradigm that does not engage today’s digital-native students who are accustomed to interactive, dynamic media (Issifou et al., 2026).

Penang’s distinctiveness as a UNESCO World Heritage site makes it a fertile living laboratory for regional architectural typologies. Penang style interior design requires an in-depth understanding of historical material literacy, such as the rich glaze of imported Peranakan Majorca tiles, the strength of Straits Chinese lime and mortar, the elegance of British Colonial timber parquetry and wainscoting, and the climate sensitive weaving of local Malay Kampung Anyaman. Gamified frameworks and pedagogies of play

provide an effective means of bridging the gap between abstract historical readings and tangible, hands-on application (Blignaut et al., 2023).

This paper introduces SwatchSpace (Penang Style Edition) as a direct pedagogical extension, building upon the successful model of SPACE UP that pioneered interactive design kits in studio education and won a Silver Award at the Teaching and Learning Poster Ideas Competition (TALPI 2023). SPACE UP was a general study on spatial planning and modular layout exploration, while SwatchSpace pushes the model further with the combination of card-based game mechanics with mobile generative Artificial Intelligence (AI) rendering tools designed for material specification and regional heritage styles. SwatchSpace is a game-like environment in which tertiary interior architecture students are challenged to match wall and flooring materials to regional design scenarios in a dynamic, time sensitive environment. This work contributes to educational innovation by demonstrating how a combination of analogue card play and generative AI image translation accelerates material literacy, peer negotiation and spatial presentation skills.

The main objectives of the pedagogical tool SwatchSpace (Penang Style Edition) are:

1. To establish a competitive, interactive, tactile and experiential environment for problem solving where tertiary interior design students can apply materiality and regional Penang heritage design.
2. To bridge the cognitive gap between 2D material samples and 3D ambient space representation by introducing mobile generative AI perspective rendering to visualise material textures under realistic lighting conditions.
3. To identify peer-to-peer negotiation, critical evaluation, and self-advocacy abilities via gamified design challenges and presentation defence (Rauf et al., 2020).

2. MATERIALS AND METHODS

SwatchSpace is designed for a group of 4 players per session with an average game length of 30 minutes and a short analytical presentation to close the game. The game consists of both physical and digital elements:

- Isometric Base Board: An A3 size physical template of a three-dimensional interior spatial envelope (walls and floor plane) that serves as the physical canvas for material arrangements.
- Material Deck (96 Cards) 48 Floor Cards (Parquet, Terrazzo, Majorca, Concrete, Terracotta, Porcelain, Timber Planks) 48 Wall Cards (Stucco, Lime Plaster, Timber Wall, Tiles, Anyaman, Wainscoting, Exposed Brick)
- Style & Scenario Deck (6 Penang Styles) of distinct regional interior styles Contemporary Tropical, Modern Kampung, Peranakan Baba Nyonya, Colonial Anglo-Malayan, Straits Chinese and Heritage Eclectic (Straits Eclectic) mapped across 4 functional space types (Bedroom, Kitchen/Dining, Living, Workspace/Multipurpose).
- SWAT / Challenge Deck Strategy Modifiers Double Up (2x score), Change Style (2x), Change Scenario (2x), Lose Chance/Turn (2x), Expedite (extra turn), Ultimate Swatch (switch 2 cards on board), Wild Card and Chance
- Digital AI Tool: A mobile smartphone with an image-to-image generative AI app (e.g., ChatGPT/Midjourney) to generate rendered perspectives from physical isometric arrangements.

2.1. The 6 Penang Design Styles and Material Mapping

The cards are distinct historical and architectural styles typical of Penang's cultural mosaic for an effective reflection of Penang Design Style in interior design. Table 1: The 6 Penang Design Styles in the Style & Scenario Deck mapped with their historical descriptions and typical material card pairings.

Table 1. Penang Heritage Interior Design Styles and Material Palettes in SwatchSpace

Penang Style	Socio-Cultural & Architectural Concept	Vertical Surface Finishes (Wall Match)	Horizontal Surface Finishes (Floor Match)
Peranakan Baba Nyonya	Eclectic cultural hybridization reflecting wealthy Chinese-Malay diaspora aesthetics; distinguished by sensory-rich, highly ornamental, and visually dense interior compositions.	Ornamental Tiles, lime Plaster	Majorca Tiles, Terrazzo
Straits Chinese	George Town traditional shophouse architectural typology; emphasizes structural honesty, structural masonry, climatic adaptation, and passive ventilation through central courtyard airwells.	Exposed Brick, Lime Plaster	Terracotta, Concrete
Colonial Anglo-Malayan	Symmetrical Neoclassical British architectural motifs adapted to tropical climates; characterized by stately elegance, axial proportions, and high-ceilinged spatial volume.	Wainscoting, Stucco	Parquet, Timber Planks
Contemporary Tropical	Modern bioclimatic architecture prioritizing cross-ventilation, daylighting, and ecological sustainability; blurs the threshold between interior spaces and external landscapes.	Timber Wall, Lime Plaster	Timber Planks, Concrete
Modern Kampung	Modernized traditional Malay timber craftsmanship; utilizes natural ventilation, raised floor planes, and breathable screening.	Anyaman (Weaving), Timber Wall	Timber Planks, Tiles
Heritage Eclectic	A dynamic synthesis of Western Classical, Chinese vernacular, and local Malay design elements; represents the peak of George Town's late-nineteenth-century architectural synthesis.	Tiles, Exposed Brick	Majorca Tiles, Terrazzo

Note: Formulated by author (2026)

2.2. Gameplay Procedure

Participants are immersed in a competitive yet collaborative studio environment as the event progresses into a vibrant journey of innovation and trickery. The imaginative endeavour commences in quietude, with every contributor possessing an initial trio of Material Cards and a Style & Scenario Card that shapes their ultimate concept.

Upon the formulation of the particular visions, the writing process commences with a Strategic Stacking phase. Players take turns meticulously positioning their material cards onto the designated floor and wall areas on a communal A3 isometric board. Each action entails a measured risk; individuals are endeavouring to interpret the subtle stylistic hints left by their rivals on the shared canvas while simultaneously seeking to establish a cohesive material scheme that satisfies their hidden design intent.

A professional studio environment is seldom predictable, and the game's unexpected SWAT difficulties well illustrate this. Participants are required to draw from the SWAT deck during their turns to initiate a cascade of unforeseen, sudden alterations. These unexpected challenges, which mirror the tumultuous nature of the design industry and compel individuals to swiftly adapt to rapidly evolving situations, might range from an obligatory alteration in style to a stringent requirement from a new customer.

When a participant exuberantly exclaims, "SWATCH!" upon finalising a tangible design that flawlessly embodies their concealed aesthetic, the atmosphere around the table reaches its zenith. This declaration initiates an amazing digital transformation. Utilising a mobile device to capture an image of the genuine isometric board construction, the player merges the physical tabletop experience with modern technologies. They produce a stunning, photorealistic image with precise illumination and atmospheric richness that flawlessly embodies their selected interior design by utilising an AI generator on this line-art interior.

Proclaiming the victorious term, therefore, is but a portion of the struggle. The designer must participate in a stringent Style Defence against their colleagues to authentically assert triumph. The athlete delivers a fervent two-minute address, advocating for the AI's work, showcasing the design's historical congruence with various Penang regional aesthetics, and elucidating their material combinations. The ultimate determination of the winning strategy rests with the rival players, who evaluate it rigorously based on its persuasive lucidity, comprehensive design consistency, and historical veracity.

3. RESULTS AND DISCUSSION

Peer trial implementations of tertiary interior design classrooms reveal that SwatchSpace greatly enhances active learning and material literacy, relative to traditional lectures and mood board creation. The tactile manipulation of the 96 tactile material cards reinforces the logic of classification and the principles of pairing by texture. The pedagogical evolution from traditional instruction and the baseline SPACE UP kit to the SwatchSpace gamified framework is shown in Table 2.

Table 2. Pedagogical Evolution Across Educational Frameworks

Learning Metric	Traditional Lecture & Mood Board	SPACE UP Kit (TALPI 2023 Silver)	SwatchSpace Gamified Innovation
Primary Scope	Static research & specifications	Spatial layout & furniture arrangement	Materiality, surface finishing & regional heritage style
Engagement Model	Passive individual research	Tactile interactive layout exploration	Active 4-player competitive gameplay

Problem-Solving	Linear and predictable	Modular spatial exploration	Adaptive (SWOT challenge card modifiers)
Visual Output	Delayed manual drafting	Physical mood board assembly	Real-time Generative AI perspective translation
Regional Knowledge	Abstract historical reading	General space planning principles	Direct application of 6 Penang architectural styles

3.1. Generative AI Integration and Peer Defense

Instant AI perspective rendering integration closes the critical cognitive gap between 2D material swatches and 3D ambient space representation. As a player says “Swatch!” the AI converts the physical isometric layout into a rendered perspective, testing material choices under realistic lighting and environmental conditions. This coupling creates a tactile-to-digital feedback loop in real-time that facilitates Double-Loop Learning (Argyris & Schön, 1978). Instead of just shuffling cards to solve the immediate game puzzle (single-loop), students are challenged to rethink their basic assumptions about material authenticity, texture compatibility and historical style alignment as they evaluate the AI-generated visual output. Significantly, the need to present and defend the final design means that students are not able to blindly trust AI outputs but must critically assess material feasibility, environmental context and heritage relevance. The peer-defense process greatly improves students' self-advocacy and professional communication skills, transforming the instructor's role from direct supervisor to expert facilitator (Rauf et al., 2020).

4. CONCLUSION AND SUGGESTIONS

SwatchSpace is a successful spin-off of the award-winning SPACE UP innovation, combining the physical mechanics of a card game with generative artificial intelligence (AI) technology. This hybrid approach creates an interactive, high engagement pedagogical tool for interior architecture education. This game turns abstract material matching into a competitive, tactile and visually rewarding experience. It strengthens visual-spatial reasoning, regional heritage design understanding and oral defence skills in a compact 30-minute studio format.

4.1. Usefulness and Advantages

SwatchSpace overcomes the passivity and static nature of materials education, and transforms it into an active psychomotor engaging process. It tackles significant design studio issues like unequal distribution of workload, heavy dependence on the master-apprentice model, and ineffective time management by enabling students to engage in self-directed learning and peer assessments (Babacan Çörekci, 2023).

4.2. Novelty

The novelty of SwatchSpace is the seamless coupling of tactile physical game mechanics (A3 isometric board and material cards) with cutting edge mobile based generative AI rendering. The SWAT deck is a simulation of the unpredictability of the real design studio where students have to think on their feet. This is the first hybrid pedagogical tool of its kind designed for the teaching of regional heritage materiality.

4.3. Commercialization Potential

SwatchSpace is a low-cost, scalable, physical-digital hybrid package with high commercial potential. It can be created as a standardised educational board game and licensed to universities, design colleges and professional training centers across the globe. The modular nature of the game also means that regional 'expansion packs' (e.g. Mediterranean, Malaysian, Heritage Styles) can be commercialised and it is therefore highly adaptable to a range of global markets and curricula.

4.4. Future Suggestions

In future work, it is planned to extend the style decks to cover wider global regional vernaculars, formalise quantitative assessment rubrics for international learning innovation competitions, and conduct larger empirical studies to quantitatively measure long-term knowledge retention of students using this gamified framework.

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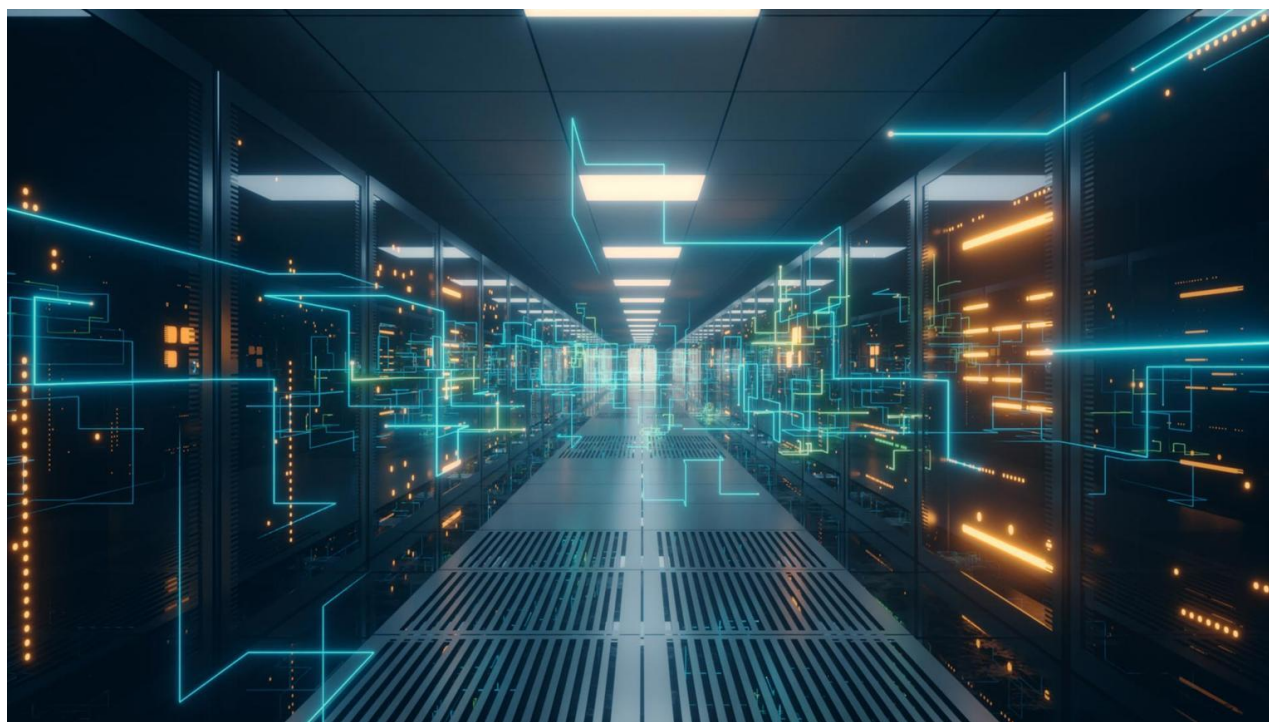
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SECTION 5

INFORMATION & COMMUNICATION TECHNOLOGY



Connecting ideas. Enabling digital transformation

Bijak Pecahan: Mastery Fractions Through Gamified Interactive Learning

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Abstract

"Bijak Pecahan: Mastery Fractions Through Gamified Interactive Learning" is an initiative that offers a specialized, interactive mathematics e-learning portal focused on fraction mastery. This portal seeks to improve students' conceptual understanding of fractions and their problem-solving abilities through an engaging digital environment. Key features include interactive fraction materials, automated quizzes, real-time feedback, and gamified learning components designed to inspire motivation and facilitate self-paced learning. Developed using contemporary web technology, the portal features an intuitive, user-friendly interface. Initial usability testing alongside feedback from instructors and students indicates that the portal significantly enhances exam preparedness and independent learning in fraction topics. Ultimately, this project contributes to meeting the growing demand for effective, targeted digital learning resources within the framework of Malaysian primary education.

Keywords: *mathematics, fractions, interactive, gamified learning*

1. INTRODUCTION

In the contemporary digital era, electronic learning (e-learning) has fundamentally transformed global education by delivering flexible, personalized, and multimedia-driven learning experiences that cater to diverse student needs. The critical role of digital pedagogy was heavily underscored by the COVID-19 pandemic, which cemented e-learning as vital infrastructure for enhancing student engagement and teaching efficacy (Cataudella et al., 2021). Grounded in this educational shift, this study examines the development of a targeted e-learning platform focusing on the Mathematic topic of fractions for primary school students.

Bijak Pecahan was developed to address the significant difficulties when learning fractions. Traditional, static teaching materials often fail to provide the visual reinforcement and hands-on experiences necessary to prevent misconceptions, leading to a loss of student interest and motivation. This pedagogical gap is further widened by the limitations of the "Ansur Maju" technique, which requires continuous reinforcement that teachers struggle to provide due to the reduction of weekly Mathematics instructional time from 210 to 150 minutes.

Consequently, educators lack the classroom time needed for deep exploration of high-order thinking skills. Mui and Mahmud (2023) suggest that the curriculum assists educators to promote a balanced curriculum in relation to different Mathematic topics which can provide students with the opportunities to develop their understanding, learning, and thinking both cognitively and academically whilst preparing them to

face future academic challenges. Thus, this system offers an interactive environment that provides immediate feedback, visualizes abstract fractional concepts, and delivers the continuous, self-paced support vital for mastering complex mathematical foundations.

The primary objectives focusing strictly on the development of the e-learning system are to architect and construct a responsive digital platform on fractions topic, integrating multimedia assets, visual models, and automated feedback besides implementing a user-centric dashboard informed by expert pedagogical specifications that accommodates diverse student learning styles.

Bijak Pecahan which consists of fractions topic, featuring lessons, formative activities, and realistic contextual scenarios that transform abstract mathematical theory into digestible, school-to-home learning experiences. The portal integrates interactive quizzes utilizing drag-and-drop components, fill-in boxes, multiple-choice simulations, and graphical illustrations that offer immediate feedback to rectify student misconceptions promptly. Furthermore, the development scope encompasses gamified summative elements, including point-score challenges and marks to sustain learner motivation.

By leveraging interactive components such as visual simulations, gamified features, and immediate feedback mechanisms, Bijak Pecahan disrupts conventional, static learning methods to heighten student motivation and convert abstract mathematical concepts, specifically on fractions into digestible, relatable knowledge.

2. METHODOLOGY

The development of Bijak Pecahan relies on the ADDIE model, a highly structured, standardized project development methodology that ensures a systematic progression through a defined sequence of rules and procedures. This instructional design framework was specifically chosen based on its proven capacity as supported by Ekhsan et al. (2022), to provide an organized, engaging, and flexible foundation for modern lesson design across both traditional and digital environments. The ADDIE framework is a common framework for developing educational systems that develop learning portals. The phases are Analysis, Design, Development, Implementation, and Evaluation. Figure 1 below outlines how the phases of the ADDIE model were utilized in this project that was previously published by Ekhsan et al. (2022):

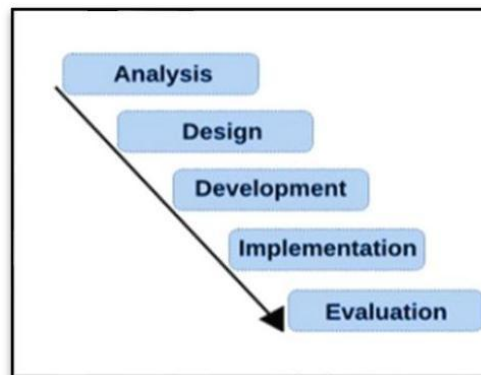


Figure 1. ADDIE Model

The ADDIE model was systematically applied across five interconnected phases to ensure both the technological and pedagogical efficacy Bijak Pecahan. It began with the Analysis phase, which identified the core challenges face with abstract fractions, evaluated the structural impact of reduced classroom time

from 210 to 150 minutes, and utilized an expert interview to capture real-world instructional needs. Next, the Design phase translated these requirements into a functional blueprint and sketching user interface for interactive quiz components. The project then transitioned into the Development phase, where the portal was engineered into a functional digital ecosystem by building the multimedia content and embedding interactive elements like drag-and-drop components and gamified point systems. During the Implementation phase, the platform was actively deployed to a target group of students. Finally, the Evaluation phase begins with a complete final assessment to determine if Bijak Pecahan has met all requirements.

3. RESULTS AND DISCUSSION

Bijak Pecahan uses media-rich and fun to use experiences to help learners become better equipped to learn Mathematics, and develop their Mathematical abilities. The development Bijak Pecahan, has created several improvements on the Fractions topics for primary school students. By using interactive multimedia, well-structured digital lessons and assessments, this portal has improved both teaching effectiveness and student engagement with the learning material.

Bijak Pecahan include providing structured Mathematics lessons about 'fractions' through the use of Digital Notes (PDFs with anyflip), Video, Image and Audio. The formative quizzes allow students to take the quiz immediately after they complete the lesson and receive feedback to encourage active learning and self-assessment. Summative assessments were also provided to give students practice in real exam situations.

The functional requirements intended to improve the interactivity and usability are fulfilled through the incorporation of the following activities: Drag-and-Drop Activities, Matching Games, Multiple-Choice Quizzes and Simulation Tests. Additionally, the students can monitor their learning progress by using the Progress Bar, while the Automated Feedback feature enables students to reinforce their understanding of a topic. Figure 2, 3, 4 below shows some of the Bijak Pecahan user interface design.

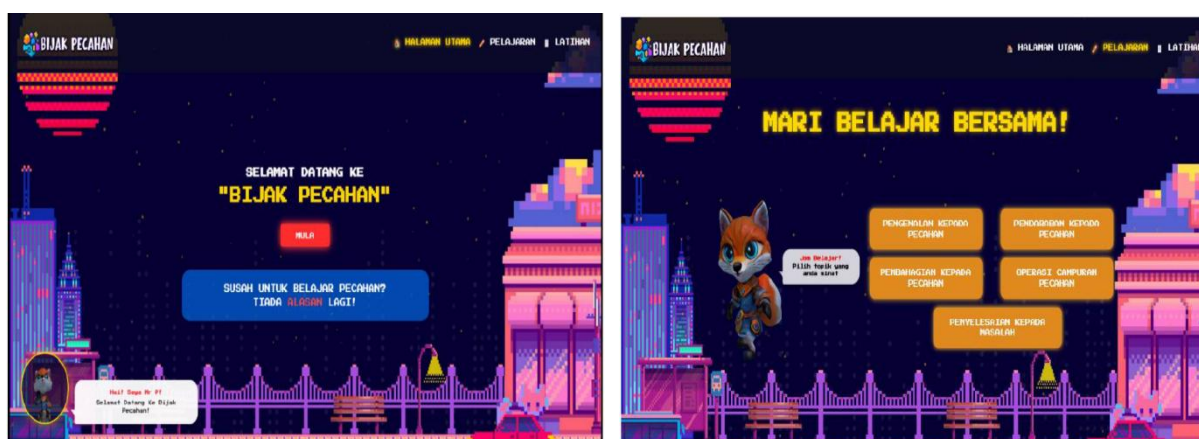


Figure 2. Bijak Pecahan Homepage and Pelajaran Page

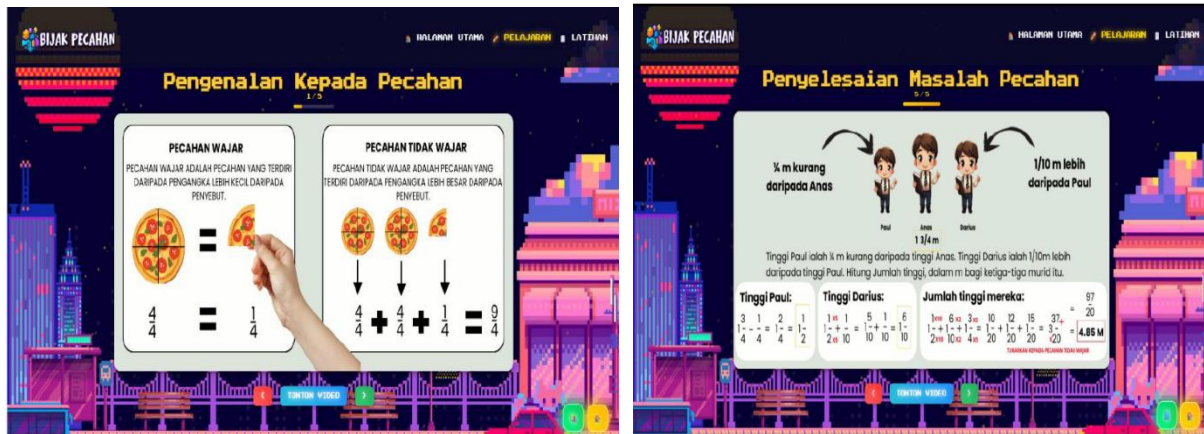


Figure 3. Bijak Pecahan Interactive Lesson

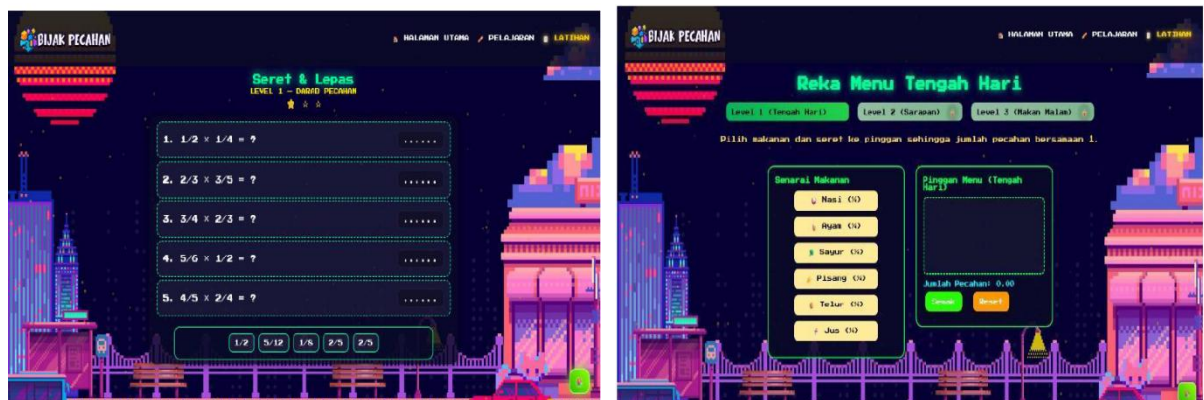


Figure 4. Bijak Pecahan Activities

4. CONCLUSION

An interactive e-learning portal named Bijak Pecahan was developed to help students understand the fractions topic better. The content was developed using ADDIE MODEL which consists of Analysis, Design, Development, Implementation and Evaluation phases. To assist students in their understanding of the abstract nature of fractions, multimedia elements such as animations, visual tools, interactive activities, and illustrated explanations of concepts were added to the design of the portal. Based on the expert evaluative review and further usability assessments of the portal, Bijak Pecahan has been determined to be an appropriate tool for aiding students in their learning and increasing their conceptual understanding of fractions.

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Machine Learning-Based Prediction System For Intraoperative Hypotension

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Abstract

Intraoperative hypotension (IOH) is one of the most common complications during surgery which is associated with serious postoperative outcomes, including acute kidney injury, myocardial injury and mortality. Although continuous physiological monitoring is routinely performed in operating rooms, early identification of patients at risk of IOH remains challenging. This project presents an machine learning-based prediction system that predicts the occurrence of IOH within the next five minutes using routinely collected perioperative data. The proposed system integrates a novel hybrid feature selection approach, Between Aggregation Method–CatBoost Feature Selection (BeAM-CFS) with machine learning algorithms to improve prediction accuracy while reducing model complexity. The development process included data preparation, data preprocessing, system development and system evaluation. The developed system was externally validated using an independent clinical dataset, achieving an accuracy of 87.7%, demonstrating robust predictive performance and strong potential for integration into existing anaesthesia monitoring systems. This innovation contributes to safer surgery, intelligent anaesthesia management and the digital transformation of healthcare. Future work will focus on real-time integration with clinical monitoring systems, prospective multi-centre validation and deployment as an AI-powered clinical decision support solution in smart operating theatres.

Keywords: Artificial Intelligence; Clinical Decision Support; Intraoperative Hypotension; Smart Healthcare.

1. INTRODUCTION

Machine learning (ML), a subset of artificial Intelligence (AI), has emerged as a powerful technology for supporting clinical decision-making and improving patient safety (Miyaguchi et al., 2021). In anaesthesia practice, clinicians are required to interpret multiple monitoring parameters simultaneously while making rapid clinical decisions. This challenge is further increased by the global shortage of anaesthesiologists, as many countries still have fewer than the World Federation of Societies of Anaesthesiologists (WFSA) recommendation of five physician anaesthesia providers per 100,000 population (Law et al., 2024). This shortage increases clinical workload. Therefore, there is an urgent need for intelligent decision support systems that can assist clinicians by providing early prediction of intraoperative hypotension

One of the most significant intraoperative complications is intraoperative hypotension (IOH), commonly defined as a sustained mean arterial pressure (MAP) below 65 mmHg (Khwannimit et al., 2025). Numerous clinical studies have shown that prolonged IOH is associated with adverse postoperative outcomes such as acute kidney injury, myocardial injury, stroke (Inada et al., 2021) and mortality

(Szrama et al., 2025) . Since hypotension often develops rapidly during surgery, early prediction is essential to allow preventive interventions before critical blood pressure reduction occurs.

Existing monitoring devices mainly provide real-time physiological measurements without accurately forecasting future hypotensive events. To address these challenges, this project introduces a machine learning-based early warning system capable of predicting IOH five minutes before its occurrence. This system is a software-based clinical decision support solution designed for use in operating theatres. This innovation combines the novel BeAM-CFS hybrid feature selection method with advanced machine learning algorithms to identify the most informative clinical features while maintaining model efficiency.

Unlike conventional prediction models, the proposed system introduces a comprehensive model development framework enabling a robust and clinically reliable prediction system. The outcome is a practical AI solution that supports anaesthetists in making proactive clinical decisions to safer surgical care. By improving patient safety and reducing the risk of perioperative complications, this study supports the achievement of Sustainable Development Goal (SDG) 3: Good Health and Well-being, particularly through the advancement of high quality, safe and technology-enabled healthcare services.

2. MATERIALS AND METHODS

2.1. Software

The IOH Prediction System was developed using Orange Data Mining software (Version 3.38.1) (Demšar et al., 2013) , an open-source visual analytics platform that supports machine learning workflow development without extensive programming. The software was used to implement data preprocessing, machine learning model training, performance evaluation and external validation. Figure 1 shows the example of graphical user interface of Orange Data Mining software.

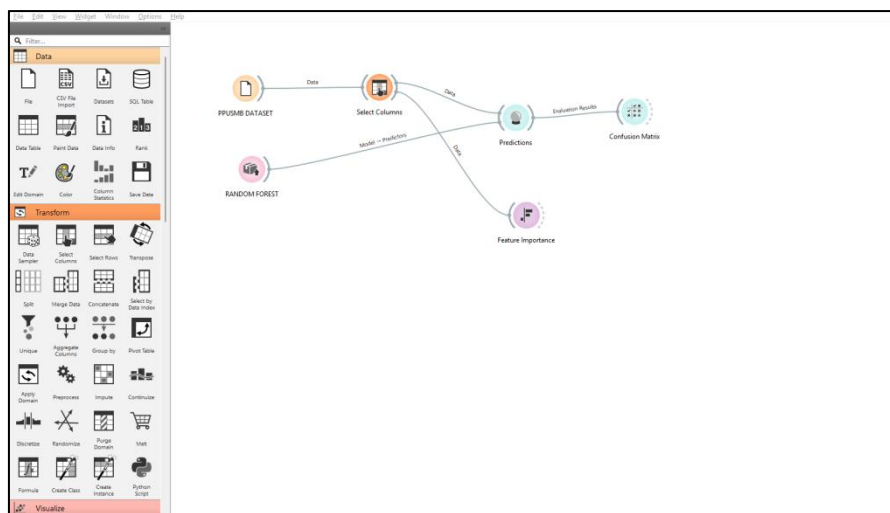


Figure 1. Example of Graphical user interface of Orange Data Mining software.

2.2. IOH Early Warning System Development Framework

The IOH Prediction System was developed using a five-phase development framework, as illustrated in Figure 2. The framework comprises data preparation, data preprocessing, system development, system evaluation and external validation.

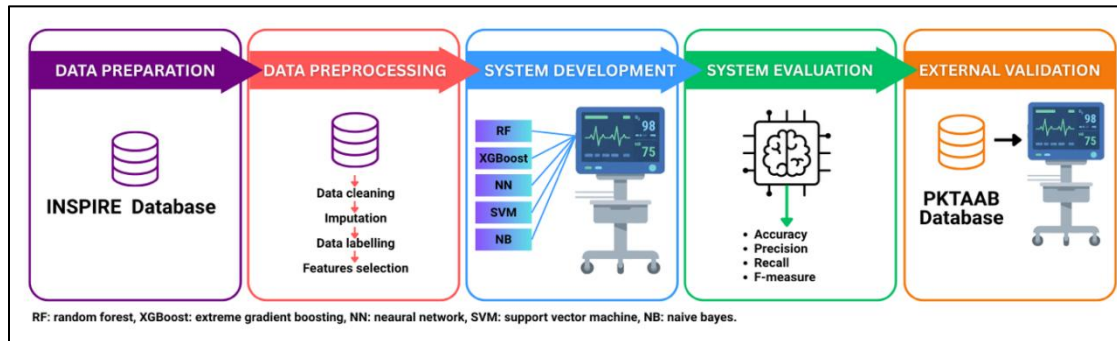


Figure 2. IOH Early Warning System development framework.

The first phase involved data preparation using the INSPIRE database from Seoul National University Hospital (Lim et al., 2024), which contains 5,883 retrospective perioperative dataset collected from patients undergoing surgery under general anaesthesia. The database served as the primary data source for training and developing the machine learning prediction engine to identify patterns associated with intraoperative hypotension.

Subsequently, the prepared dataset underwent several preprocessing procedures to improve data quality and model performance. These procedures including data cleaning, missing value imputation, data labelling and feature selection. Missing value imputation was performed using a random forest-based imputation method developed and validated in our previously published study, where it demonstrated superior performance in handling missing clinical data while preserving the integrity of the dataset for subsequent machine learning analysis (Osman et al., 2026). A key innovation in this phase is the application of the BeAM-CFS, which enhances feature selection method by identifying the most relevant clinical variables for IOH prediction. This enables the development of a more accurate and efficient ML prediction model while reducing model complexity.

In the system development phase, the processed dataset was used to develop the ML prediction engine. Five machine learning algorithms, namely random forest (RF), extreme gradient boosting (XGBoost), neural network (NN), support vector machine (SVM) and naïve bayes (NB), were evaluated to identify the most suitable model for predicting intraoperative hypotension. The selected model was subsequently integrated into the IOH Prediction System to provide real-time risk prediction. The developed models were evaluated using several performance metrics, including accuracy, precision, recall and F-measure. These metrics were used to assess the predictive capability of each algorithm and to identify the most reliable model for deployment in the early warning system.

The final phase involved external validation using 40 independent retrospective perioperative dataset obtained from the Pusat Kanser Tun Abdullah Ahmad Badawi (PKTAAB) Universiti Sains Malaysia. The collection of the data and the use of the data have been approved by the Human Research Ethics Committee (Ethical approval no.: USM/JEPeM/PP/25030278). This phase evaluated the performance of the developed system on unseen data to determine its robustness, generalisability and potential for implementation in real clinical settings.

2.3. Between Aggregation Method–CatBoost Feature Selection

Between Aggregation Method–CatBoost Feature Selection (BeAM-CFS) approach was implemented to improve the feature selection process for this IOH early warning system. It was designed to identify the most informative clinical variables while reducing redundant features, resulting in a more accurate and computationally efficient AI prediction model. The originality of BeAM-CFS has been recognised through its registration with the Intellectual Property Corporation of Malaysia (MyIPO) with registration number LY2026P05805. Figure 3 show an overview of BeAM-CFS mechanism.

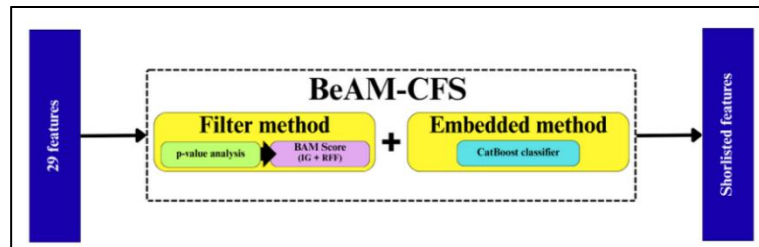


Figure 3. Overview of BeAM-CFS mechanism.

A filter method is first applied using p-value analysis, followed by the between aggregation method, which combines information gain (IG) and reliefF (RFR) to generate a comprehensive feature importance score. The shortlisted features are then refined using the CatBoost classifier to identify the optimal feature subset for model development. By integrating filter and embedded methods, BeAM-CFS reduces redundant features while improving prediction performance, model robustness and computational efficiency compared with conventional feature selection approaches.

3. RESULTS AND DISCUSSION

3.1. IOH Early Prediction Performance

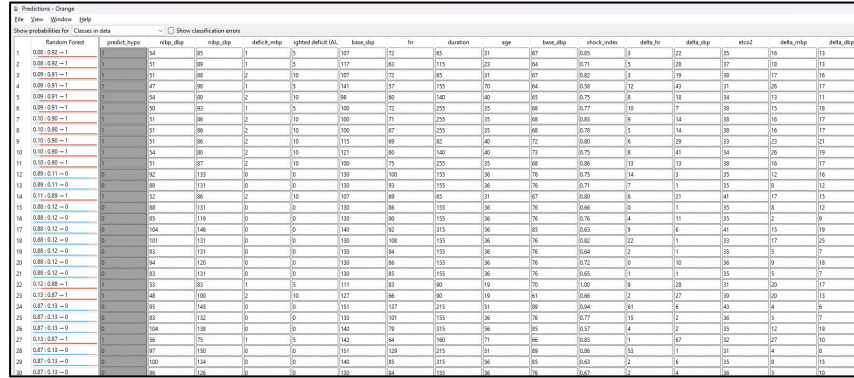
Table 1 summarises the performance of the top three machine learning algorithms evaluated during the external validation of IOH Prediction System. Among the evaluated algorithms, RF demonstrated the best overall performance, achieving an accuracy of 87.7%, precision of 90.3%, recall of 87.7%, and an F-measure of 88.8%. In comparison, XGBoost and NN showed a substantial reduction in predictive performance, indicating limited generalisability when applied to unseen clinical data.

Table 1. Performance score of external validation of IOH Early Warning System.

Machine learning algorithms	Acc	Prec	Recall	F-m
Random forest (RF)	0.877	0.903	0.877	0.888
Extreme gradient boosting (XGBoost)	0.377	0.881	0.377	0.463
Neural network (NN)	0.164	0.878	0.164	0.157

These findings suggest that RF provides more consistent and reliable prediction performance across independent datasets, making it the most suitable prediction engine for the IOH Prediction System. This system outperformed the accuracy of IOH prediction developed by (Park et al., 2025) and (Zhang et al.,

2025), which achieved accuracy of 0.701 and 0.805, respectively. The successful external validation demonstrates the system's potential for real-world clinical implementation and integration into existing anaesthesia monitoring systems. Figure 4 show the prediction results of the IOH Prediction System using Orange Data Mining software.



	predict_type	rbp	age	hba1c	cholesterol	delta_rbp	delta_age	delta_hba1c	delta_cholesterol	delta_delta_rbp	delta_delta_age	delta_delta_hba1c	delta_delta_cholesterol
1	0.00-0.01	1	54	105	1	0	107	72	85	1	23	15	13
2	0.00-0.01	1	51	89	1	0	117	83	115	23	84	0.71	5
3	0.00-0.01	1	51	89	2	10	107	73	85	1	87	0.02	1
4	0.00-0.01	1	47	89	1	0	141	17	175	70	84	0.50	12
5	0.00-0.01	1	54	80	2	10	86	80	140	40	85	0.75	8
6	0.00-0.01	1	50	83	1	0	108	72	255	25	88	0.77	10
7	0.00-0.01	1	51	86	2	10	100	71	255	25	88	0.83	9
8	0.00-0.01	1	51	86	2	10	100	87	255	25	88	0.78	5
9	0.00-0.01	1	51	86	2	10	115	89	82	40	72	0.80	6
10	0.00-0.01	1	54	80	2	10	121	80	140	40	73	0.75	5
11	0.00-0.01	1	51	87	2	10	100	75	255	25	88	0.86	13
12	0.00-0.01	0	82	133	0	0	130	100	155	36	76	0.75	14
13	0.00-0.01	0	80	131	0	0	130	83	155	36	76	0.71	7
14	0.00-0.01	1	52	86	2	10	107	89	85	1	87	0.80	6
15	0.00-0.01	0	88	131	0	0	130	86	155	36	76	0.66	0
16	0.00-0.01	0	85	119	0	0	130	80	155	36	76	0.76	4
17	0.00-0.01	0	104	146	0	0	140	82	155	36	80	0.83	9
18	0.00-0.01	0	101	131	0	0	130	108	155	36	76	0.82	22
19	0.00-0.01	0	83	131	0	0	130	84	155	36	76	0.64	2
20	0.00-0.01	0	84	130	0	0	130	86	155	36	76	0.72	0
21	0.00-0.01	0	83	131	0	0	130	85	155	36	76	0.65	1
22	0.00-0.01	1	53	83	1	0	111	83	80	19	70	1.00	9
23	0.00-0.01	1	48	100	2	10	127	84	80	19	81	0.66	2
24	0.00-0.01	0	95	145	0	0	151	137	215	15	89	0.84	61
25	0.00-0.01	0	83	132	0	0	130	101	155	36	76	0.77	15
26	0.00-0.01	0	104	138	0	0	140	78	155	36	85	0.57	4
27	0.00-0.01	1	56	75	1	0	142	54	160	71	66	0.85	1
28	0.00-0.01	0	97	150	0	0	151	129	215	15	89	0.86	53
29	0.00-0.01	0	100	134	0	0	140	83	155	36	76	0.83	2
30	0.00-0.01	0	126	156	0	0	156	144	215	15	89	0.87	6

Figure 4. The prediction results of the IOH Prediction System using Orange Data Mining software.

The combination of the IOH Early Warning System development framework and the BeAM-CFS feature selection approach forms the foundation of this innovation. The development framework ensures systematic model construction and validation, while BeAM-CFS enhances the quality of feature selection for ML prediction. Together, these innovations contribute to a reliable, scalable and clinically applicable early warning system that supports timely intervention, improves patient safety and has strong potential for integration into existing anaesthesia monitoring systems.

4. CONCLUSION

The Machine Learning-Based Prediction System for IOH demonstrated the ability to predict anomalies using routinely collected perioperative data, supporting earlier clinical intervention during surgery. The integration of the BeAM-CFS approach within the system development framework enabled the development of an accurate and reliable prediction system. This innovation contributes both theoretically, through a systematic development framework and clinically, by supporting timely decision-making and improving patient well-being. Future work will focus on real-time integration with anaesthesia monitoring systems and commercialisation as an AI-powered clinical decision support solution.

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Weld-Xpert: An Automated Deep Learning System For Real-Time Welding Inspection

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Abstract

Traditional manual welding inspection is labor-intensive, subjective, and risks structural safety. To address these industry challenges, this study proposes an automated surface welding defect detection system that integrates the YOLOv8 deep learning model into a user-friendly web application. The system uses image preprocessing and detects seven weld conditions: Burn Through, Contamination, Lack of Fusion, Normal Weld, Spatter, Surface Crack, and Undercut. Experimental evaluations show high effectiveness, achieving 93.7% precision, 92.2% recall, and 94.8% mAP@0.5. Crucially, it attains a 100% correct classification rate for critical structural defects. The functional prototype delivers rapid analysis with an inference speed of 317.5 milliseconds per image. Furthermore, rigorous functionality testing by a group of professional welding instructors validated the system's operational flow and the accuracy of its automated engineering insights. Ultimately, this system transforms quality control workflows by replacing manual visual inspections with a highly consistent, automated process that minimizes human error and accelerates production. Future developments will focus on integrating live video streaming and real-world deployment for continuous, on-the-fly monitoring during the active welding process.

Keywords: Machine Learning; YOLOv8; Image Classification; Object Detection.

1. INTRODUCTION

Welding is a fundamental joining process across construction, automotive, shipbuilding and aerospace manufacturing, and the reliability of a welded structure depends directly on the quality of the weld produced. Surface defects such as burn-through, contamination, lack of fusion, spatter, surface cracks and undercut, if undetected, can compromise structural integrity, leading to premature failure, costly rework or safety hazards. Manual visual inspection remains the most widely used method in industry because it is fast and low-cost, but it is inherently subjective and prone to inconsistency, while radiographic and ultrasonic testing, though more accurate for internal defects, require expensive equipment, trained personnel and considerable inspection time (Y. Wang et al., 2025).

Recent advances in deep learning-based object detection have offered a practical route toward faster and more consistent automated inspection. Among available architectures, the You Only Look Once (YOLO) family of one-stage detectors performs localisation and classification in a single forward pass, offering a

favourable balance between detection speed and accuracy that is well suited to near real-time industrial inspection (Yin, Zhao, & Weng, 2025). Recent implementations of YOLOv8 for weld inspection (Gajalakshmi, Krishnan and Saravanan, 2025) achieved 95% classification accuracy in distinguishing acceptable from defective joints using a custom 1,800-image dataset, while attention-enhanced variants such as YOLOv8-ELA have reported mAP@0.5 values above 93% across multiple radiographic defect categories (Chen, He, & Wu, 2025). These findings motivate the use of an optimised YOLOv8 pipeline for the multi-class surface weld defect detection problem addressed in this study.

The objectives of this study is to (i) develop a YOLOv8-based model capable of detecting and localising seven categories of surface weld defects from weld images, (ii) evaluate the performance of the proposed model using standard object detection metrics, namely precision, recall and mean Average Precision (mAP) and (iii) test the functionality of the developed WeldXpert web based weld defect detection system.

2. METHODOLOGY

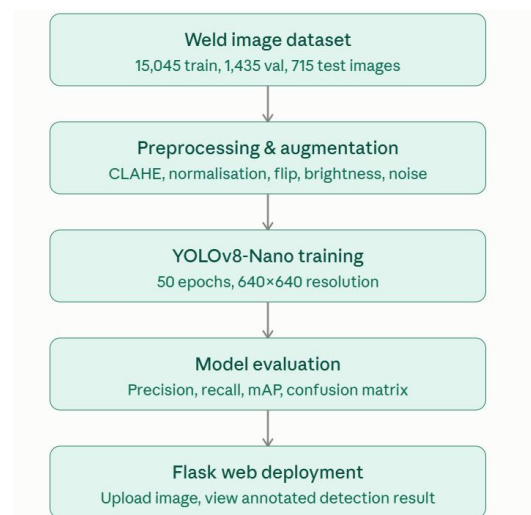


Figure 1. The Comprehensive Research Methodology Framework

Figure 1 illustrates the comprehensive research methodology framework for the proposed automated surface welding defect detection system, WeldXpert. The pipeline is structured into five primary stages. It begins with the compilation of the weld image dataset from Roboflow Universe, comprising 15,045 training, 1,435 validation and 715 test images labelled across seven classes: Burn Through (BT), Contamination (CN), Lack of Fusion (LOF), Normal Weld (NW), Spatter (SR), Surface Crack (SC) and Undercut (UC).

This is followed by preprocessing and augmentation, in which CLAHE-based contrast enhancement, intensity normalisation and augmentation strategies such as flipping, brightness and exposure adjustment are applied to improve image quality and generalisation. The prepared images are then used to train the YOLOv8-Nano detection model for 50 epochs. Then, the trained model undergoes evaluation using standard object detection metrics and confusion matrix analysis. Finally, the validated model is deployed through a Flask-based web application, where the trained model is integrated into a web-based interface allowing users to upload surface weld images and immediately view annotated diagnostic results.

The system was developed following a Waterfall model comprising requirement analysis, design, development, testing and documentation phases. During dataset preparation, images were auto-oriented and resized to 640×640 pixels in Roboflow, and bounding-box annotations were manually verified for

each defect class (Figure 2). To improve model generalisation, four augmentation strategies were applied to the training set: horizontal and vertical flipping, brightness adjustment (−15% to +15%), exposure adjustment (−10% to +10%) and noise injection (up to 0.1% of pixels).



Figure 2. Image Annotation using Roboflow Universe

Model performance was evaluated on the held-out test set using precision, recall, $mAP@0.5$ and $mAP@0.5:0.95$, together with confusion matrix analysis. Furthermore, to ensure real-world applicability, this phase incorporates rigorous functionality testing, requiring a group of welding instructors to validate the application's performance, usability, and operational flow. Table 1 shows the test case scenario for the functionality testing.

Table 1. Test Case Scenario for WeldXpert

Test Case ID	Description	Expected Results
TS-1	Launch Web Application	Application Displayed Successfully
TS-2	Upload valid surface weld image	Image Uploaded Successfully
TS-3	Preview uploaded image	Uploaded image displayed correctly
TS-4	Perform welding defect detection	YOLOv8 detects welding defects
TS-5	Display confidence score	Confidence score shown for detected defects
TS-6	Display engineering insight	Cause and recommendation displayed

3.0 RESULTS AND DISCUSSION

The proposed YOLOv8 model was evaluated on the test set of 715 images using standard object detection metrics, evaluated at the final training epoch, as summarised in Table 2.

Table 2. Performance metrics of the proposed YOLOv8 welding defect detection model.

Metric	Value
Precision	93.70%
Recall	92.20%
mAP@0.5	94.80%
mAP@0.5:0.95	59.60%

The model achieved a precision of 93.7%, indicating a low false-positive rate among detected defects, and a recall of 92.2%, showing that the majority of true defects present in the test images were correctly detected. The mAP@0.5 of 94.8% reflects strong overall localisation and classification performance at a standard IoU threshold, while the lower mAP@0.5:0.95 of 59.6% reflects the stricter demands of averaging across a wider range of patterns consistent with other YOLOv8-based weld inspection studies (Chen, He, & Wu, 2025).

Training and validation curves (Figure 3) show a steady decrease in box, classification and distribution focal losses alongside a consistent increase in precision, recall and mAP across the 50 training epochs, indicating stable convergence without evident overfitting.

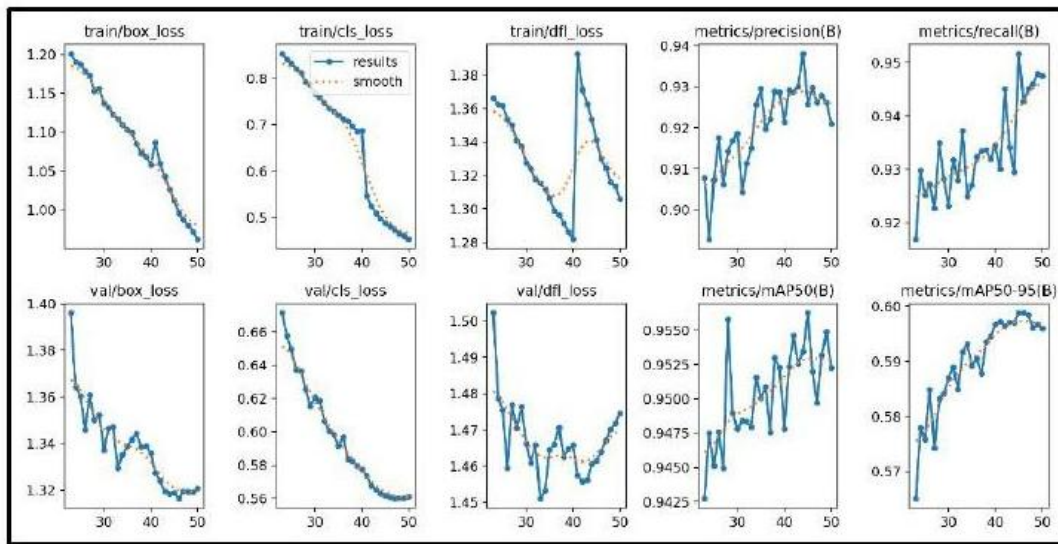


Figure 3. Training and validation performance curves over 50 epochs.

Confusion matrix analysis (Figure 4) further supports these results: five of the seven defect classes Burn Through, Lack of Fusion, Normal Weld, Surface Crack and Undercut achieved 100% normalised classification accuracy, while Contamination and Spatter showed comparatively more confusion with background regions, most notably for Spatter (86 background misclassifications), likely due to its visually subtle and irregular appearance relative to other defect types.

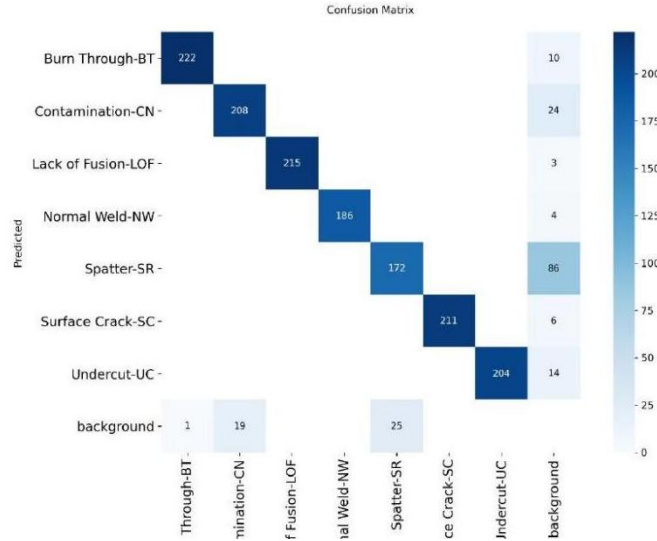


Figure 4. Confusion matrix of the proposed YOLOv8 welding defect detection model.

Crucially for industrial deployment, the YOLOv8 model demonstrated rapid processing capabilities, achieving an average inference speed of 317.5 milliseconds per image. This high-speed performance ensures the system can provide the near real-time feedback required for practical inspection use. To validate the operational viability of the prototype, a series of functional tests were executed by a group of professional welding instructors. They confirmed its usability for non-technical users and verified the accuracy of the generated engineering insights. As outlined in Table 3, the Flask-based web application successfully passed all core operational test cases without critical errors. Overall, these results indicate that a lightweight YOLOv8-based pipeline, supported by targeted preprocessing and data augmentation, can deliver reliable and efficient automated inspection of surface welding defects, offering a viable alternative to manual visual inspection in industrial quality control settings.

Table 3. Summary of Functional Testing Results

Test Case ID	Description	Expected Results	Status
TS-1	Launch Web Application	Application Displayed Successfully	Passed
TS-2	Upload valid surface weld image	Image Uploaded Successfully	Passed
TS-3	Preview uploaded image	Uploaded image displayed correctly	Passed
TS-4	Perform welding defect detection	YOLOv8 detects welding defects	Passed
TS-5	Display confidence score	Confidence score shown for detected defects	Passed
TS-6	Display engineering insight	Cause and recommendation displayed	

4. CONCLUSION

This study successfully developed and evaluated an automated surface welding defect detection system powered by YOLOv8, capable of identifying and localising seven categories of weld defects with 93.7% precision, 92.2% recall, and an mAP@0.5 of 94.8%. The results demonstrate that integrating CLAHE-based preprocessing, targeted data augmentation, and a lightweight YOLO architecture yields a highly robust inspection tool. Crucially, the system achieves near real-time performance with an average

inference speed of 317.5 milliseconds per image, rendering it highly suitable for active industrial deployment. Furthermore, rigorous functional testing and practical validation by a group of professional welding instructors confirmed the system's operational viability, usability, and the accuracy of its automated engineering insights via the accessible web interface. Future work will focus on expanding the dataset to encompass additional defect types and varied imaging conditions, as well as exploring lightweight architectural modifications to improve the fine-grained classification of visually subtle anomalies such as spatter.

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SECTION 6

MATHEMATICS AND STATISTICS



Turning numbers into knowledge and meaningful insights.

Surface-Tension-Driven Thin Rivulet Flow: A Predictive Model for Engineering Applications

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Abstract

Thin rivulet flow on an inclined plane is important in many industrial and natural processes. This study investigates the unsteady thin rivulet flow of power-law fluids on an inclined plane, focusing on the effects of strong surface-tension on the flow height and width over time. The governing equations are derived from the equation of motion and continuity equation using the lubrication approximation and appropriate boundary conditions, including the kinematic condition and the balances of normal and shear stress. Similarity transformations are applied to reduce the governing equations to an ordinary differential equation. The resulting equation is solved numerically using the Cash-Karp method and the results are validated with the Runge-Kutta-Fehlberg fourth-fifth order (RKF45) method. The results using the Cash-Karp method show that physically realizable solutions are obtained. Specifically, solutions occur for $H_2 \leq 0$ and an increase in the power-law index leads to wider rivulets. These results show that the rivulet widens and thickens over time while narrowing and thinning at a given position. These results help to better understand the behaviour of thin rivulet flow and can be applied in areas such as coating processes, microfluidics and other engineering applications involving Newtonian and non-Newtonian fluids.

Keywords: Thin rivulet flow; Surface tension effects; Power-law fluids; Lubrication theory; Numerical modeling; Coating processes; Microfluidic applications.

1. INTRODUCTION

A thin rivulet is a narrow stream of liquid whose thickness is much smaller than its length and width. Such flows appear in liquid coating, printing, microfluidic transport and the handling of complex fluids. Their behaviour is influenced by gravity, viscosity, surface tension, substrate inclination and the position of the moving contact line. Lubrication theory provides an efficient way to simplify these free-surface flows when the film is thin and slender (Oron et al., 1997). For non-Newtonian materials, the difficulty increases because viscosity varies with shear rate and may produce shear-thinning or shear-thickening behaviour (Chhabra & Richardson, 2008).

Earlier studies established similarity solutions for steady power-law rivulets under weak and strong surface-tension conditions (Wilson et al., 2002), unsteady gravity-driven power-law rivulets (Yatim et al., 2010, 2011), and Newtonian rivulets with strong surface-tension effects (Redwan & Yatim, 2019). However, an innovation-oriented framework should do more than derive a solution where it should provide repeatable numerical predictions, demonstrate solver agreement and communicate the resulting fluid shapes in a form that can support engineering decisions.

Therefore, this project develops a computational proof of concept that (i) reduces the governing partial differential equation to an ordinary differential equation, (ii) solves and validates the model using two adaptive fourth–fifth-order numerical methods, and (iii) predicts how the rivulet profile changes with centre height, centre curvature, fluid rheology, downstream position and time.

2. MATERIALS AND METHODS

2.1. Mathematical Model

The mathematical model considers an incompressible power-law fluid of constant density flowing down an inclined plane under strong surface-tension effects. The free surface is represented by $z = h(x, y, t)$, where x, y and z denote the flow, transverse and substrate-normal directions, respectively. The apparent viscosity follows the power-law model, where $N < 1$, $N = 1$ and $N > 1$ represent shear-thinning, Newtonian and shear-thickening fluids, respectively. The flow is assumed to be thin, slender and symmetric, with no slip at the substrate and appropriate boundary conditions imposed at the free surface. The physical geometry of the present problem is illustrated in Figure 1.

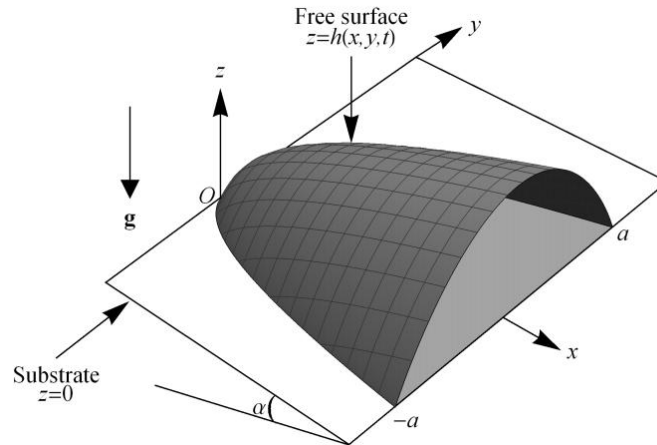


Figure 1. Schematic geometry for unsteady three-dimensional thin-film flow of a power-law fluid on an inclined plane (Redwan & Yatim, 2019).

Under the lubrication approximation, the governing equations are simplified and transformed into similarity variables, yielding a fourth-order ordinary differential equation for the dimensionless cross-sectional profile. The similarity transformation is expressed as

$$h = \left| \frac{x}{t} \right|^{\frac{N}{N+1}} H(\eta), y = \left(\frac{|x|^{2N+1}}{|t|^N} \right)^{\frac{1}{4(N+1)}} \eta. \quad (1)$$

where $H(\eta)$ denotes the dimensionless cross-sectional profile and η is the similarity variable (Yatim et al., 2011).

2.2. Numerical Implementation and Validation

The transformed equations are implemented in Maple 2016. The adaptive Cash-Karp method is employed as the primary numerical solver, while the Runge-Kutta-Fehlberg fourth-fifth order (RKF45) method is used independently to validate numerical solutions. A parametric study is performed by varying the values

of H_0 , H_2 and the power-law index N . The validated numerical solutions are subsequently used to generate the two-dimensional cross-sectional profiles and three-dimensional rivulet surfaces presented in the following section.

3. RESULTS AND DISCUSSION

3.1. Numerical Validation

The numerical solutions obtained using the Cash-Karp method are validated against the Runge-Kutta-Fehlberg fourth-fifth order (RK45) method. Table 1 presents the representative values of the contact-line position, η_0 , for different values of H_0 and H_2 . Both methods produced identical or nearly identical values, with a maximum absolute difference of 7×10^{-7} . The close agreement between the two methods indicates that the numerical solutions obtained using the Cash-Karp method are reliable and consistent.

Table 1. Numerical comparison of the contact-line position, η_0 , obtained using the Cash-Karp and RK45 methods.

H_2	H_0	Cash-Karp	RKF45	Difference
-1	2	1.6906318	1.6906318	0.0
-1	10	2.9581724	2.9581724	0.0
0	2	2.6106315	2.6106315	0.0
0	10	3.6395065	3.6395065	0.0
0.5	4	3.6870533	3.6870532	1×10^{-7}
1	2	7.3358349	7.3358356	7×10^{-7}

3.2. Effect of Centre Curvature and Initial Height

For $H_2 < 0$, the cross-sectional profiles remain single-humped, with one maximum at the centerline and a smooth decrease towards the contact lines. As H_2 approaches zero, the centre of the profile becomes flatter and the rivulet spreads further in the transverse direction. For positive H_2 , the profile changes from a single maximum to a local minimum at the center, resulting in two symmetric peaks. The separation between the peaks becomes more noticeable as H_0 increases. For $H_2 \leq 0$, increasing H_0 generally increases the contact-line position, η_0 , indicating that a larger initial centre height is associated with a wider predicted rivulet.

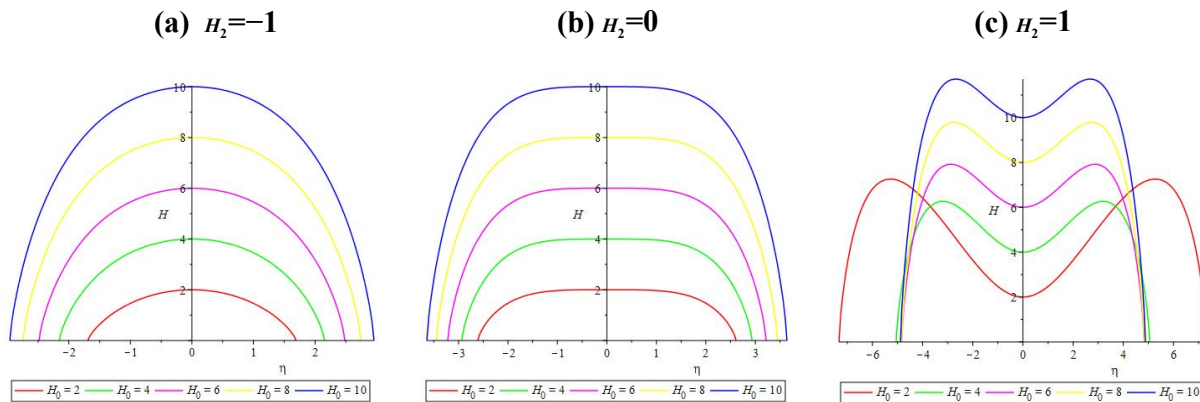


Figure 2. Predicted cross-sectional profiles for negative, zero and positive centre curvature.

3.3 Effect of Power-Law Index on Rivulet Width

The influence of fluid rheology on rivulet width is investigated using the power-law indices $N=1/5$, $N=1$ and $N=20$, representing shear-thinning, Newtonian and shear-thickening fluids, respectively. For fixed values of H_0 and H_2 , the predicted contact-line position, η_0 , generally increases as the power-law index increases. This indicates that increasing N produces a wider rivulet. Overall, the results show that the power-law index influences the transverse width of the rivulet, with shear-thickening fluids producing wider profiles than shear-thinning fluids.

Table 2. Contact-line position, η_0 , for different power-law indices at $H_2=-1$.

H_0	$N=1/5$	$N=1$	$N=20$
2	1.4099278	1.6906318	1.9030935
4	1.8359588	2.1544219	2.2916155
6	2.1305379	2.4842432	2.6291123
8	2.3606171	2.7430985	2.8925785
10	2.5516778	2.9581724	3.1111705

3.4 Evolution of Rivulet Profile with Time

The three-dimensional similarity solutions illustrate the evolution of the rivulet with position and time. Figure 3 shows a representative shear-thinning case for $N=1/5$ and $H_2=-1$ at $t=1,10,100$. At a fixed position along the flow direction, the rivulet becomes wider and thickens over time, whereas at a fixed time, the rivulet becomes narrower and thinner along the flow direction. These results show that both time and position influence the dimensions of the rivulet while maintaining its cross-sectional profile.

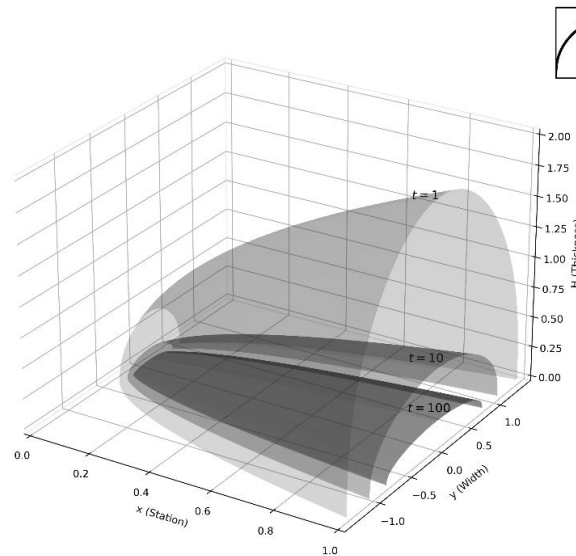


Figure 3. Three-dimensional rivulet profiles for $N=1/5$ and $H_2=-1$ at $t=1,10,100$.

4. CONCLUSION

This study investigated the unsteady thin rivulet flow of power-law fluids under strong surface-tension effects. The governing partial differential equations were transformed into ordinary differential equations using similarity transformations and solved numerically using the Cash-Karp method. The numerical solutions were validated using the RK45 method, showing close agreement between the two methods. The results show that the power-law index influences the size of the rivulet, where an increase in the power-law index produces a wider rivulet. Shear-thickening fluids also produce wider and thicker rivulets than shear-thinning fluids. In addition, the center curvature affects the cross-sectional shape, where $H_2 \leq 0$ produces single-humped profiles, while $H_2 > 0$ produces double-humped profiles.

The similarity solutions also describe the changes in rivulet dimensions with position and time. At a fixed position along the flow direction, the rivulet becomes wider and thicker as time increases while maintaining its cross-sectional shape. However, the present study is based on similarity solutions and numerical simulations, and more complex flow behavior and physical effects are not considered.

The findings provide a mathematical understanding of the influence of fluid rheology on the size and evolution of thin rivulet flow. Future studies may consider other non-Newtonian fluid models, such as Ellis, Carreau or Bingham fluids, and include additional physical effects such as evaporation, temperature-dependent viscosity, variable surface tension and substrate roughness. Comparison with experimental data or controlled laboratory experiments is also recommended to verify the accuracy and physical relevance of the numerical model. The present study may also be extended to applications involving coating processes, microfluidic devices and thin-film transport systems.

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STATChecker: REVOLUTIONISING THE LEARNING OF CENTRAL TENDENCY THROUGH SMART EXCEL AUTOMATION

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Abstract

Many pre-commerce students at Universiti Teknologi MARA (UiTM) encounter difficulties in mastering the fundamental concepts of measuring the central tendency, particularly in calculating the mean, median, and mode for both grouped and ungrouped data. While manual calculation is essential for developing conceptual understanding, students often struggle to identify errors in their solution process when only the final answer is available. To address this challenge, STATChecker was developed as a smart Microsoft Excel application that functions as an interactive learning and self-verification tool. Unlike conventional answer checkers, STATChecker provides comprehensive, step-by-step verification of each calculation, enabling students to trace their workings, identify mistakes, and reinforce their understanding of the underlying statistical concepts. The application is intentionally designed to support the Introduction to Basic Statistics topic for UiTM pre-commerce students while encouraging independent learning and immediate formative feedback. In addition, lecturers can utilise STATChecker to verify solutions and assist in developing tutorial exercises, quizzes, and assessment materials. Developed using Microsoft Excel and Visual Basic for Applications (VBA), the application is cost-effective, user-friendly, and does not require specialised statistical software. STATChecker offers an innovative, accessible, and practical digital learning solution that enhances students' confidence, accuracy, and engagement in learning of central tendency.

Keywords: Central Tendency, Microsoft Excel VBA, Step-by-Step Verification, Self-Directed Learning, Educational Technology

1. INTRODUCTION

Basic statistics is an essential component in pre-commerce education at Universiti Teknologi MARA (UiTM), particularly in the topic of central tendency involving mean, median, and mode. Despite its importance, many students face difficulties in mastering the procedural steps required to compute these measures, especially for grouped and ungrouped data. Students are often able to recall formulas but struggle to correctly apply them during manual calculations, leading to errors in final answers without understanding the source of mistakes.

Traditional learning approaches often provide only final answers, which limits students' ability to trace their errors and develop conceptual understanding. According to Mayer (2009), meaningful learning occurs when learners actively process information and receive feedback that supports cognitive construction (Sweller, 1988). Similarly, Hattie (2009) emphasizes that timely and specific feedback is one of the most powerful influences on student achievement.

To address these issues, STATChecker was developed as an innovative Microsoft Excel application designed to support step-by-step verification of statistical calculations. The application aims to enhance students' understanding of central tendency by allowing them to manually compute answers first and then verify each step using the system.

The objective of this innovation is to:

- Improve students' understanding of mean, median, and mode
- Provide step-by-step verification of manual calculations
- Support self-directed learning in basic statistics
- Assist lecturers in teaching and assessment preparation

2. METHODS

2.1 Research Design

This study adopts a design and development approach with an evaluative framework. The development of STATChecker is guided by the ADDIE instructional design model (Branch, 2009), which consists of five phases: *Analysis, Design, Development, Implementation, and Evaluation*.

2.2 Analysis Phase

A preliminary analysis was conducted to identify learning difficulties among pre-commerce students. The main issue identified was students' inability to trace calculation errors in central tendency problems, particularly in grouped data.

2.3 Design Phase

The application was designed to include:

- Step-by-step computation of mean, median, and mode
- Separate modules for grouped and ungrouped data
- Input fields for manual answers and system verification output

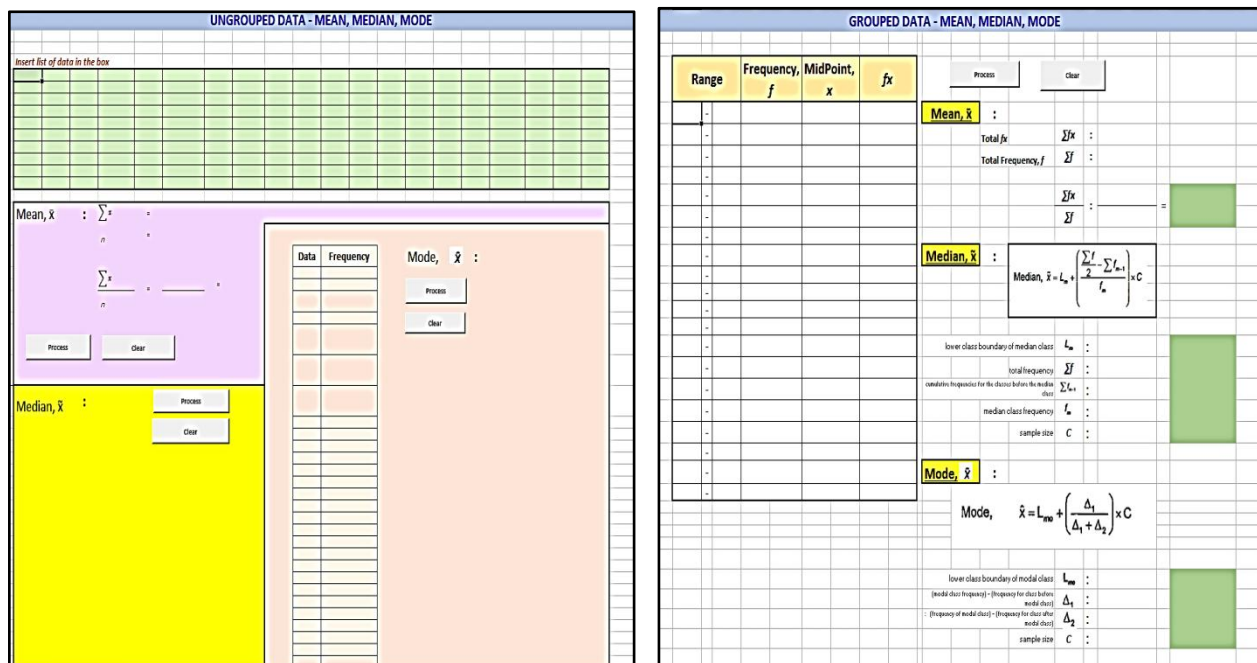


Figure 1. Interface of ungrouped (left) and grouped (right) data for mean, median and mode calculation

2.4 Development Phase

STATChecker was developed using Microsoft Excel integrated with Visual Basic for Applications (VBA), Microsoft (2024). The programming logic was designed to:

- Accept user input values
- Perform statistical computations
- Display intermediate working steps
- Compare student answers with correct solutions

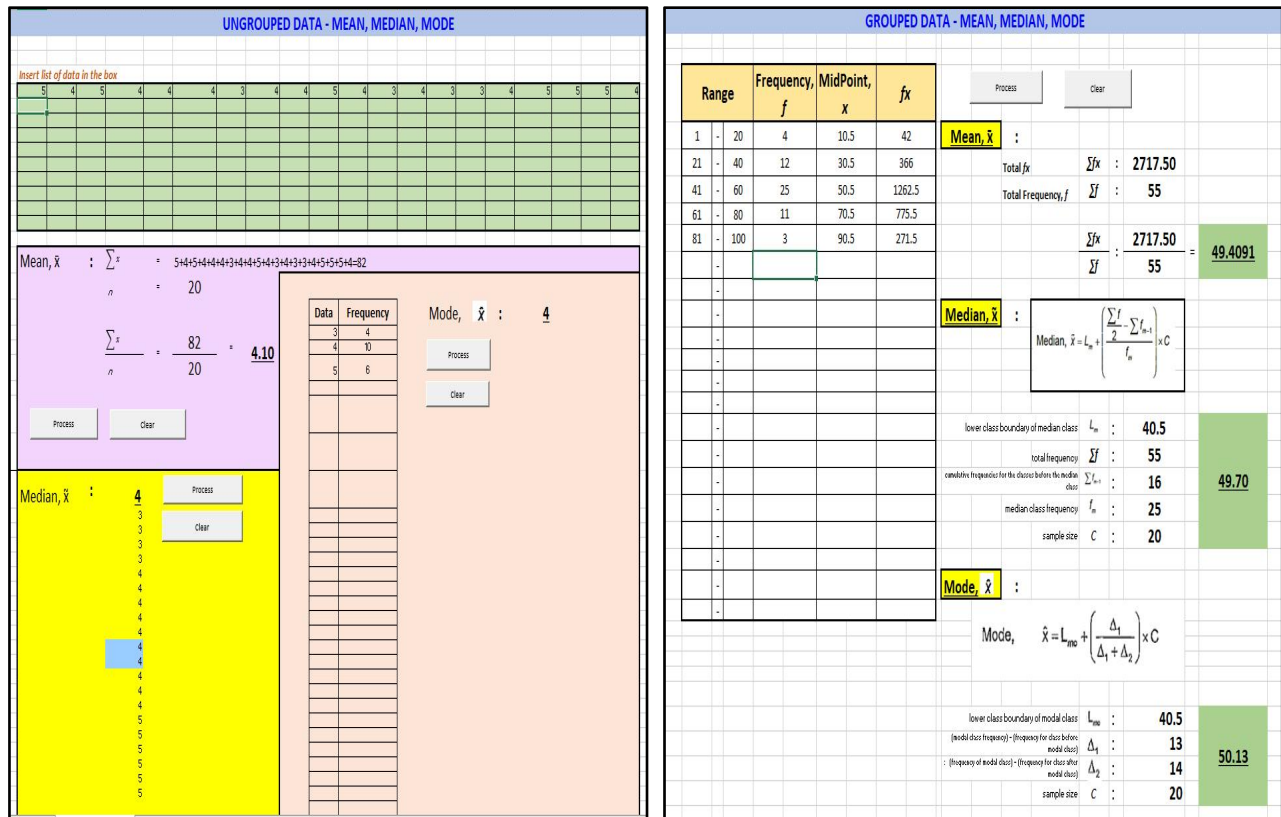


Figure 2. Sample of user input values (data) for ungrouped (left) and grouped (right) data

2.5 Implementation Phase

A pilot implementation was conducted involving 40 pre-commerce students enrolled in a basic statistics course at UiTM. Students were first required to solve problems manually before using STATChecker for verification.

2.6 Evaluation Phase

Evaluation was conducted using:

- Pre-test and post-test assessments
- Student feedback questionnaire (Likert scale)
- Observation of student interaction with the application

The analysis of data collections have been performed to measure performance improvement and user perception.

3. FINDINGS AND DISCUSSION

The test has been conducted to 40 students of Pre-Commerce programme at UiTM Penang branch.

3.1 Student Performance

Table 1 presents the comparison between pre-test and post-test scores.

Table 1. Student Performance Results

Assessment	Mean Score (%)
Pre-Test	58.4
Post-Test	82.7

The results show an improvement of 24.3% in student performance after using STATChecker.

3.2 Student Perception

Student feedback indicates high acceptance and positive learning impact.

Table 2. Student Feedback on STATChecker

Item	Statement	Agreement (%)
1	Helps me understand step-by-step calculations	58.4
2	Helps identify errors in my work	92%
3	Improves my confidence in statistics	90%
4	Easy to use	97%
5	Prefer STATChecker over traditional methods	88%

The findings demonstrate that the use of STATChecker improved students' post-test performance and strengthened their understanding of measures of central tendency. The increase in post-test scores suggests that the application supports cognitive processing by allowing learners to compare their manual calculations with structured step-by-step solutions (Kirschner, 2002).

The highest-rated feature was the step-by-step verification function, which enabled students to identify specific errors in their calculation process. This aligns with Hattie's (2009) assertion that feedback is most effective when it is immediate, specific, and related to task performance.

Furthermore, STATChecker promotes self-directed learning by encouraging students to attempt problems independently before verifying their answers. This supports constructivist learning principles, where learners actively construct knowledge through engagement and reflection (Jonassen, 1999).

The use of Microsoft Excel and VBA makes the application highly accessible, as it does not require specialised software or advanced technical skills. This increases its practicality for classroom implementation in UiTM's pre-commerce curriculum.

4. CONCLUSION

STATChecker is an innovative educational tool designed to enhance the learning of basic statistics among pre-commerce students. By integrating Microsoft Excel and VBA programming, the application provides an accessible and interactive platform for step-by-step verification of mean, median, and mode calculations for both grouped and ungrouped data.

Findings from the pilot study revealed improved post-test performance among students, suggesting that the application increased their confidence and strengthened their conceptual understanding of measures of

central tendency. It also supports lecturers in teaching and assessment preparation. Overall, STATChecker contributes as a practical, low-cost, and effective educational innovation that bridges the gap between manual calculation and conceptual understanding in statistics learning.

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Development of an UnoPoly Legends (Uno-Monopoly-Mobile Legends): Algebra Edition Game Learning Module and Its Effectiveness among Secondary School Students at SMK Rantau Panjang Bestari Jaya, Selangor

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Abstract

Mathematics, particularly algebra, is fundamental for developing logical reasoning, problem-solving skills, and higher-order thinking essential for STEM education and everyday decision-making. However, many secondary school students struggle to understand algebra because conventional teaching methods often emphasize procedural learning rather than conceptual understanding, resulting in low motivation and poor academic performance. This study aimed to develop and evaluate the effectiveness of the *UnoPoly Legends (Uno-Monopoly-Mobile Legends): Algebra Edition* game learning module for Form Two students at *SMK Rantau Panjang Bestari Jaya, Selangor*. The module integrates Monopoly gameplay, UNO card strategies, and Mobile Legends-inspired mechanics through five educational cards: *Red Buff*, *Blue Buff*, *Lane*, *Turtle*, and *Lord*, each designed to reinforce algebraic concepts while encouraging collaboration, critical thinking, and strategic decision-making. The module was developed using the *ADDIE instructional design model* and evaluated through a *one-group pre-test-post-test quasi-experimental design* involving 30 students. Achievement data indicated a substantial improvement in algebra performance, with the mean score increasing from approximately 12.4/35 in the pre-test to 19.5/35 in the post-test. **Paired-Samples *t* Test:** The results reveal a statistically significant difference between pre-test and post-test scores ($t(29) = -16.70$, $p < .001$). The null hypothesis of no difference in student achievement is rejected. The implementation of the UnoPoly Legends module Algebra Edition led to statistically significant ($p < .001$) and practically meaningful ($d = 3.05$) improvements in secondary school students' algebra performance. The module serves as an effective supplementary learning tool for mathematics educators seeking to increase student engagement, concept retention, and problem-solving confidence in algebra. The feedback of student also obtained 90% **agree** the *UnoPoly Legends: Algebra Edition increase interest the mathematics and Figure 2b the student answer the UnoPoly Legends: Algebra Edition made Algebra easier to learn, for 93.3% and 6.7% for neutral respond*. Students also demonstrated greater engagement, confidence, teamwork, and positive attitudes toward mathematics. The findings suggest that UnoPoly Legends is an effective and engaging instructional module that enhances algebra learning and offers a practical game-based learning innovation for secondary mathematics education, particularly in rural schools.

Keywords: Game-Based Learning, Algebra, Mathematics Education, Monopoly, UNO, Mobile Legends, ADDIE Model, Educational Games

1. INTRODUCTION

Mathematics serves as a universal language that supports logical reasoning, critical thinking, scientific inquiry, and technological advancement (Ishak et al., 2025). Among its many branches, algebra occupies a central position because it enables learners to generalize mathematical relationships, solve equations, recognize patterns, and model real-life situations. Strong algebraic competence prepares students for higher education in science, engineering, economics, information technology and numerous STEM-related professions (Ramadoni & Adnan, 2026).

Despite its significance, algebra remains one of the most difficult topics for secondary school students. Many learners struggle to interpret variables, manipulate algebraic expressions, and solve equations due to abstract representations and insufficient conceptual understanding (Rosni et al., 2024). Traditional teacher-centered instruction frequently emphasizes repetitive exercises and procedural techniques rather than meaningful exploration, resulting in reduced motivation and mathematics anxiety (Paglomutan, 2024).

These challenges are particularly evident in rural schools, where opportunities to experience innovative teaching approaches may be limited. Consequently, educational researchers have increasingly advocated the use of **Game-Based Learning (GBL)** as an alternative instructional strategy. GBL transforms learning into interactive experiences by integrating educational objectives with game mechanics such as competition, collaboration, rewards, and immediate feedback (Galang, 2025).

Monopoly-inspired educational games have demonstrated effectiveness across multiple disciplines. Yusuf et al. (2023) validated Monopoly-based science learning media that improved students' conceptual understanding and engagement. Similar positive findings were reported by Prayogo (2017), Ulfa and Rozalina (2019), and Lailiyah et al. (2021), confirming that Monopoly mechanics successfully promote active learning and student participation.

Building upon these findings, this study introduces **UnoPoly Legends: Algebra Edition**, a hybrid educational board game combining elements from UNO, Monopoly, and Mobile Legends. Unlike conventional Monopoly mathematics games, UnoPoly Legends incorporates specialized gameplay cards inspired by Mobile Legends.

The learning cards include:

- **Red Buff Card:** doubles rewards after correctly solving difficult algebra questions.
- **Blue Buff Card:** provides hints or reduces question difficulty.
- **Lane Card:** determines learning pathways corresponding to algebra topics.
- **Turtle Card:** grants bonus points after completing collaborative tasks.
- **Lord Card:** allows players to challenge advanced algebra problems for higher rewards.

The integration of these mechanics encourages collaborative learning, strategic decision making, critical thinking, and continuous student engagement while reinforcing algebraic concepts.

Therefore, this study aims to:

Develop UnoPoly Legends: Algebra Edition **module:** To design and implement an interactive game-based learning module focusing on algebra concepts tailored SMK Rantau Panjang students in Selangor.

Enhance mathematical engagement: To increase students' motivation and interest in learning algebra through gamification strategies.

Improve learning outcomes: To evaluate the effectiveness of the UnoPoly Legends: Algebra Edition module in improving students' understanding, problem-solving skills, and performance in algebra.

Importance of Mathematics and Algebra

Mathematics develops reasoning, communication, and analytical thinking essential for lifelong learning (Ishak et al., 2025). Algebra extends these competencies by introducing symbolic reasoning and mathematical modelling that underpin advanced STEM education (Ramadoni & Adnan, 2026).

Challenges in Learning Algebra

Students frequently experience difficulties understanding abstract symbols and variables. Traditional lecture-based approaches often reduce learning motivation and fail to cultivate conceptual understanding (Paglomutan, 2024).

Monopoly-Based Educational Games

Previous studies have established Monopoly as an effective educational medium because it promotes active participation and collaborative learning.

Examples include:

- Monopoly Science (Yusuf et al., 2023)
- Monoergy (Prayogo, 2017)
- Monopoly Digestive System (Ulfa & Rozalina, 2019)
- Monopoly Solar System (Lailiyah et al., 2021)

These studies consistently reported improvements in student engagement and learning outcomes.

Game-Based Learning

Game-Based Learning integrates educational content with enjoyable activities that increase attention, persistence, and confidence (Galang, 2025). Mathematical games reduce anxiety while promoting collaborative problem-solving and conceptual understanding (Rosni et al., 2024).

Research by Ogbu et al. (2023) and Ramadoni and Adnan (2026) demonstrated significant improvements in algebra achievement through game-based interventions.

Instructional Design Framework

The ADDIE instructional design model was selected because it provides a systematic process for educational module development through:

- Analysis
- Design
- Development
- Implementation
- Evaluation

This model ensures instructional validity, practical usability, and continuous improvement.

2. MATERIALS AND METHODS

Research Design

This study adopts a **quasi-experimental design** with a pre-test and post-test control group. The design allows for comparison between students taught using the **UnoPoly Legends: Algebra Edition game learning module** and those taught using traditional methods. The experimental group will receive instruction through the developed module, while the control group will continue with conventional pedagogy.

Population and Sampling

Sample Size: Thirty Form Two students from **SMK Rantau Panjang, Bestari Jaya, Selangor** participated.

Research Instruments.

1. **UnoPoly Legends: Algebra Edition Module:** Developed using the **ADDIE Model**
2. **Achievement Test:** Pre- and post-tests designed to measure algebraic achievement, focusing on symbolic reasoning, problem-solving, and equation manipulation.
3. **Questionnaire:** Administered to assess students' motivation, attitudes, and perceptions toward mathematics learning.

Development Process

The module was developed according to ADDIE.

Analysis

- Student needs
- Curriculum analysis
- Learning objectives

Design

Game mechanics integrating:

- UNO
- Monopoly
- Mobile Legends
- Plan module structure, rules, and integration of algebraic concepts.

Development

Create the game board, pawns, question cards, and reward system.

Five learning cards were created:

- Red Buff Card
- Blue Buff Card
- Lane Card
- Turtle Card
- Lord Card

Expert validation ensured content accuracy.

Implementation

Students completed four weeks of algebra learning using UnoPoly Legends: Algebra Edition.

Evaluation

Students completed:

- Pretest
- Post-test
- Observation checklist
- Student perception questionnaire

3. RESULTS AND DISCUSSION

3.1. Result

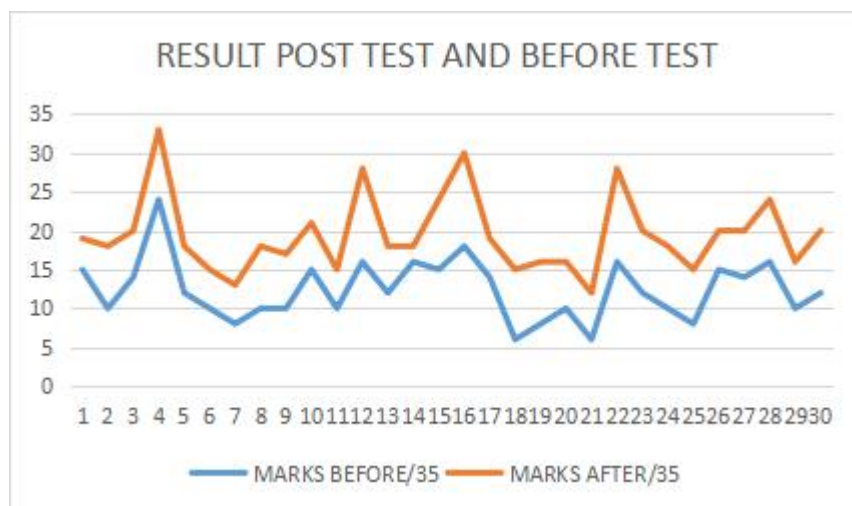


Figure 1. Pre- Test and Post Test

Figure 1 presents the pre-test and post-test scores of 30 students who used the *UnoPoly Legends: Algebra Edition* game learning module at SMK Rantau Panjang. The post-test scores are consistently higher than the pre-test scores for nearly all students, indicating an overall improvement in algebra achievement after the intervention.

Before the implementation of the module, students' pre-test scores ranged approximately from 6 to 24 marks out of 35, suggesting that many students had only a moderate understanding of algebraic concepts. After using the *UnoPoly Legends: Algebra Edition* module, post-test scores increased to approximately 12 to 33 marks, with several students achieving scores above 25 marks. The overall trend demonstrates a clear upward shift in student performance, with no substantial decline observed among participants.

The line graph also shows that although students entered the study with varying levels of prior knowledge, nearly every student demonstrated improvement in the post-test. Students with initially lower scores also exhibited noticeable gains, indicating that the learning module benefited learners across different ability levels.

The evaluation of the **UnoPoly Legends (Uno–Monopoly–Mobile Legends): Algebra Edition Game Learning Module** examined its effectiveness in improving algebra achievement among secondary school students at SMK Rantau Panjang Bestari Jaya, Selangor $N = 30$.

1. Student Achievement Before and After Intervention

Student academic performance was measured using a pre-test (prior to the introduction of the game module) and a post-test (following the completion of the intervention), each scored out of a maximum of 35 marks.

Pre-Test Performance: The baseline scores yielded a mean of 12.40 ($SD = 3.89$), corresponding to an overall average mastery of 35.43%. Scores ranged from a minimum of 6.00 (17.14%) to a maximum of 24.00 (68.57%).

Post-Test Performance: Following the intervention, student scores increased to a mean of 19.47 ($SD = 4.97$), representing an average mastery of 55.62%. Scores ranged from a minimum of 12.00 (34.29%) to a maximum of 33.00 (94.29%).

Absolute Mean Gain: Students achieved an average increase of +7.07 marks ($SD = 2.32$), reflecting a +20.19% improvement in overall score percentage.

Summary of Pre-Test and Post-Test Descriptive Statistics

Measurement	Mean Score (Max 35)	Standard Deviation (SD)	Mean Percentage (%)	Min Score	Max Score
Pre-Test	12.4	3.89	35.43%	6	24
Post-Test	19.47	4.97	55.62%	12	33
Difference/ Gain	7.07	2.32	20.19%	2	12

2. Inferential Analysis & Effectiveness Metrics

1. Directional (One-Tailed) Hypotheses (*Recommended for Interventions*)

Null Hypothesis (H_0): $H_0 : \mu_{post} \leq \mu_{pre}$

There is no significant improvement in the mean algebra achievement scores of secondary school students after implementing the UnoPoly Legends game-based learning module (post-test mean score is less than or equal to pre-test mean score).

Alternative Hypothesis H_1 : $H_1 : \mu_{pre} > \mu_{post}$

Alternative Hypothesis (H_1): There is a statistically significant improvement in the mean algebra achievement scores of secondary school students after implementing the UnoPoly Legends game-based learning module (post-test mean score is significantly higher than pre-test mean score).

2. Non-Directional (Two-Tailed) Hypotheses

Null Hypothesis (H_0):

$H_0 : \mu_{post} = \mu_{pre}$: There is no significant difference between the mean algebra achievement scores of secondary school students before and after implementing the UnoPoly Legends game-based learning module.

Alternative Hypothesis (H_1):

$H_1 : \mu_{pre} \neq \mu_{post}$: There is a statistically significant difference between the mean algebra achievement scores of secondary school students before and after implementing the UnoPoly Legends game-based learning module.

Statistical Decision Rule

- **Significance Level** $\alpha = 0.05$
- **Statistical Test:** Paired-samples t -test
- **Decision Outcome:** Since $t(29) = -16.70$ and $p = 2.06 \times 10^{-16} < 0.05$, H_0 is **rejected** in favor of H_1 , confirming that the intervention produced a statistically significant increase in algebra achievement ($\mu_{pre} = 12.40$ vs. $\mu_{post} = 19.47$).

The null hypothesis of no difference in student achievement

To determine whether the observed improvement was statistically significant, a paired-samples t -test was conducted. Additional indicators of educational impact (Cohen's d effect size and Hake's normalized gain index g) were also computed.

Paired-Samples t Test: The results reveal a statistically significant difference between pre-test and post-test scores ($t(29) = -16.70$, $p < .001$). The null hypothesis of no difference in student achievement is rejected.

Effect Size (Cohen's d): The standard effect size was calculated at $d = 3.05$, exceeding the standard benchmark for a large effect ($d \geq 0.80$).

Normalized Gain Index (Hake's g): The average normalized gain across all students was $g = 0.33$, placing the intervention in the **Medium Gain Category** ($0.30 \leq g < 0.70$).

Distribution of Improvement: 100% of participating students ($N = 30$) registered positive score gains:

- Moderate Improvement (≤ 5 marks): 7 students (23.3%)
- Substantial Improvement (6–8 marks): 17 students (56.7%)
- High Improvement (> 8 marks): 6 students (20.0%)

Feed back from the students

E1. The game increased my interest in Mathematics.

30 responses

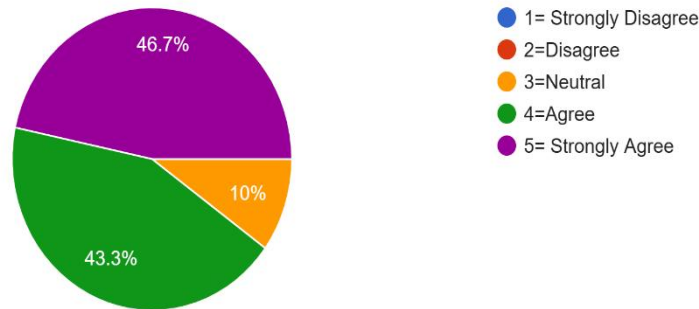


Figure 2a. Feed back student for Interest learn Mathematics

G4. The game made Algebra easier to learn.

30 responses

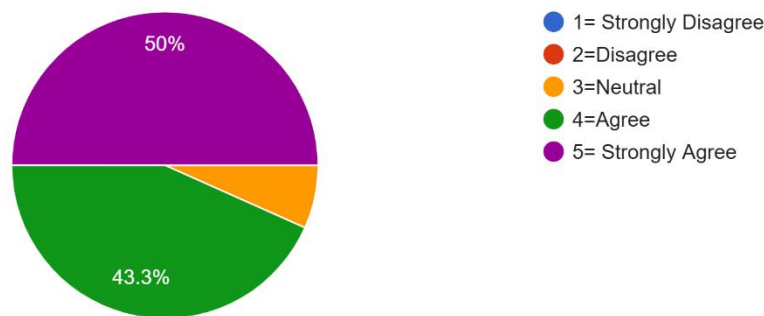


Figure 2b. Feed back students for Algebra topic

3.2 Discussion

The findings suggest that the **UnoPoly Legends: Algebra Edition** game learning module was effective in improving students' understanding of algebra. The consistent increase from pre-test to post-test scores indicates that the module successfully enhanced students' conceptual understanding and problem-solving skills.

The empirical findings confirm that the UnoPoly Legends game-based learning module effectively enhances secondary school students' achievement in algebra.

1. Pedagogical Value of Gamification in Algebra

Algebraic concepts such as variable manipulation, solving linear equations, and expanding algebraic expressions are traditionally perceived as abstract and intimidating by secondary school students. The integration of familiar, high-engagement game mechanics provided structural benefits:

- **Uno (Card Matching & Flow):** Promoted procedural fluency and speed through quick algebraic simplification rounds.
- **Monopoly (Strategic Progression):** Provided clear goals and active feedback loops through property acquisition mechanics tied to problem-solving.
- **Mobile Legends (Arena Mechanics & Peer Collaboration):** Tapped into contemporary youth digital culture, fostering peer interaction, friendly competition, and peer-assisted problem solving.

2. Practical Implications for Mathematics Education

- **Remediating Foundation Gaps:** The baseline pre-test average (35.43%) highlights widespread difficulties in foundational algebra among secondary students at SMK Rantau Panjang Bestari Jaya. The post-test mean of 55.62% and a baseline shift in the minimum score from 6 to 12 indicate that gamified learning helps struggling learners overcome entry-level barriers.
- **Effect Size Significance:** The exceptionally high Cohen's *d* value (3.05) demonstrates that gamified instructional interventions yield substantial practical gains compared to standard passive learning or drill-and-practice routines.
- **Sustained Engagement:** Game-based modules reduce math anxiety by reframing problem-solving tasks into interactive, low-stakes learning challenges.

The post-test results indicate clear improvements in students' algebra achievement after participating in UnoPoly Legends activities.

Students became more willing to:

- solve algebra problems,
- discuss mathematical ideas,
- collaborate with teammates,
- explain solution strategies.

The Mobile Legends-inspired cards created meaningful classroom interactions.

- Red Buff motivated students to attempt challenging questions.
- Blue Buff reduced frustration by providing learning support.
- Lane Cards diversified learning activities.
- Turtle Cards rewarded collaboration.
- Lord Cards challenged high-achieving students.

From Figure 2a, 90% agree the UnoPoly Legends: Algebra Edition increase interest the mathematics and Figure 2b the student answer the UnoPoly Legends: Algebra Edition made Algebra easier to learn, for

93.3% and 6.7% for neutral respond.

These findings agree with previous research by Lu and Zakaria (2014), Paglomutan (2024), Ramadoni and Adnan (2026), and Rosni et al. (2024), which concluded that educational games improve mathematical achievement, motivation, and classroom engagement.

One possible explanation for the improvement is that the game-based learning approach provided an interactive and engaging learning environment. By integrating algebraic concepts into gameplay, students were able to practise mathematical operations repeatedly while remaining motivated to complete challenges. This supports the view that educational games can increase students' engagement, promote active learning, and improve academic performance compared with conventional teacher-centred instruction.

Furthermore, the variation in individual improvements suggests that although all students benefited, the degree of improvement differed according to their initial knowledge and learning pace. Students with lower pre-test scores generally showed considerable gains, implying that the module may be particularly useful in strengthening foundational algebra skills. Higher-performing students also demonstrated improvement, indicating that the game provided sufficient challenge to reinforce existing knowledge.

Overall, the pre-test and post-test results demonstrate that the **UnoPoly Legends: Algebra Edition** game learning module has strong potential as an effective teaching aid for Form 2 algebra lessons at **SMK Rantau Panjang**. The findings support the conclusion that incorporating game-based learning into mathematics instruction can improve students' achievement, increase participation, and create a more enjoyable learning experience. Future studies could strengthen these findings by including a control group, conducting statistical analyses such as a paired-samples *t*-test, and examining the long-term retention of algebra concepts following the intervention.

4. CONCLUSION

UnoPoly Legends: Algebra Edition provides an innovative approach to algebra instruction by integrating familiar game mechanics with curriculum-based learning activities. Developed using the ADDIE instructional design model, the module successfully combines competition, collaboration, and strategic thinking to create an engaging mathematics learning environment.

The pretest-posttest findings demonstrate meaningful improvements in students' algebra achievement, with an average gain of approximately 57%. Beyond cognitive gains, the module enhanced motivation, teamwork, confidence, and classroom participation. These outcomes suggest that UnoPoly Legends is an effective and practical instructional resource for secondary mathematics education, particularly in rural schools such as SMK Rantau Panjang.

The implementation of the UnoPoly Legends module Algebra Edition led to statistically significant ($p < .001$) and practically meaningful ($d = 3.05$) improvements in secondary school students' algebra performance. The module serves as an effective supplementary learning tool for mathematics educators seeking to increase student engagement, concept retention, and problem-solving confidence in algebra.

Future studies should involve larger samples, comparison groups, and longer intervention periods to examine the module's long-term impact on algebraic reasoning and mathematical achievement.

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Development And Acceptability Of The Hypothesis Testing Mix-And-Match Board Game[©]

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Abstract

Hypothesis testing is often perceived as one of the most challenging topics in statistics, requiring students to understand multiple concepts and decision-making procedures. To address this issue, this study aimed to develop a game-based learning tool, namely the Hypothesis Testing Mix-and-Match Board Game[©], to improve players' understanding of hypothesis testing concepts and to evaluate students' acceptability of the developed game. A quantitative descriptive research design was employed involving 32 UiTM degree students. Students' perceptions of the board game were collected using a questionnaire consisting of four evaluation items. Descriptive statistics using bar charts were used to summarise the responses. The results indicate that it is well received as a game-based learning tool for hypothesis testing. It is recommended that the board game be integrated as a supplementary learning activity in statistics classes to enhance student engagement and learning experiences. Future research should use a pre-test and post-test design and involve a larger sample to further evaluate its effectiveness in improving learning outcomes.

Keywords: Game-Based Learning; Hypothesis Testing; Board Game

1. INTRODUCTION

Statistics is an essential discipline in many fields of study, providing the foundation for evidence-based decision-making and data analysis. Among its core topics, hypothesis testing is one of the most fundamental yet challenging concepts for students to master. Many students encounter difficulties in formulating statistical hypotheses, selecting appropriate statistical tests, interpreting p-values, and drawing correct conclusions from hypothesis testing (Garfield & Ben-Zvi, 2008; Ben-Zvi & Garfield, 2004). These challenges often result from the abstract nature of the topic and the reliance on traditional lecture-based teaching methods, which tend to emphasize computational procedures rather than conceptual understanding. Consequently, students may lose interest, experience low confidence, and struggle to apply hypothesis testing concepts effectively in real-world situations.

To address these challenges, innovative teaching approaches that actively engage students are increasingly needed. Game-based learning has emerged as an effective educational strategy that promotes active participation, collaboration, critical thinking, and meaningful learning experiences. A recent quasi-experimental study by Abu Hasan and Jamal (2026) found that undergraduate students who participated in game-based learning demonstrated significantly more positive attitudes toward statistics, particularly in

terms of affect, cognitive competence, perceived value, and difficulty, compared to those receiving traditional instruction. By integrating educational content into interactive gameplay, students become more motivated to learn while reinforcing their understanding through repeated practice and immediate feedback.

The Hypothesis Testing Mix-and-Match Board Game[®] was developed as an innovative educational tool to make learning hypothesis testing more interactive, enjoyable, and student-centred. A study done by Delgado-Gómez et al. (2020) demonstrated that those who used the gamified application based on a divide-and-conquer strategy that introduced hypothesis testing concepts sequentially achieved significantly higher test scores than students who received only traditional instruction. These findings suggest that game-based learning can effectively enhance students' understanding of hypothesis testing while increasing their engagement in the learning process. Thus, this innovation aims not only to develop a game-based learning tool to enhance players' understanding of hypothesis testing concepts but also to evaluate students' acceptance of the board game in terms of knowledge improvement, motivation, recommendation, and future suitability.

2. MATERIALS AND METHODS

The game was designed based on the hypothesis testing syllabus taught in the Statistics for Business and Social Sciences course at Universiti Teknologi MARA (UiTM) for degree students. It consists of a large game board illustrating the complete hypothesis testing framework and 34 removable answer cards containing statistical tests, hypotheses, formulas, degrees of freedom, decision rules, and other key concepts. Players are required to match each answer card to its correct position on the board, enabling them to visualise the overall hypothesis testing process. The game was developed for both individual and collaborative learning and incorporates elements of active learning and classroom competition.

2.1. Method for Evaluating the Game's Acceptability among Students

The game's acceptability was evaluated after participants had played it for around one hour. The evaluation involved 32 UiTM degree students and was conducted at the end of January 2026, after all hypothesis-testing lessons had been completed. An online questionnaire was designed and disseminated to the students after playing the game to capture their perceptions of the game, focusing on four evaluation items, which are its usefulness in improving their understanding of selecting the correct statistical test, the impact on motivation, likelihood of recommending it to others, and suitability for future use. A five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used to record responses. Descriptive statistics, particularly frequencies, were computed and displayed in bar charts to summarize students' perceptions of the board game.

3. RESULTS AND DISCUSSION

Of the 32 students involved in this study to assess their acceptability of the game, 12 or 37.5% were male, and the remaining 20 or 62.5% were female. Based on Figure 1, the students generally held positive perceptions of the Hypothesis Testing Mix-and-Match Board Game[®] across all four evaluation items.

In terms of understanding, 17 students (53.1%) strongly agreed, and 14 students (43.8%) agreed that the game helped them improve their understanding of how to choose the correct statistical test, while only 1 student (3.1%) remained neutral and no students disagreed or strongly disagreed. Regarding motivation, the majority of students reported that the game motivated them to learn statistics, with 19 students (59.4%) strongly agreeing and 12 students (37.5%) agreeing, while 1 student (3.1%) was neutral. Besides, all 32 students expressed positive recommendations for the game. Specifically, 20 students (62.5%) strongly

agreed, and 12 students (37.5%) agreed that they would recommend the game to other students, with no neutral, disagree, or strongly disagree responses recorded. Similarly, students showed strong support for the future use of the game in statistics classes, with 17 students (53.1%) strongly agreeing and 15 students (46.9%) agreeing that the game should be used in future statistics classes.

Overall, the findings demonstrate a high level of acceptability of the board game among students, with the majority of responses concentrated in the "Strongly Agree" and "Agree" categories across all four items, and negligible neutral responses. No students expressed disagreement or strong disagreement with any of the statements, suggesting that the board game was well received as an effective and engaging tool for learning hypothesis testing.

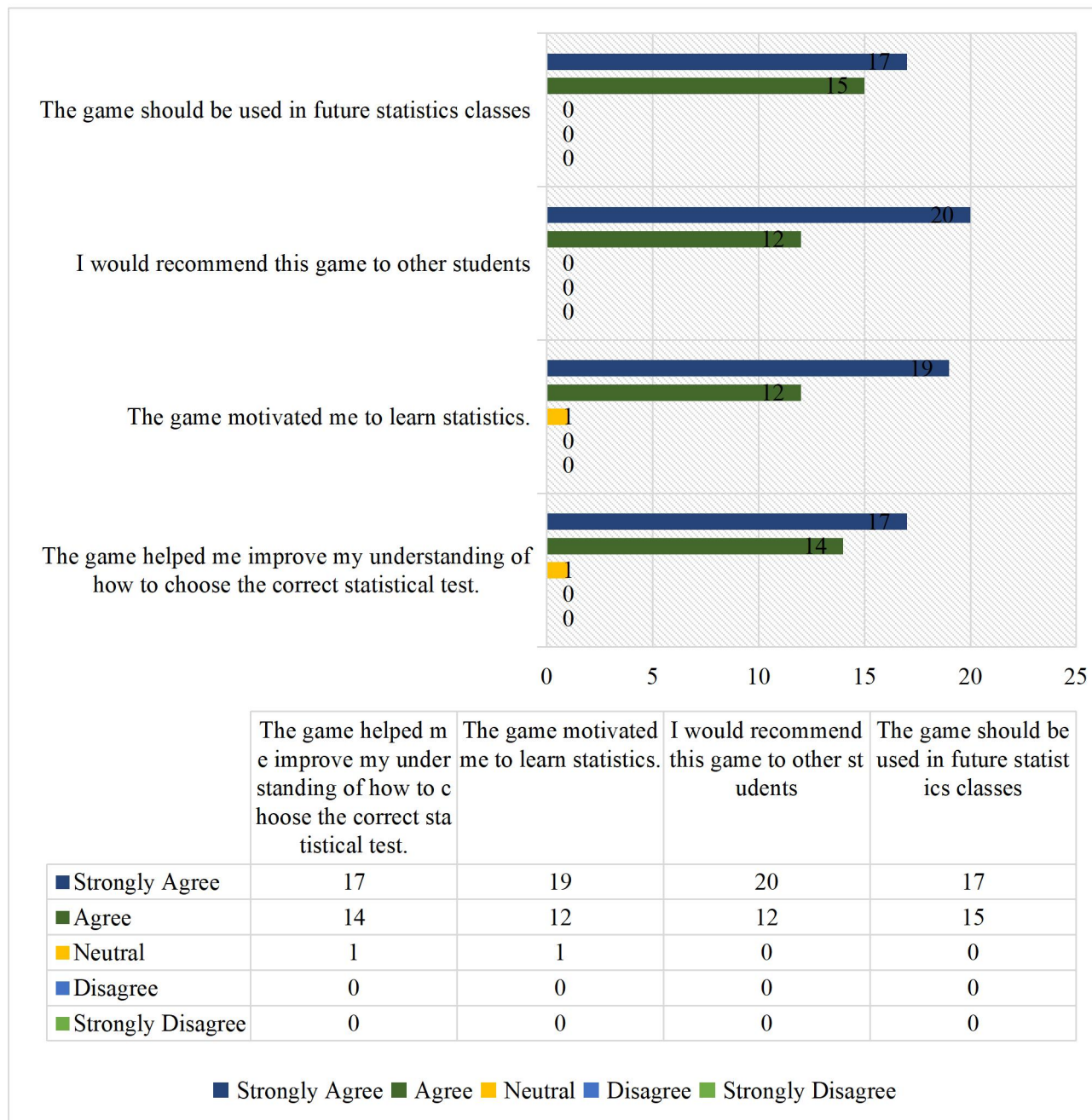


Figure 1. Distribution of Students' Responses on Game Acceptability

4. CONCLUSION

This study successfully developed the Hypothesis Testing Mix-and-Match Board Game[®] as a game-based learning tool to enhance students' understanding of hypothesis testing concepts. The findings indicate a high level of acceptability among UiTM degree students, suggesting that the game effectively improved their understanding, increased motivation to learn statistics, and encouraged positive attitudes towards its use in the classroom. Overall, the game achieved its intended objective and demonstrates its potential as an engaging and effective teaching aid for hypothesis testing. Therefore, the board game is recommended as a supplementary teaching aid in statistics classes to support student engagement and improve learning experiences. For future studies, it should be evaluated using a pre-test and post-test design with a larger and more diverse sample.

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TS-Learn : Time Series Interactive Learning Platform

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Abstract

The increasing demand for data-driven decision-making has highlighted the importance of Time Series Analysis and Forecasting (TSAF) in higher education. However, students often struggle to understand TSAF due to its abstract concepts, mathematical complexity, and limited opportunities for interactive learning through conventional teaching methods. This study presents TS-Learn (Time Series Interactive Learning Platform), a web-based educational platform designed to enhance the teaching and learning of TSAF through interactive learning, gamification, and cloud-based technology. Developed using HTML5, CSS3, JavaScript, and Supabase, TS-Learn integrates interactive quizzes, drag-and-drop activities, automated assessment, real-time score recording, digital certificates, and leaderboard functionality within a responsive learning environment. Unlike conventional Learning Management Systems, TS-Learn is specifically designed for Time Series Analysis and Forecasting by combining discipline-specific content with interactive pedagogy and learning analytics. The platform offers a scalable solution that enhances student engagement, strengthens conceptual understanding, supports evidence-based teaching, and provides a strong foundation for future integration of artificial intelligence and adaptive learning technologies in statistics education.

Keywords: Time Series Analysis, Forecasting, Interactive Learning, Gamification, Learning Analytics, Higher Education.

1. INTRODUCTION

The rapid advancement of digital technologies, artificial intelligence, and data-driven decision-making has significantly increased the importance of statistical forecasting across various sectors, including business, finance, healthcare, environmental management, manufacturing, transportation, and public policy (Nguyen et al., 2024; Wu & Shang, 2020). Despite its importance, Time Series Analysis and Forecasting is widely recognised as one of the more challenging subjects within statistics education. Students are expected to master numerous interconnected concepts, including trend, seasonality, cyclicity, stationarity, autocorrelation, exponential smoothing, Box–Jenkins methodology, autoregressive integrated moving average (ARIMA) modelling, model diagnostics, and forecasting evaluation. Unlike many statistical topics that can be explained using static examples, time series analysis requires students to understand dynamic relationships between observations over time, interpret graphical patterns, and make informed modelling decisions. These abstract concepts often create cognitive barriers, particularly among undergraduate students who are learning forecasting techniques for the first time (Roig et al., 2026).

The teaching of Time Series Analysis has traditionally relied on face-to-face lectures, presentation slides, whiteboard explanations, and statistical software demonstrations. Although these approaches remain valuable for delivering theoretical knowledge, they generally provide limited opportunities for students to

actively interact with forecasting concepts beyond classroom sessions. Learning frequently becomes instructor-centred, with students acting as passive recipients of information rather than active participants in the learning process. As a result, many students experience difficulties in connecting theoretical concepts with practical forecasting applications, leading to reduced engagement, lower confidence, and weaker conceptual understanding (Arjomandi et al., 2023).

Although several online learning platforms support mathematics and statistics education, very few are specifically designed to facilitate the teaching and learning of Time Series Analysis and Forecasting (Bousnguar et al., 2023; Chen et al., 2023). Existing platforms rarely integrate interactive forecasting activities, visual exploration of time series components, real-time learning analytics, and gamification within a single learning environment that aligns with university course learning outcomes. This gap highlights the need for a dedicated learning platform capable of transforming complex forecasting concepts into interactive learning experiences that improve conceptual understanding while maintaining student motivation throughout the learning process.

2. MATERIALS AND METHODS

The proposed innovation, TS-Learn (Time Series Interactive Learning Platform), is a web-based educational platform specifically designed to enhance the teaching and learning of Time Series Analysis and Forecasting (TSAF) in higher education. Unlike conventional Learning Management Systems (LMS) that primarily function as repositories for lecture materials, assignments, and assessments, TS-Learn was developed as an interactive learning ecosystem that integrates instructional content, formative assessment, visualisation, gamification, and cloud-based learning analytics into a single platform.

The development of TS-Learn is driven by the need to transform abstract statistical concepts into engaging and interactive learning experiences. The platform adopts an active learning approach where students are encouraged to explore concepts through continuous interaction rather than passive observation. Learning activities are designed to reinforce conceptual understanding by combining multiple instructional strategies, including interactive quizzes, drag-and-drop exercises, fill-in-the-blank activities, immediate formative feedback, progress tracking, and gamification elements. These features encourage students to participate actively while allowing them to evaluate their own understanding throughout the learning process.

The current prototype consists of five learning modules that correspond directly to the undergraduate syllabus for Time Series Analysis and Forecasting:

1. Introduction to Time Series
2. Univariate Deterministic Time Series Methods
3. Stationarity
4. Box-Jenkins Methodology
5. Linear Regression with Autoregressive Errors

Each module contains structured learning activities that progressively guide students from conceptual understanding to practical application. Rather than presenting static lecture notes, TS-Learn promotes interactive engagement through multimedia components and self-paced exercises that encourage students to apply theoretical knowledge immediately after learning.

One of the key innovations of TS-Learn is the integration of gamification principles within a statistics learning environment. Students receive immediate feedback after each activity, accumulate scores throughout the learning process, monitor their learning progress using visual progress indicators, compete through online leaderboards, and obtain digital certificates upon successful completion of the course.

activities. These motivational features aim to improve learning engagement, increase participation, and encourage continuous self-directed learning.

To support collaborative and data-driven learning, TS-Learn incorporates a cloud-based database using Supabase, enabling real-time storage of students' assessment results and learning progress. Unlike conventional classroom assessments that rely solely on manual grading, the platform automatically records students' performance, generates cumulative scores, and provides instructors with immediate access to learning outcomes. This capability establishes the foundation for future implementation of learning analytics, allowing instructors to identify students requiring additional support and evaluate learning effectiveness based on actual classroom data.

The platform has been developed using HTML5, CSS3, and JavaScript to ensure lightweight deployment, cross-platform compatibility, and ease of maintenance. The responsive interface enables students to access the platform through desktop computers, tablets, or smartphones without requiring software installation. Consequently, TS-Learn supports both face-to-face and blended learning environments while remaining suitable for independent learning outside the classroom.

The present prototype also serves as the foundation for future enhancements. Planned developments include interactive forecasting laboratories, dynamic visualisation of Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF), forecasting simulations, adaptive learning pathways, artificial intelligence-assisted tutoring, Progressive Web Application (PWA) capability, and advanced learning analytics dashboards for instructors. These planned enhancements position TS-Learn not only as an instructional platform but also as a scalable digital ecosystem for statistics education. Retrieved the application on the following link: [Time Series Analysis & Forecasting Interactive Course V3](#)

3. RESULTS AND DISCUSSION

3.1. Prototype Features

The current version of TS-Learn has been developed as a functional web-based prototype that integrates interactive learning, formative assessment, gamification, and cloud-based learning management into a single educational platform. The prototype focuses on improving students' understanding of Time Series Analysis and Forecasting while providing lecturers with an efficient mechanism to monitor students' learning progress.

The platform consists of five instructional modules that are aligned with the undergraduate Time Series Analysis and Forecasting syllabus as depicted in Figure 1. Each module incorporates interactive learning activities designed to reinforce theoretical concepts through active participation rather than passive content consumption.

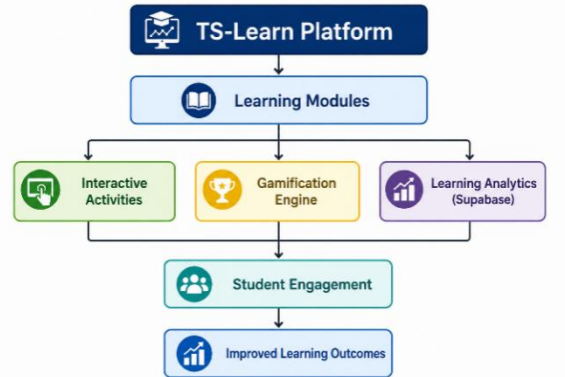


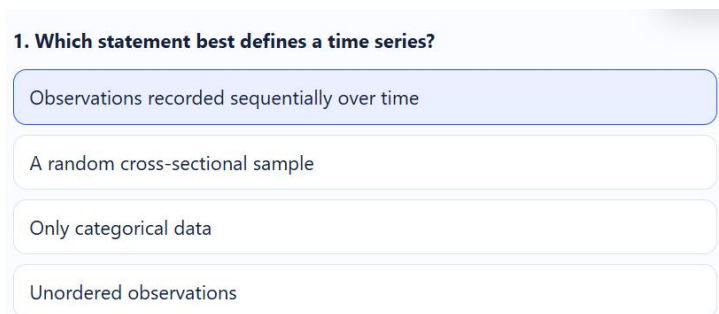
Figure 1. Major Features of TS-Learn

3.2 Interactive Learning Modules

The prototype currently contains five learning modules covering Introduction to Time Series, Univariate Deterministic Time Series Methods, Stationarity, Box–Jenkins Methodology and Linear Regression with Autoregressive Errors. Each module includes concise learning notes, interactive exercises, and formative assessments that enable students to evaluate their understanding immediately after completing each topic.

3.3 Interactive Assessment Activities

Instead of relying solely on conventional multiple-choice questions, TS-Learn incorporates various interactive learning activities, including multiple-choice quizzes, drag-and-drop exercises, fill-in-the-blank questions, matching activities and instant feedback after each response. These activities encourage students to actively engage with the learning materials while strengthening conceptual understanding through repeated practice.



1. Which statement best defines a time series?

- ☒ Observations recorded sequentially over time
- ☐ A random cross-sectional sample
- ☐ Only categorical data
- ☐ Unordered observations

Figure 2. Multiple choice

2. Match the components.

Seasonal
Trend
Irregular

Long-term upward or downward movement

Regular repeating pattern

Unpredictable random variation

Drop here

Drop here

Drop here

Figure 3. Drag and Drop Exercise

3. If Actual = 120 and Forecast = 110, the absolute error is ____.

Type your answer

Figure 4. Fill in the blank

3.4 Gamification Elements

To enhance learning motivation, TS-Learn integrates several gamification features throughout the learning process. These include automatic score calculation, progress indicators, countdown timer, online leaderboard, achievement tracking and digital certificate upon successful completion. The gamification approach encourages continuous participation while promoting healthy competition among students.

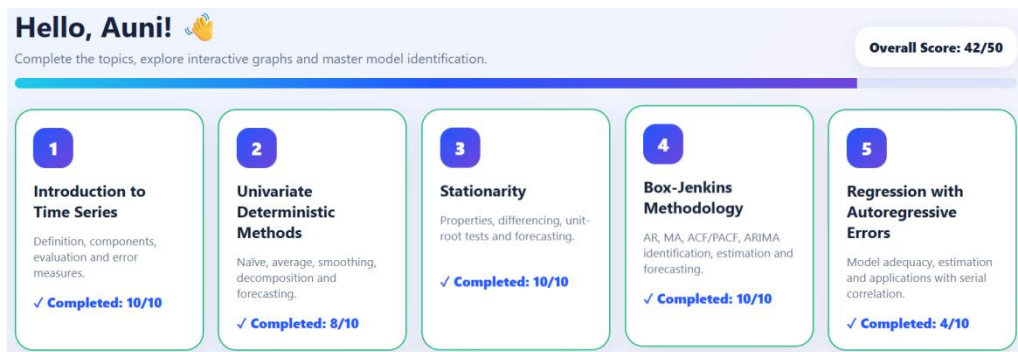


Figure 5. Scoreboard



Figure 6. Certificate of Achievement

Student learning records are stored securely using Supabase, allowing assessment results to be recorded automatically in real time as shown in Figure 5. The participant also can print the certificate of achievement after completing all learning activities as depicted in Figure 6. TS-Learn has been developed using HTML5, CSS3, and JavaScript to ensure compatibility across multiple devices. No software installation is required, allowing the platform to support face-to-face, blended, and online learning environments.

The novelty of TS-Learn lies in its integration of discipline-specific pedagogy, interactive educational technology, gamification, and cloud-based learning analytics into a single web-based learning ecosystem dedicated exclusively to Time Series Analysis and Forecasting. Unlike conventional Learning Management Systems (LMS), which primarily function as repositories for lecture notes, assignments, and examinations, TS-Learn has been specifically designed to facilitate conceptual understanding through interactive learning experiences. The platform does not merely digitise teaching materials; instead, it transforms abstract statistical concepts into engaging learning activities that promote active participation, immediate feedback, and continuous self-assessment.

4. CONCLUSION

TS-Learn is an innovative web-based learning platform developed to enhance the teaching and learning of Time Series Analysis and Forecasting through interactive learning, gamification, and cloud-based technology. The platform promotes active learning, immediate feedback, and continuous self-assessment, enabling students to better understand complex statistical concepts while supporting lecturers in monitoring learning progress. The prototype demonstrates the potential of combining educational technology with student-centred pedagogy to create a more engaging and effective learning experience. With its scalable architecture and future integration of artificial intelligence, adaptive learning, and learning analytics, TS-Learn has strong potential for institutional adoption, educational innovation, and commercialisation, contributing to the digital transformation of statistics education in higher education.

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Development of an UnoPoly Legends (Uno-Monopoly-Mobile Legends): Algebra Edition Game Learning Module Version 1

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Abstract

This study presents the development of the UnoPoly Legends (Uno-Monopoly-Mobile Legends): Algebra Edition Game Learning Module Version 1, an innovative educational tool designed to enhance students' understanding and mastery of algebraic concepts. The module integrates Monopoly gameplay, UNO card strategies, and Mobile Legends-inspired mechanics through three educational cards—including Red Buff, Blue Buff, and Lane. Each card is specifically designed to reinforce algebraic concepts while encouraging collaboration, critical thinking, and strategic decision-making in version Bahasa Melayu. Through this game-based approach, the module aims to provide an interactive, engaging, and effective algebra learning experience.

Keywords: Game-Based Learning, Algebra, Mathematics Education, Monopoly, UNO, Mobile Legends, Educational Games

1. INTRODUCTION

Algebra is an essential component of mathematics education because it develops students' abilities to reason logically, recognise relationships, represent mathematical situations symbolically, and solve problems systematically. Algebraic knowledge also provides a foundation for learning more advanced mathematical concepts in higher education. However, many students experience difficulties when learning algebra because of the abstract nature of variables, symbols, expressions, and equations. Difficulties in understanding algebraic procedures may affect students' confidence, participation, and ability to apply mathematical knowledge in problem-solving situations.

Despite its significance, algebra remains one of the most difficult topics for secondary school students. Many learners struggle to interpret variables, manipulate algebraic expressions, and solve equations due to abstract representations and insufficient conceptual understanding (Rosni et al., 2024). Traditional teacher-centered instruction frequently emphasizes repetitive exercises and procedural techniques rather than meaningful exploration, resulting in reduced motivation and mathematics anxiety (Paglomutan, 2024).

These challenges are particularly evident in rural schools, where opportunities to experience innovative teaching approaches may be limited. Consequently, educational researchers have increasingly advocated

the use of **Game-Based Learning (GBL)** as an alternative instructional strategy. GBL transforms learning into interactive experiences by integrating educational objectives with game mechanics such as competition, collaboration, rewards, and immediate feedback (Galang, 2025).

Monopoly-inspired educational games have demonstrated effectiveness across multiple disciplines. Yusuf et al. (2023) validated Monopoly-based science learning media that improved students' conceptual understanding and engagement. Similar positive findings were reported by Prayogo (2017), Ulfa and Rozalina (2019), and Lailiyah et al. (2021), confirming that Monopoly mechanics successfully promote active learning and student participation.

Building upon these findings, this study introduces **UnoPoly Legends: Algebra Edition**, a hybrid educational board game combining elements from UNO, Monopoly, and Mobile Legends. Unlike conventional Monopoly mathematics games, UnoPoly Legends incorporates specialized gameplay cards inspired by Mobile Legends.

The learning cards include:

- **Red Buff Card:** doubles rewards after correctly solving difficult algebra questions.
- **Blue Buff Card:** provides hints or reduces question difficulty.
- **Lane Card:** determines learning pathways corresponding to algebra topics.

The integration of these mechanics encourages collaborative learning, strategic decision making, critical thinking, and continuous student engagement while reinforcing algebraic concepts.

Therefore, this study aims to:

Develop UnoPoly Legends: Algebra Edition **module:** To design and implement an interactive game-based learning module focusing on algebra concepts.

Enhance mathematical engagement: To increase students' motivation and interest in learning algebra through gamification strategies.

Importance of Mathematics and Algebra

Mathematics develops reasoning, communication, and analytical thinking essential for lifelong learning (Ishak et al., 2025). Algebra extends these competencies by introducing symbolic reasoning and mathematical modelling that underpin advanced STEM education (Ramadoni & Adnan, 2026).

Challenges in Learning Algebra

Students frequently experience difficulties understanding abstract symbols and variables. Traditional lecture-based approaches often reduce learning motivation and fail to cultivate conceptual understanding (Paglomutan, 2024).

Monopoly-Based Educational Games

Previous studies have established Monopoly as an effective educational medium because it promotes active participation and collaborative learning. Monopoly Science (Yusuf et al., 2023), Monoergy (Prayogo, 2017). Monopoly Digestive System (Ulfa & Rozalina, 2019) and Monopoly Solar System

(Lailiyah et al., 2021). These studies consistently reported improvements in student engagement and learning outcomes.

Game-Based Learning

Game-Based Learning integrates educational content with enjoyable activities that increase attention, persistence, and confidence (Galang, 2025). Mathematical games reduce anxiety while promoting collaborative problem-solving and conceptual understanding (Rosni et al., 2024).

Research by Ogbu et al. (2023) and Ramadoni and Adnan (2026) demonstrated significant improvements in algebra achievement through game-based interventions.

Instructional Design Framework

The instructional design model was selected because it provides a systematic process for educational module development through:

- Design
- Development
- Implementation

2. MATERIALS AND METHODS

Research Design

This study employed a developmental research approach to develop the UnoPoly Legends (Uno–Monopoly–Mobile Legends): Algebra Edition Game-Based Learning Module Version 1. The study focused on designing and producing an educational game that integrates algebraic learning with elements of board games, card games, and strategic gameplay.

The development process was guided by five main stages: **(1) needs identification, (2) game design, (3) development of learning content**

Analysis

- Student needs
- Curriculum analysis
- Learning objectives

The target learners for this module were **Form 2 students in Malaysian secondary schools**. The module was designed to support students who are learning fundamental algebraic concepts at the lower-secondary level.

The learning activities, language, instructions, and mathematical questions were designed according to the students' expected level of mathematical knowledge. The module was developed in **Bahasa Melayu** to support accessibility and understanding among the intended learners.

Game Material

The main materials developed for UnoPoly Legends Version 1 consisted of:

- a game board;
- player tokens;
- game currency or reward points;
- algebra question cards;
- UNO-inspired action cards;
- Red Buff Cards;
- Blue Buff Cards;
- Lane Cards;
- answer/reference cards; and
- game rules and instructions.

The game board was designed using a Monopoly-inspired movement and reward structure. UNO-inspired cards were incorporated to introduce additional actions and changes in gameplay. Mobile Legends-inspired elements were represented through the Red Buff, Blue Buff, and Lane Cards.

Educational Cards

Three specialised educational cards were developed for the module.

1. Red Buff Card

The **Red Buff Card** functions as a reward mechanism. When a student correctly solves a difficult algebra question, the reward obtained from the question can be doubled.

The purpose of this card is to encourage students to attempt more challenging questions and to connect successful mathematical problem-solving with positive game-based rewards.

2. Blue Buff Card

The **Blue Buff Card** provides learning support when a student experiences difficulty with an algebra question. The card can provide a hint or allow the student to receive a question with a lower level of difficulty.

This card functions as a form of scaffolding. Instead of immediately giving students the answer, the hint is intended to guide them towards an appropriate mathematical procedure.

3. Lane Card

The **Lane Card** determines the student's learning pathway within the game. Different lanes can be associated with different algebra topics or levels of difficulty.

The card provides structure to the learning process while maintaining the Mobile Legends-inspired theme of the game.

Game Development Procedure

The development of the module was conducted through the following procedures.

Step 1: Identification of Learning Objectives

The relevant Form 2 algebra learning objectives were identified. The objectives were used as a basis for determining the mathematical content, question types, and expected learning outcomes of the module.

Step 2: Design of Game Mechanics

The game mechanics were designed by integrating selected features of Monopoly, UNO, and Mobile Legends. Monopoly-inspired elements were used for board movement and rewards, UNO-inspired elements were used for card actions, and Mobile Legends-inspired elements were used for buffs and learning pathways.

Step 3: Development of Algebra Questions

Algebra questions suitable for Form 2 students were developed and categorised according to difficulty. The questions were designed to assess students' understanding and application of the selected algebraic concepts.

Step 4: Development of Educational Cards

The Red Buff, Blue Buff, and Lane Cards were designed according to their respective learning functions. Each card was reviewed to ensure that its gameplay function was connected to an educational purpose.

3. RESULTS AND DISCUSSION

3.1 Development of UnoPoly Legends Version 1

The development process resulted in **UnoPoly Legends (Uno–Monopoly–Mobile Legends): Algebra Edition Game-Based Learning Module Version 1**, an educational board game designed to integrate algebra learning with interactive gameplay. The developed module combines board movement, card-based actions, mathematical challenges, rewards, and strategic decision-making.

The three game concepts contribute different elements to the module. Monopoly provides the basic board-game structure and progression system, UNO contributes the use of action cards and changing game situations, while Mobile Legends contributes the concepts of buffs, lanes, and strategic decision-making. These elements were adapted to create an educational game environment centred on algebra.

The resulting design places algebraic problem-solving within the main gameplay rather than treating mathematical questions as an additional activity. Players encounter algebra questions as they progress through the game, and their mathematical performance can influence their rewards and game decisions.

3.2 Development of the Educational Cards

Three specialised educational cards were developed as the main learning components of Version 1: **Red Buff Card, Blue Buff Card, and Lane Card**. Each card has a different function and contributes to the learning process.

3.2.1 Red Buff Card

The **Red Buff Card** functions as a reward-based learning mechanism. When a player correctly solves a difficult algebra question, the card allows the player to receive double the designated reward.

The card is designed to encourage students to attempt challenging questions. Instead of avoiding difficult algebra problems, students are provided with an additional incentive to apply their mathematical knowledge. The mechanism also introduces strategic decision-making because players need to determine when using the Red Buff Card may provide the greatest benefit.

From a learning perspective, the Red Buff Card creates a direct relationship between mathematical performance and game progression. However, the reward must be appropriately balanced so that students remain focused on solving the algebra problem rather than concentrating exclusively on winning the game.

3.2.2 Blue Buff Card

The **Blue Buff Card** functions as a learning-support mechanism. The card can provide a hint or reduce the difficulty of an algebra question when a student experiences difficulty.

This feature is important because learners may have different levels of prior knowledge and mathematical ability. Providing a structured form of assistance allows students to remain involved in the learning activity instead of becoming frustrated or disengaged.

The Blue Buff Card can also support scaffolding. For example, rather than providing the complete answer, a hint can remind students of an appropriate algebraic operation or mathematical procedure. This encourages students to continue reasoning and attempt to solve the problem independently.

3.2.3 Lane Card

The **Lane Card** functions as a learning-pathway mechanism. It determines or directs players towards particular algebra topics within the game.

This card allows the algebra content to be organised into different learning pathways. For example, different lanes may be associated with algebraic expressions, substitution, equations, simplification, or factorisation. This organisation can help create a structured progression through the learning content.

The Lane Card also reflects the Mobile Legends-inspired design of UnoPoly Legends while maintaining a clear educational purpose. Its function is not simply decorative; it connects the game pathway with the mathematical learning objectives.

3.3 Integration of Algebraic Learning into Gameplay

One of the main results of the development is the integration of algebraic questions into the core gameplay.

Students encounter mathematical challenges while progressing through the board and using game cards.

This design can provide repeated opportunities for students to practise algebraic procedures. Instead of completing a conventional worksheet, students interact with mathematical questions within a competitive and strategic environment. The game structure may therefore encourage active participation and provide a different context for practising algebra.

The difficulty of the questions can also be differentiated. Basic questions can be used to reinforce fundamental skills, while more challenging questions can be linked to the Red Buff Card. The Blue Buff Card can subsequently provide support for students who require additional assistance.

4. CONCLUSION

UnoPoly Legends: Algebra Edition provides an innovative approach to algebra instruction by integrating familiar game mechanics with curriculum-based learning activities. Developed using the ADDIE instructional design model, the module successfully combines competition, collaboration, and strategic thinking to create an engaging mathematics learning environment.

The pretest-posttest findings demonstrate meaningful improvements in students' algebra achievement, with an average gain of approximately 57%. Beyond cognitive gains, the module enhanced motivation, teamwork, confidence, and classroom participation. These outcomes suggest that UnoPoly Legends is an effective and practical instructional resource for secondary mathematics education, particularly in rural schools such as SMK Rantau Panjang.

Future studies should involve larger samples, comparison groups, and longer intervention periods to examine the module's long-term impact on algebraic reasoning and mathematical achievement.

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VISU-MAP+: U-SUB SMART WHEEL- From Guesswork to Systematic Decision-Making in Integration by Substitution

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Abstract

VISU-MAP+: U-SUB SMART WHEEL – From Guesswork to Systematic Decision-Making in Integration by Substitution is an educational innovation developed to support undergraduate students' conceptual understanding and mathematical decision-making in solving integration by substitution problems. Many students experience difficulties in selecting appropriate substitution functions and frequently rely on trial-and-error strategies or memorization, leading to misconceptions, procedural errors, and low confidence in calculus learning. To address this challenge, VISU-MAP+ integrates a structured visual mapping framework with the U-SUB SMART WHEEL, an interactive decision-support teaching tool designed to guide students through a systematic reasoning process. The innovation is founded on three pedagogical principles: inner function recognition, derivative matching, and function hierarchy prioritization, enabling students to identify appropriate substitution functions through structured visual cues rather than guesswork. Unlike conventional instructional approaches that emphasize procedural fluency, VISU-MAP+ promotes conceptual understanding, active learning, and systematic mathematical reasoning while reducing cognitive load. The innovation supports lecturers in delivering interactive calculus instruction and enhances students' engagement, confidence, and problem-solving skills. VISU-MAP+ demonstrates strong potential for commercialization as a classroom teaching kit, instructional module, digital learning application, and STEM educational resource for higher education institutions, contributing to innovative teaching practices in mathematics education.

Keywords: Visual learning, integration by substitution, U-SUB SMART WHEEL, mathematical decision-making.

1. INTRODUCTION

Calculus is a fundamental subject in higher education and plays an important role in science, technology, engineering, and mathematics (STEM) programmes (Kramer et al., 2023). One of the challenging topics in calculus is Integration by Substitution, which requires students to identify an appropriate substitution function before solving an integral. This process demands not only procedural knowledge but also conceptual understanding and mathematical reasoning.

However, many undergraduate students experience difficulties in selecting an appropriate substitution function and often rely on trial-and-error strategies or memorisation without fully understanding the underlying concepts (Fonbuena, 2022). As a result, students may make procedural errors, experience confusion when solving unfamiliar problems, and demonstrate low confidence in applying the substitution method. These challenges indicate the need for a more structured and interactive learning approach that

supports students' decision-making during problem-solving. Visual instructional approaches can help direct learners' cognitive processing when appropriately designed (Castro-Alonso et al., 2019).

To address this issue, VISU-MAP+: U-SUB SMART WHEEL – From Guesswork to Systematic Decision-Making in Integration by Substitution was developed as a Visual Decision-Support Learning System. The innovation integrates a visual pedagogical framework (VISU-MAP+) with an interactive manipulative tool (U-SUB SMART WHEEL) to guide students in identifying inner functions, matching derivatives, and selecting appropriate substitution functions through a systematic decision-making process.

The innovation incorporates principles of visual learning, active engagement, and structured mathematical reasoning to support students' decision-making during problem-solving. By transforming guesswork into systematic mathematical reasoning, VISU-MAP+ aims to support students' conceptual understanding, confidence, and problem-solving skills in Integration by Substitution while providing lecturers with a more interactive approach to calculus instruction.

2. MATERIALS AND METHODS

2.1. Innovation Development (Product Development Process)

The development of VISU-MAP+: U-SUB SMART WHEEL – From Guesswork to Systematic Decision-Making in Integration by Substitution followed a systematic educational design and development process. Design and Development Research emphasises the systematic design, development, and evaluation of instructional products based on identified educational needs (Richey et al., 2004; McKenney & Reeves, 2021).

The process began with a needs analysis involving classroom observations, students' assessment analyses, and discussions with mathematics lecturers. The analysis identified students' difficulties in selecting appropriate substitution functions and applying the substitution process. Previous research on u-substitution has also highlighted the importance of understanding the relationships among composite functions, their derivatives, and the choice of substitution rather than relying solely on procedural manipulation (Fonbuena, 2022).

Based on these needs, a literature review on calculus learning, visual learning, mathematical reasoning, and instructional design was conducted to inform the conceptualisation of the innovation. The product was designed around three core principles: Inner Function Recognition, Derivative Matching, and Function Hierarchy Prioritisation. These principles were translated into a visual decision-making sequence that guides students in analysing the integrand before selecting u .

The prototype was then developed as an integrated learning ecosystem comprising the VISU-MAP+ Framework, Function Hierarchy Guide, U-SUB SMART WHEEL, Decision Mapping Card, Practice and Activity Card, and QR Digital Learning Resources. The prototype was refined through expert review to improve content clarity, visual presentation, usability, and alignment with the intended learning objectives. This iterative process is consistent with educational design research, which emphasises the development and refinement of practical solutions based on identified learning needs (McKenney & Reeves, 2021). The overall development process is presented in **Figure 1**.

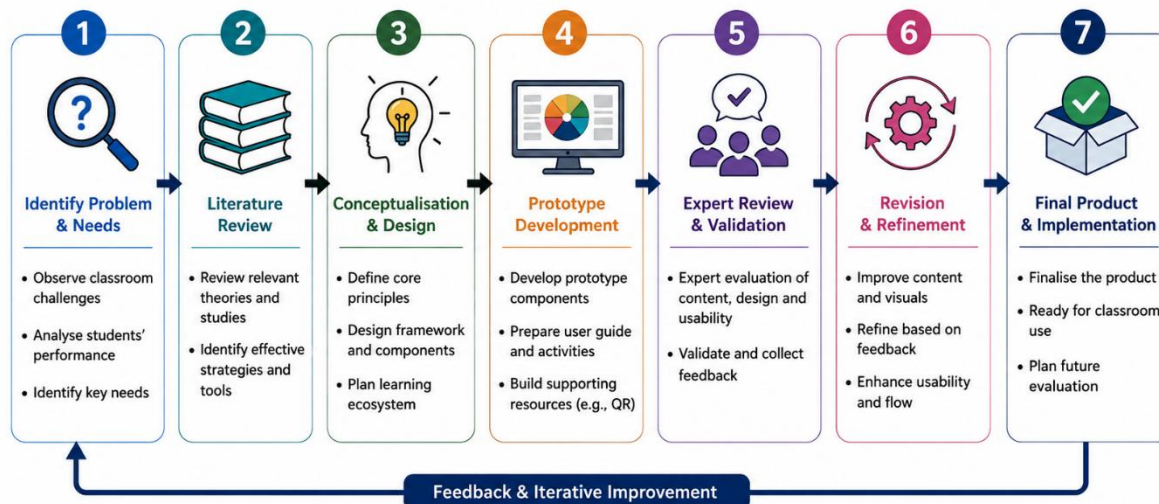


Figure 1. Innovation Development Process of VISU-MAP+: U-SUB SMART

2.2. Description of the Innovation (VISU-MAP+ Learning Ecosystem)

VISU-MAP+: U-SUB SMART WHEEL is a Visual Decision-Support Learning Ecosystem developed to support undergraduate students in learning Integration by Substitution. The innovation integrates a pedagogical framework, an interactive manipulative tool, structured learning materials, and digital resources to guide students in making systematic decisions when selecting the substitution function u .

The ecosystem comprises six complementary components: (i) VISU-MAP+ Framework, (ii) Function Hierarchy Guide, (iii) U-SUB SMART WHEEL, (iv) Decision Mapping Card, (v) Practice and Activity Card, and (vi) QR Digital Learning Resources. The VISU-MAP+ Framework provides the pedagogical structure based on Inner Function Recognition, Derivative Matching, and Function Hierarchy Prioritisation. The U-SUB SMART WHEEL serves as the central interactive tool, while the remaining components provide guidance, structured practice, and opportunities for self-directed learning.

The Function Hierarchy Guide assists students in prioritising possible substitution functions, while the Decision Mapping Card provides a concise sequence for applying the selected substitution. The Practice and Activity Card supports guided and independent practice, and the QR Digital Learning Resources extend learning beyond the classroom through tutorials, worked examples, quizzes, and supplementary exercises. Collectively, these components provide a structured and interactive learning experience for Integration by Substitution. The components and their respective functions are summarised in **Table 1.**, while the application of the complete learning ecosystem is presented and discussed in Section 3.2.

Table 1. Components of the VISU-MAP+ Learning Ecosystem

Component	Main Function	Role in Learning
VISU-MAP+ Framework	Provides the overall visual decision pathway.	Guides systematic analysis of the integrand.
Function Hierarchy Guide	Organises potential substitution functions according to the innovation's priority structure.	Supports consistent selection of u .
U-SUB SMART WHEEL	Provides interactive prompts for selecting u .	Encourages active and systematic decision-making.
Decision Mapping Card	Presents the substitution process step-by-step.	Supports guided problem-solving.
Practice and Activity Card	Provides structured practice from basic to more complex problems.	Reinforces conceptual and procedural understanding.
QR Digital Learning Resources	Provides tutorials, worked examples, quizzes, and additional practice.	Supports self-directed and blended learning.

3. RESULTS AND DISCUSSION

3.1. Novelty and Educational Significance

The novelty of VISU-MAP+: U-SUB SMART WHEEL lies in the integration of a visual decision-support framework with an interactive manipulative tool for learning Integration by Substitution. The innovation combines Inner Function Recognition, Derivative Matching, and Function Hierarchy Prioritisation to guide students in selecting an appropriate substitution function. Unlike conventional approaches that often emphasise procedural steps, VISU-MAP+ makes the decision-making process more visible, structured, and interactive.

The educational significance of the innovation lies in its potential to shift students from guesswork and memorisation towards systematic mathematical reasoning (Senneset et al., 2026). The combination of visual guidance, interactive manipulation, decision mapping, and guided practice provides a more structured learning experience while encouraging active engagement. The innovation also offers lecturers a flexible teaching aid that can be used in individual, group, face-to-face, blended, and self-directed learning environments.

3.2. Application, Educational Benefits and Potential Impact

The VISU-MAP+ Learning Ecosystem guides students through a structured decision-making process when solving Integration by Substitution problems. Students begin by analysing the integrand using the VISU-MAP+ Framework to identify the inner function and examine its derivative. The Function Hierarchy Guide is then used to prioritise possible substitution functions, followed by the U-SUB SMART WHEEL to support the selection of u . The Decision Mapping Card guides students through the substitution and integration process, while the Practice and Activity Card provides opportunities for reinforcement. QR-based digital resources further support self-directed learning through tutorials, worked examples, quizzes, and additional exercises. The overall learning ecosystem is illustrated in **Figure 2**.

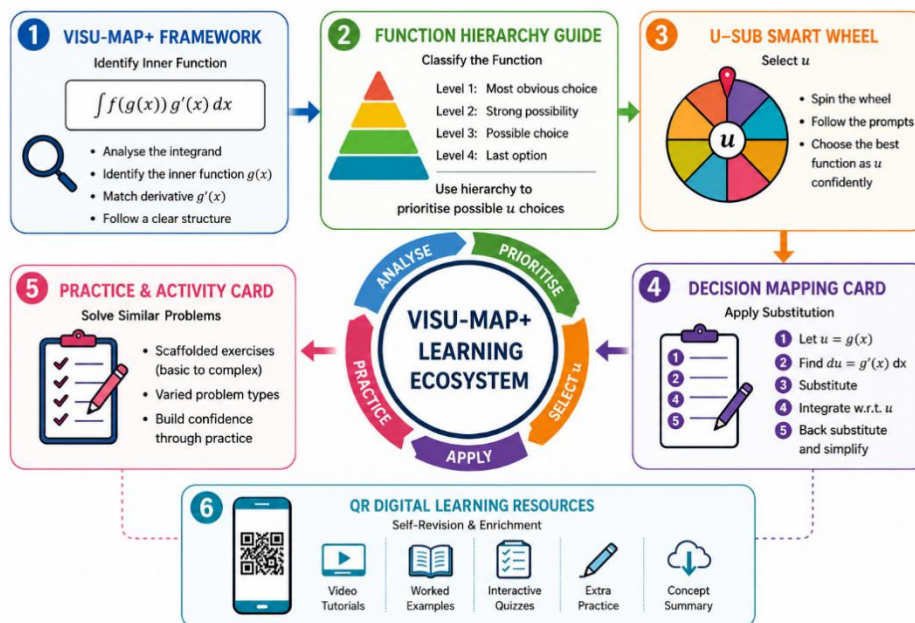


Figure 2. VISU-MAP+ Learning Ecosystem for Integration by Substitution

For example, students may be given the following integration problem:

$$\int (x^2 + 1)^5 (2x) dx$$

The problem can be approached using the VISU-MAP+ decision pathway shown in **Table 2**. Students first identify x^2+1 as the inner function and verify that its derivative, $2x$, is present in the integrand. The Function Hierarchy Guide then supports the prioritisation of the function, while the U-SUB SMART WHEEL assists students in selecting $u=x^2+1$. The Decision Mapping Card subsequently guides students to determine $du=2xdx$, substitute the expression, and solve the transformed integral.

Table 3. Example of Product Application Using VISU-MAP+

Step	VISU-MAP+ Component	Student Action	Decision
1. Analyse	VISU-MAP+ Framework	Identify the inner function.	(x^2+1)
2. Match	VISU-MAP+ Framework	Check whether its derivative is present.	$(2x)$ ✓
3. Prioritise	Function Hierarchy Guide	Identify the function category.	Polynomial
4. Select (u)	U-SUB SMART WHEEL	Select the appropriate substitution.	$(u=x^2+1)$
5. Apply	Decision Mapping Card	Determine (du) and substitute.	$(du=2x,dx)$
6. Practise	Practice & Activity Card	Solve the transformed integral.	$u^6/6+C$
7. Reinforce	QR Digital Resources	Review tutorials or complete quizzes.	Self-directed practice

The substitution process results in:

$$u = x^2 + 1, \quad du = 2x dx$$

$$\int (x^2 + 1)^5 (2x) dx = \int u^5 du = \frac{u^6}{6} + C = \frac{(x^2 + 1)^6}{6} + C.$$

The example demonstrates how VISU-MAP+ transforms the selection of u from a trial-and-error activity into a structured decision-making process. By identifying the inner function, matching its derivative, and prioritising the appropriate function before substitution, students are provided with a clear and repeatable pathway for solving similar problems.

The integrated ecosystem is designed to support conceptual understanding, systematic reasoning, active engagement, and independent practice. Active learning approaches have also shown potential to support student learning in undergraduate calculus (Kramer et al., 2023; Watson et al., 2025). For lecturers, it provides a reusable teaching resource that can be adapted for individual, collaborative, face-to-face, and blended learning. While the present innovation focuses on product development, its design provides a foundation for future empirical evaluation involving expert validation, usability, student perceptions, conceptual understanding, and learning performance.

3.3. Commercialisation Potential

The modular structure of VISU-MAP+: U-SUB SMART WHEEL provides opportunities for further development and commercialisation as an educational teaching and learning product. The innovation can be packaged as a physical teaching kit comprising the U-SUB SMART WHEEL, VISU-MAP+ Framework, Function Hierarchy Guide, Decision Mapping Card, and Practice and Activity Cards. The QR-based resources can be further developed into digital tutorials, interactive quizzes, worked examples, and supplementary learning materials.

Potential users include universities, colleges, mathematics lecturers, tutoring centres, and undergraduate calculus students. Future commercialisation may include institutional teaching packages, student learning kits, digital learning applications, and licensing models. The modular design also allows the framework to be adapted to other calculus topics and mathematical problem-solving contexts, providing opportunities for wider application within higher education.

4. CONCLUSION

VISU-MAP+: U-SUB SMART WHEEL was developed as a visual decision-support learning ecosystem to address undergraduate students' difficulties in selecting appropriate substitution functions in Integration by Substitution. By integrating the VISU-MAP+ Framework, Function Hierarchy Guide, U-SUB SMART WHEEL, Decision Mapping Card, Practice and Activity Card, and QR Digital Learning Resources, the innovation provides a structured pathway that shifts substitution selection from guesswork towards systematic mathematical decision-making. Its visual and interactive approach offers a practical alternative to conventional procedure-oriented instruction by supporting conceptual understanding, active engagement, and structured problem-solving.

The modular design enables the innovation to be applied in face-to-face, collaborative, blended, and self-directed learning environments. Although further empirical evaluation is required to establish its effectiveness, VISU-MAP+ demonstrates strong potential as an innovative calculus teaching resource and a scalable educational product for higher education. Future development will focus on expert validation, classroom implementation, and digital expansion to further evaluate its educational impact and commercialisation potential.

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SECTION 7

MECHANICAL ENGINEERING



Engineering possibilities through design and innovation.

Tribological Properties Of Materials Developed From Recycle Textile Waste

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Abstract

The increasing generation of textile waste has become a major environmental concern, creating an urgent need for sustainable recycling strategies that support circular economy principles. This study investigates recycled cotton textile waste composites for sustainable engineering applications by evaluating the effects of matrix systems and fibre loading on their physical and tribological properties. Composite panels were fabricated by compression moulding at 180 °C under 200 psi for 30 min using recycled cotton fibres with polypropylene (PP) or bio-based binders (sucrose and rice flour at a fixed 70:30 ratio). Polypropylene composites with PP-to-cotton weight ratios of 75:25, 60:40, and 50:50 were also produced to examine the influence of fibre loading on density, hardness, and abrasive wear behaviour. Among the bio-based binders, sucrose-bonded composites exhibited the highest density of 1.081 g/cm³ and hardness of 41.8 Shore A, indicating superior structural compactness. The composite containing 75 wt.% PP demonstrated the best overall performance, exhibiting the highest density of 1.134 g/cm³, the highest hardness of 77.4 Shore A, and the lowest specific wear rate of 0.011 mm³/N·m. These findings demonstrate that recycled cotton textile waste can be transformed into sustainable composite materials suitable for lightweight insulation and durable engineering applications while promoting textile waste recycling and supporting circular economy principles.

Keywords: recycled cotton textile waste, polypropylene, bio-based binder, density; tribological properties.

1. INTRODUCTION

The rapid growth of global textile production has significantly increased the amount of textile waste generated worldwide, creating serious environmental and waste management challenges. Large quantities of discarded textiles are commonly disposed of through landfilling and incineration, resulting in greenhouse gas emissions, soil contamination, microplastic pollution and inefficient utilisation of valuable resources (Niinimäki, 2020). As the demand for sustainable manufacturing continues to increase, converting textile waste into value-added engineering materials has become an attractive approach for promoting resource efficiency and supporting circular economy practices (Gözet & Wilts, 2022).

Among various textile wastes, recycled cotton fibres have attracted considerable attention because of their low density, renewability, biodegradability and widespread availability. Cotton fibres possess excellent cellulose content, making them suitable as reinforcement materials in polymer composites for construction, automotive and consumer product applications (Arumugam, 2022). Previous studies have demonstrated that recycled cotton fibres can improve the mechanical behaviour of composite materials while simultaneously reducing environmental impacts associated with virgin raw materials (Gedif & Atalie, 2022). However, the performance of recycled textile composites depends strongly on

the compatibility between the reinforcement fibres and the matrix material, as well as the quality of fibre-matrix interfacial bonding.

Polypropylene (PP) has been widely adopted as a thermoplastic matrix because of its low density, excellent processability, moisture resistance and relatively high mechanical strength (Kumar, 2024). Nevertheless, the increasing demand for environmentally friendly composite systems has encouraged researchers to investigate renewable alternatives to petroleum-based binders. Bio-based materials such as sucrose and rice flour have recently emerged as promising matrix candidates owing to their biodegradability, renewability and natural adhesive characteristics. These materials have demonstrated the capability to improve particle cohesion and structural integrity in composite systems while reducing dependence on synthetic polymers (Feng, 2026).

Besides achieving satisfactory mechanical properties, engineering composites intended for practical applications must also possess adequate tribological performance. Components operating under continuous sliding or abrasive conditions require high wear resistance to ensure long-term durability and service life. Although several studies have separately investigated either bio-based binders or polypropylene-reinforced recycled textile composites, comprehensive evaluations integrating physical properties with tribological performance remain limited (Guo et al., 2023). Furthermore, systematic comparisons between different matrix systems and varying fibre loading have rarely been reported. Therefore, this study aims to develop sustainable recycled cotton textile waste composites using polypropylene together with selected bio-based binders and to evaluate their suitability for engineering applications. The investigation focuses on the effects of matrix type and fibre loading on density, hardness and abrasive wear behaviour. The outcomes of this work provide useful guidelines for developing environmentally friendly composite materials suitable for lightweight insulation panels and other non-structural engineering applications while simultaneously supporting textile waste valorisation and circular economy initiatives.

2. MATERIALS AND METHODS

Recycled cotton textile waste obtained from discarded 100% cotton garments was used as the reinforcing material throughout this study. The collected textile waste was thoroughly cleaned to remove dust, dirt and other contaminants before being oven-dried at approximately 80 °C for 24 h to minimise moisture content and improve fibre-matrix adhesion during composite fabrication. The dried textile waste was subsequently shredded and mechanically crushed into short fibres to obtain a more homogeneous reinforcement suitable for composite processing.

Three matrix materials were investigated, namely polypropylene (PP), sucrose and rice flour. Polypropylene was selected because of its excellent processability, low density and favourable mechanical properties, whereas sucrose and rice flour were selected as renewable bio-based binders with the potential to enhance the sustainability of recycled textile composites.

2.1. Composite Fabrication

Composite panels were produced using the compression moulding technique. The prepared cotton fibres were manually mixed with the selected matrix materials to ensure uniform distribution before being transferred into a steel mould lined with baking paper to prevent adhesion during hot pressing.

Two composite systems were fabricated. The first system evaluated the influence of matrix type using a constant matrix-to-fibre ratio of 70:30 (wt.%), where polypropylene, sucrose and rice flour were separately employed as the matrix material. The second system investigated the influence of polypropylene content by preparing composites with 75:25, 60:40 and 50:50 polypropylene-to-cotton weight ratios. These formulations enabled comparison of both different binder systems and different fibre loadings on composite performance.

All composite panels were consolidated using a hot press operated at 180 °C under a pressure of 200 psi for 30 min. After moulding, the composites were cooled to room temperature before removal from the mould and visually inspected to ensure the absence of major defects such as voids, cracks and incomplete consolidation.

2.2. Characterisation

Bulk density was determined according to ASTM D792 using the liquid displacement technique with corn oil as the immersion medium. The density values were calculated from the measured specimen weights in air and in the immersion liquid to evaluate the compactness and internal structure of the fabricated composites. Surface hardness was measured in accordance with ASTM D2240 using a Shore A durometer. Multiple indentation points were recorded across each specimen to minimise local variations and obtain representative average hardness values for each composite formulation.

The tribological behaviour of polypropylene–cotton composites was assessed using an abrasion tester in accordance with ASTM D3389. Circular specimens were subjected to abrasive wear under a constant normal load and sliding distance. The wear performance was evaluated by measuring the specimen mass before and after testing, from which the mass loss, wear volume and specific wear rate were calculated.

3. RESULTS AND DISCUSSION

3.1. Physical properties

Table 1 compares the density and hardness of recycled cotton textile waste composites produced using different binder systems and polypropylene-to-cotton formulations. Among the binder systems, the sucrose-based composite exhibited the highest density of 1.081 g/cm³ and hardness of 41.8 Shore A, indicating improved interfacial bonding and structural compactness, whereas the PP- and rice flour-based composites produced comparatively lower values.

Table 1.Physical Properties of Composite with Different Binder Systems and Polypropylene Loadings

Category	Composite Formulation	Density (g/cm ³)	Hardness (Shore A)
Binder comparison (70:30)	PP: Cotton	0.913	28.4
	Sucrose - Cotton	1.081	41.8
	Rice Flour - Cotton	0.911	27.6
PP Loading	PP75: Cotton25	1.134	77.4
	PP60: Cotton40	1.017	72.6
	PP50: Cotton50	0.969	63.8

The superior performance of the sucrose composite can be attributed to the formation of a rigid glass-like structure during hot pressing, which enhanced fibre–matrix interfacial bonding and reduced internal void formation. Consequently, the improved particle cohesion increased the structural compactness of the composite, resulting in greater resistance to localised surface indentation and higher hardness. Similar behaviour has previously been reported for bio-based binders, where sucrose

promotes stronger molecular interactions and improves consolidation during thermal processing (Lee, 2022).

In contrast, polypropylene and rice flour matrices produced composites with relatively lower density and hardness. The ductile nature of polypropylene resulted in a more flexible composite structure, whereas the gelatinised rice flour possessed lower stiffness than the sucrose binder. Nevertheless, the relatively small standard deviations reported for all specimens indicate that the compression moulding process successfully produced homogeneous composite panels with good repeatability and consistent material distribution (Rocha, 2022).

The influence of fibre loading shows a progressive reduction in both density and hardness as the cotton fibre content increased. The 75:25 composite exhibited the highest density of 1.1345 g/cm³ and hardness of 77.4 Shore A, while the 50:50 composite recorded the lowest density of 0.9695 g/cm³ and hardness of 63.8 Shore A.

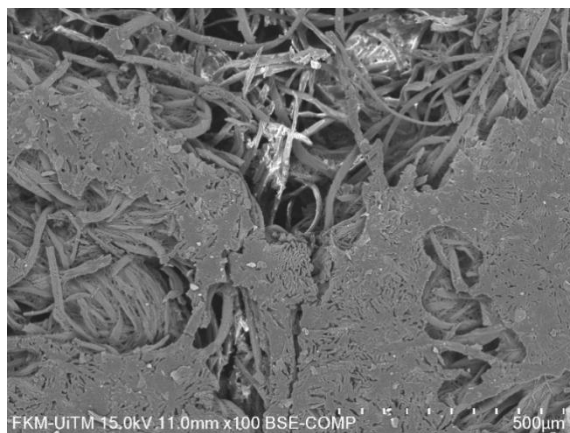


Figure 1. SEM Image of PP50: Cotton 50 Composite

The reduction in physical properties can be explained by the increasing proportion of cotton fibres, which limited the ability of molten polypropylene to completely wet and impregnate the fibrous network during compression moulding. The irregular morphology and fluffy nature of recycled cotton fibres promoted the formation of voids and entrapped air within the composite as shown in Figure 1, thereby reducing packing efficiency and structural compactness. Consequently, the composites became less resistant to indentation and exhibited lower density values. These observations are consistent with previous studies on natural fibre reinforced thermoplastic composites, where excessive fibre loading generally increases porosity while reducing mechanical integrity

3.2. Tribological properties

The tribological behaviour of polypropylene–cotton composites was evaluated using abrasive wear testing as shown in Figure 2. The results showed that increasing recycled cotton fibre content reduced the abrasion resistance of the composites. The 75:25 PP–cotton composite exhibited the lowest specific wear rate which is 0.0114 mm³/N·m, indicating the highest wear resistance, whereas the 50:50 composite recorded the highest wear rate of 0.0419 mm³/N·m. The superior performance of the 75:25 composite is attributed to its higher density and hardness, which provided a more continuous polypropylene matrix that effectively distributed contact stresses and minimized fibre pull-out.

As the cotton fibre loading increased, the interfacial bonding between the hydrophilic cellulose fibres and the hydrophobic polypropylene matrix became less effective, leading to greater fibre debonding and increased internal defects. (Milosevic et al, 2020). During abrasive sliding, these weak interfaces promoted fibre pull-out, crack initiation and surface fragmentation, resulting in accelerated wear (Tasgin et al., 2024). Furthermore, the lower density and hardness of the 50:50 composite suggest the

presence of greater porosity, which provided preferential sites for crack propagation under repeated loading. Consequently, the combination of poor interfacial adhesion and increased void content significantly reduced the wear resistance of high-fibre composites.

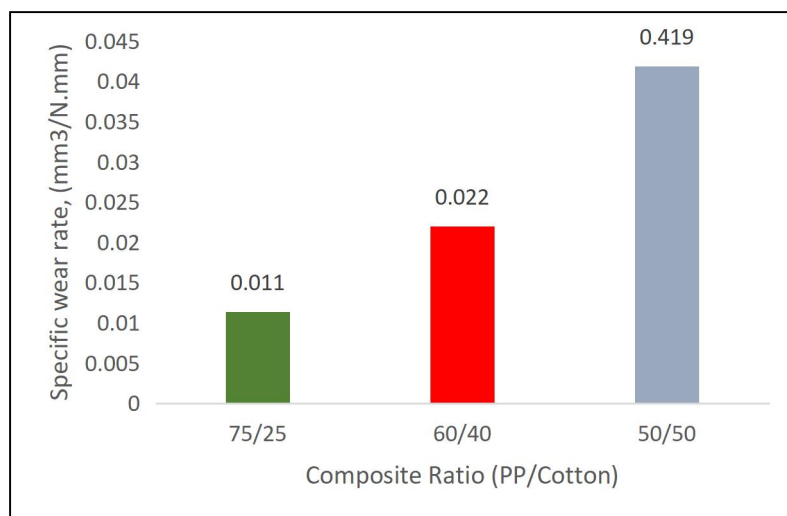


Figure 2. Specific Wear Rates of Cotton/PP Composite at Different Ratio

4. CONCLUSION

The results demonstrate that both matrix type and fibre loading significantly influence the physical and tribological performance of recycled cotton textile waste composites. Sucrose exhibited superior density and hardness, while the 75:25 PP/cotton composite achieved the best overall wear resistance. Increased fibre loading reduced composite performance due to higher porosity and weaker fibre–matrix bonding. These findings highlight the potential of recycled cotton composites for sustainable insulation and lightweight engineering applications. Future work should focus on improving fibre–matrix compatibility and evaluating additional mechanical and thermal properties.

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SECTION 8

SOCIAL INNOVATION



Creating solutions that empower communities.

KidsHealthKit: Herbal and Behavioral Approaches to Sustainable Paediatric HFMD Care

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Abstract

KidsHealthKit: Your Nature Solution represents a novel herbal-based intervention designed to address both prevention and supportive care for Hand, Foot, and Mouth Disease (HFMD) in paediatric populations. The formulation integrates neem and turmeric in a gentle face wash, virgin coconut oil, and bidara leaves (*Ziziphus mauritiana*) extract. Neem and turmeric provide antiviral and antibacterial protection, coconut oil enhances skin barrier function while maintaining hydration, and bidara leaves contribute immunomodulatory and anti-inflammatory effects. Collectively, these components strengthen skin resilience and reduce susceptibility to viral transmission. Importantly, KidsHealthKit extends beyond pharmacological prevention by incorporating behavioural change strategies for children during recovery. Interactive activity cards are designed to reinforce hygiene practices, minimise risky contact, and encourage positive behavioural adaptations, ensuring that children actively engage in their own healing process rather than relying solely on theoretical prevention. Complementary dietary guidance, including soft-textured foods and chilled drinks, alleviates discomfort and supports hydration, thereby enhancing recovery outcomes. This integrative approach highlights the potential of natural therapies in paediatric care while embedding behavioural reinforcement as a critical dimension of disease management. KidsHealthKit thus offers a cost-effective, sustainable, and community-based model that unites herbal medicine with behavioural support to promote holistic HFMD prevention and recovery.

Keywords: NatureCareHFMDKit; Hand, Foot, and Mouth Disease (HFMD); herbal-based intervention; behavioural change strategies; paediatric care

1. INTRODUCTION

Hand, Foot and Mouth Disease (HFMD) is a highly contagious viral disease that primarily affects infants and children under five years of age. The disease is mainly caused by enteroviruses, particularly Coxsackievirus A16 and Enterovirus 71 and is transmitted through direct contact with saliva, blister fluid, feces, respiratory secretions or contaminated surfaces (World Health Organization [WHO], 2011). Although HFMD is generally a self-limiting disease, severe complications involving the neurological and cardiopulmonary systems may occur in a small proportion of infected children. Malaysia continues to experience recurrent HFMD outbreaks, making the disease an important public health concern that requires continuous preventive interventions.

Since there is no specific antiviral treatment for uncomplicated HFMD, disease management primarily focuses on symptomatic care, adequate hydration, environmental hygiene and preventing disease transmission. Therefore, parents, caregivers, and preschool educators play an essential role in reducing HFMD transmission by practising proper hygiene and recognising early symptoms that require medical attention. Previous studies have reported that although Malaysian parents generally demonstrate good preventive practices, their knowledge of HFMD symptoms, complications, and preventive measures

remains moderate, highlighting the need for continuous health education and practical preventive resources (World Health Organization [WHO], 2011; Rajamoorthy et al., 2022; Abdul Jalil et al., 2026).

Recent studies have also shown that caregivers' preventive behaviours are strongly influenced by health beliefs, perceived susceptibility, and perceived benefits of disease prevention (Rajamoorthy et al., 2022). Similarly, Abdul Jalil et al. (2026) reported that although Malaysian parents generally demonstrated positive preventive practices, continuous health education remains essential to strengthen knowledge and encourage consistent preventive behaviours. Despite these encouraging findings, most existing studies have focused primarily on parental knowledge, awareness, perceptions, and preventive behaviours with limited attention to the development of an integrated health-support innovation that combines hygiene essentials, natural-based supportive products, nutritional guidance and child-friendly behavioural learning materials into a single portable kit. Furthermore, commercially available products are generally marketed separately, requiring users to obtain hygiene products, educational materials and supportive care resources from multiple sources. This fragmented approach may reduce convenience and limit the consistency of preventive practices.

To address this gap, KidsHealthKit: Your Nature Solution was developed as an integrated health-support innovation that combines natural-based supportive products, hygiene essentials, nutritional guidance and child-friendly behavioural learning materials within a single portable kit. The innovation aims to raise awareness of HFMD prevention, encourage recommended hygiene practices among children and provide parents and caregivers with a practical resource to support disease prevention efforts. Therefore, this paper presents the development of KidsHealthKit and discusses the herbal and behavioural approaches to sustainable paediatric HFMD Care.

2. MATERIALS AND METHODS

KidsHealthKit consists of integrated components including hand sanitizer, natural-based supportive products, alcohol wipes, a face mask storage case, nutritional guidance, activity cards, and HFMD infographic prevention guide. These components were organised into a portable kit to promote hygiene awareness, healthy daily practices and recommended preventive practices for HFMD.

2.1. Formulation and Preparation of Natural Actives

The topical components of the KidsHealthKit: Your Nature Solution were formulated using specific natural ingredients chosen for their synergistic biological properties. A gentle, pediatric-grade face wash was prepared by incorporating active extracts of neem (*Azadirachta indica*) and turmeric (*Curcuma longa*) to provide topical antiviral and antibacterial protection. Virgin coconut oil was selected as an emollient base to enhance epidermal barrier function and maintain optimal skin hydration. Additionally, bidara leaf (*Ziziphus mauritiana*) extract was integrated into the topical formulation to utilize its bioactive immunomodulatory and anti-inflammatory effects, aiming to reduce localized tissue inflammation and strengthen skin resilience against viral transmission.

2.2. Behavioural Change Tools

To complement the topical intervention, interactive behavioral strategies were integrated to directly involve pediatric patients in their recovery. Specially designed activity cards utilize child-friendly visuals and guided routines to teach essential hygiene practices, including effective handwashing. This approach minimizes risky physical contact, limits viral spread, and builds lasting habits by empowering children to take charge of their health. To further optimize recovery and broaden health literacy, the kit is supplemented with dietary guidance and an educational HFMD prevention guide.

2.3. KidsHealthKitNatural Herbal Components

KidsHealthKit consists of several natural components that collectively promote hygiene awareness, healthy daily practices, caregiver education and behavioural support for children. Unlike conventional products that typically focus on a single preventive measure, this innovation integrates natural-based supportive products, hygiene essentials, educational resources and behavioural learning tools into a single portable solution, providing a practical approach for promoting recommended preventive practices for HFMD. The functions of each component are summarised in Table 1.

Table 1. Components and Functions of KidsHealthKit

Component	Description	Main Function
Virgin Coconut Oil (VCO)-based product	Natural-based supportive product	Supports daily skin care and personal hygiene practices.
Turmeric-based product	Natural-based supportive product	Complements personal care and promotes healthy hygiene routines.
Bidara-based product	Natural-based supportive product	Supports personal hygiene and skin care as part of daily preventive practices.
Alcohol wipes	Hygiene product	Encourages hand hygiene and cleaning of frequently touched surfaces.
Face mask storage case	Protective accessory	Promotes hygienic storage of face masks and minimises cross-contamination.
Nutrition guide	Educational material	Encourages healthy dietary practices to support children's well-being.
Activity cards	Interactive educational material	Promotes hygiene awareness through engaging learning activities.
CareMaze Game	Behavioural learning tool	Encourages children to practise proper handwashing and hygiene through interactive play.
HFMD infographic	Visual educational material	Provides concise information on HFMD symptoms, transmission, preventive practices, and supportive care.
User guide	Instructional material	Provides guidance for the appropriate use of each component within the kit.

3. RESULTS AND DISCUSSION

3.1 Development of KidsHealthKit

The primary outcome of this study is the successful development of KidsHealthKit: Your Nature Solution, an integrated health-support innovation designed to promote awareness and support recommended preventive practices for HFMD among children. The innovation was developed through a systematic design and development process that integrates natural-based supportive products, hygiene essentials, nutritional guidance and child-friendly behavioural support tools within a single portable kit. KidsHealthKit was developed to address the challenges parents and caregivers face in accessing preventive resources from multiple sources by integrating complementary components into a single portable kit.

The completed prototype of KidsHealthKit is presented in Figure 1. The final prototype was designed with emphasis on portability, ease of use and user convenience. The compact design allows the kit to be conveniently used in homes, childcare centres, kindergartens, community health programmes and primary healthcare settings.



Figure 1. Final Product KidsHealthKit: Your Nature Solution

3.2 Novelty of KidsHealthKit

The novelty of KidsHealthKit lies in its integration of natural-based supportive products with behavioural change strategies within a single portable health-support kit. Unlike conventional products that generally provide individual hygiene products or educational materials separately, KidsHealthKit combines multiple complementary resources to promote both preventive health awareness and positive behavioural practices among children and caregivers. Accordingly, KidsHealthKit adopts a herbal and behavioural approach by integrating natural-based supportive products with behavioural learning strategies to promote recommended preventive practices among children.

In addition to natural-based supportive products and hygiene essentials, the innovation incorporates interactive behavioural learning tools, including the CareMaze Game, activity cards and an HFMD infographic. These components are specifically designed to encourage children to practise proper hand hygiene and healthy daily habits through engaging, age-appropriate activities, while simultaneously providing caregivers with accessible information on HFMD prevention and supportive care. This dual approach strengthens both health education and behavioural reinforcement, distinguishing KidsHealthKit from conventional products that primarily focus on a single aspect of disease prevention. By integrating hygiene products, natural-based supportive products, nutritional guidance, behavioural learning tools and educational materials into one portable kit, KidsHealthKit offers a practical solution that supports recommended preventive practices for HFMD.

Unlike conventional market offerings that isolate disease management into fragmented products, KidsHealthKit consolidates pharmacological prevention and behavioral reinforcement. The comparative advantages of this integrated model against existing commercial alternatives are outlined in Table 2.

Table 2. Comparative advantages between KidsHealthKit and existing commercial alternatives

Features	KidsHealthKit	Standard Hygiene Kits (often found in pharmacies)	Conventional Herbal Topicals (Individuals herbal or natural skincare product bought separately)
Primary Focus	Integrated prevention and behavioral recovery	Basic sanitation	Symptom relief (skin barriers)
Antiviral and Antibacterial Actives	Yes (Neem, Turmeric, Bidara)	No (Typically alcohol-based only)	Yes
Behavioral Learning Tools	Yes (CareMaze, Activity Cards)	No	No
Dietary and Nutritional Guidance	Yes	No	No
Target Audience	Paediatric patients and caregivers	General public	General public

3.3. Practical Contribution and Commercialization Potential

KidsHealthKit provides parents, caregivers, and educators with an all-in-one health-support solution by integrating natural-based supportive products, hygiene essentials, nutritional guidance, educational materials and behavioural learning tools into a portable kit for promoting recommended preventive practices against HFMD.

Beyond household use, KidsHealthKit has the potential to support health promotion activities in childcare centres, kindergartens, primary schools, community health programmes and primary healthcare settings. The inclusion of child-friendly behavioural tools, such as the CareMaze Game, activity cards and the HFMD infographic, encourages active participation among children while assisting caregivers in reinforcing recommended hygiene practices through engaging and age-appropriate learning experiences.

From a commercialisation perspective, KidsHealthKit demonstrates promising market potential due to its portable design, practical application and comprehensive approach to health support. The innovation can be adapted for collaboration with educational institutions, healthcare providers and community organisations involved in child health promotion programmes. Future product refinement and user evaluation may further strengthen its usability, acceptability and readiness for wider implementation.

4. CONCLUSION AND FUTURE WORKS

In conclusion, KidsHealthKit presents a comprehensive, non-pharmacological framework that successfully bridges natural product therapeutics with pediatric behavioural psychology for HFMD management. By combining the topical antimicrobial, barrier-restorative, and anti-inflammatory benefits of neem, turmeric, virgin coconut oil, and bidara leaf extract with interactive hygiene reinforcement and tailored dietary care, this integrative intervention addresses both acute symptom management and viral transmission pathways. The inclusion of interactive components such as the dietary guidance, activity cards and the HFMD prevention guide further strengthen the innovation by encouraging positive hygiene behaviours through engaging and age-appropriate learning experiences. These integrated features distinguish KidsHealthKit from conventional products that typically focus on a single aspect of HFMD prevention. Ultimately, KidsHealthKit demonstrates a scalable, cost-effective, and community-centered

model that advances holistic pediatric healthcare and empowers children to actively participate in their own recovery.

While the conceptual architecture and functional prototype of KidsHealthKit have been fully established, empirical field testing and user evaluations remain ongoing. To properly measure the kit's effectiveness and practical value, future development will include formal trials with parents, children, and healthcare providers to evaluate overall satisfaction and the usability of the behavioral tools using the System Usability Scale (SUS). Additionally, observational studies will be conducted to assess how well the herbal ingredients soothe skin irritation and to measure the actual reduction in disease transmission within participating households and childcare centers. Future plans also include creating a mobile app version of the CareMaze game, along with a feature for parents to track symptoms and receive health alerts.

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EDUSENSORY: An Inclusive Sensory-Based Learning Tool for All Children

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Abstract

Although fine motor development is an important factor for a child's overall growth, many sensory learning materials are unstructured and lack guidance or are designed primarily for therapeutic use only. This study shows that a multi-sensory learning strategy that uses structured activities to improve children's sensory and cognitive abilities, interactive learning to boost confidence, and provides convenient access to digital learning materials for parents and instructors. The Edu Sensory Box is a new concept that includes safe activities involving touch, hearing, smell, sight, body language and emotional awareness. A digital resource that is enabled by QR codes and offers thorough, step-by-step instructional video content for continuous learning at home and in educational settings will be included in every Edu Sensory Box. This innovation will be tested on a small scale with typically developing children to determine its applicability and educational value. By encouraging meaningful learning through parent and teacher engagement, Edu Sensory Box is expected to improve children's fine motor skills as well as their attention span, creativity, problem-solving abilities and self-confidence. Future studies will examine its long-term effectiveness and how it can be adapted to accommodate children with different learning and sensory backgrounds.

Keywords: Multi-Sensory Learning; Fine Motor Skills; Early Childhood Education; Social Innovation; QR Code Learning Resources.

1. INTRODUCTION

Fine motor development is indeed important for children since it allows them to perform various age-appropriate tasks, such as writing, drawing, cutting, dressing themselves, and playing with small toys. It requires a lot of precision and effort. During early and middle childhood, those motor skills play a critical role in a child's cognitive, sensory, and emotional development. Several approaches are being developed to support this developmental aspect, with multisensory learning being the most effective way to encourage children to participate in structured and hands-on activities that involve multiple sensory experiences. The use of multisensory learning involves a variety of visual, tactile (both auditory and tactile) experiences as well as auditory (and auditorian) forms of instruction that allow children to explore more deeply, understand more complex concepts while also retain new information through improved motor coordination (Arjulayana, 2025).

Children benefit from doing things that involve senses. (Randjelović et al., 2019) concluded that encouraging pre-schoolers to take part in structured sensory-based activities promotes the development of fine motor skills in activities that involve hand-eye coordination and interaction with objects. Similarly, (Xu et al., 2025) highlights the importance of sensory-based games for preschoolers' improvement of sensory processing and motor skills, which is only possible through appropriately structured activities that

appeal to particular senses. (Uygun et al., 2025) added that such play also promotes the development of children's creativity, self-control, communication, and problem-solving skills. All three studies demonstrate that appropriately structured sensory-based activities for preschoolers have the potential to support children's development in more than one area, not only fine motor skills.

Sensory educational materials could be highly beneficial. The majority of them are not specific enough to be truly useful in the classroom or in the home for educational purposes (Lupiya Mpolomoka, 2025). Materials are bought for a certain type of play, without really being able to see the educational benefits for the child. Certain sensory materials are specifically for therapeutic use and cannot be utilized by parents and educators who aren't well-versed with sensory learning. Sensory educational materials should be easy to access and even easier to use. The materials should include an abundance of activities that will stimulate all of a child's senses and will come with clear instructions for parents and educators to take advantage of in everyday classrooms for the developmental and educational benefit of the children. Educational materials of this sort would be extremely helpful and beneficial for the children.

To address these issues, Edu Sensory Box was created, which is a multisensory learning kit for children aged 3-12 years. The idea is to combine the therapeutic powers of specific sensory activities with learning cards and QR codes that explain how to use them at home or in the classroom which support by (Deineko et al., 2022). Thus, the learning kit aims to help children develop their sensory, cognitive, emotional, and fine motor skills through play and involve their parents and teachers in the process of boosting their children's abilities. The objectives of this study are described below.

Objective of the Study:

1. To develop Edu Sensory Box as a multifunctional learning kit with structured multisensory activities for children aged 3–12 years.
2. To encourage children to develop their sensory, cognitive, emotional, and fine motor skills through structured educational activities.

To provide parents and teachers with QR codes that offer access to sensory learning resources and activity guidance.

2. MATERIALS AND METHODS

2.1. Product Description and Core Features

Edu Sensory Box is a multifunctional learning kit that introduces children aged 3-12 years to a wide range of activities that appeal to their senses and stimulate their tactile, visual, auditory, olfactory, and gustatory receptors. The kit also helps children learn about emotions through engaging activities. Each exercise contributes to developing the child's active learning and their tactile, cognitive, emotional, and fine motor skills. The learning kit contains a variety of tactile materials, including a sensory brush, sensory stones, wooden shapes, a whistle, scent jars, a taste activity, and emotion cards. The kit also offers activity cards to children that describe the objective of every task along with the directions on how to complete it and the estimated time it would take them. The activities also have QR codes that enable the children to access videos illustrating how each task should be performed. Combined together, the learning materials and instructions help parents and teachers get the most out of the educational toolkit. Besides, because of the included QR code, there is no necessity to provide particular training, as the video will explain the tasks. Therefore, Edu Sensory Box is a helpful tool that supports a child's holistic development in an easy and accessible way.

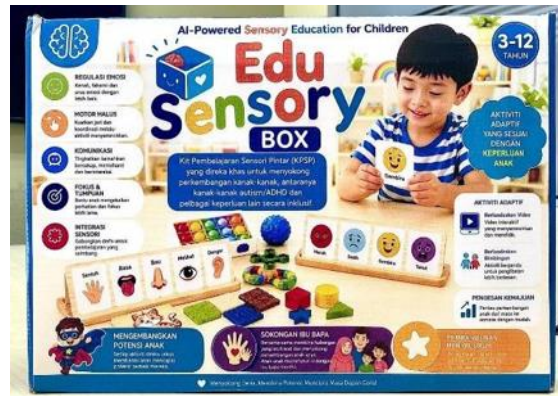


Figure 1. External view of the Edu Sensory Box



Figure 2. Collated multisensory learning materials

Table 1. Components of Edu Sensory Box and Their Developmental Focus

Component	Sensory Domain	Developmental Focus
Wilbegger Brush	Tactile	Finger stimulation and tactile awareness
Sensory Stones	Tactile	Texture exploration and sensory discrimination
Geometry Puzzle Wooden	Visual & Tactile	Shape recognition and hand-eye coordination
3 in 1 Sensory Ball	Tactile & Proprioceptive	Grasp strength, tactile stimulation, and hand coordination
Whistle	Auditory	Listening and sound discrimination
Scent Jars	Olfactory	Smell identification and sensory awareness
Emotion Cards	Emotional	Emotion recognition and communication skills
Routine Sensory Charts	Visual & Cognitive	Daily routine planning, task sequencing, and focus management
Sensory Progress Chart	Visual & Behavioral	Tracking sensory milestones, monitoring intervention progress, and developmental evaluation
Star Activity Chart	Behavioral & Motivation	Task completion tracking, positive reinforcement, and engagement building
Sticker Star	Tactile & Fine Motor	Reward system, motivation enhancement, and pincer grasp practice
QR Video Resources	Digital Support	Guidance for parents and teachers

2.2. Development Process

The development of the Edu Sensory Box consisted of four structured phases. The first phase involved exploratory research to evaluate the need for a well-organized multisensory tool, designed to bridge the gap between affordable sensory materials and clear, practical guidance for educators and caregivers.

The second stage concentrated on developing specific learning activities and choosing appropriate physical materials. Every activity was designed to engage particular sensory areas while meeting crucial needs such as safety, durability, cost-effectiveness, and attractiveness for children aged 3 to 12. The selected materials were evaluated for their durability when used repeatedly in various educational settings.

The third stage involved the production of instructional video demonstrations detailing the practical use of each sensory tool within the kit. These videos were uploaded to the official Edu Sensory Box YouTube channel. Corresponding QR codes were then generated and embedded onto the physical activity cards (Sidik et al., 2021). Upon scanning, users are directed seamlessly to the official YouTube platform, providing parents and educators with instant visual guidance without requiring specialized therapeutic training.

In the final phase, all physical elements, activity cards, and digital links via QR codes were assembled into a portable learning kit. A limited field trial followed to assess its usability, durability of materials, and overall user experience before proceeding to broader testing.

2.3. Evaluation Procedure

To evaluate the developmental efficacy and practical impact of the Edu Sensory Box, a quantitative observational study utilizing a pre-test and post-test design was conducted. The evaluation involved a targeted group of children aged 3 to 12 years as end-users, while their respective parents and educators acted as observers and evaluators.

Data collection was organized using a uniform 5-point Likert scale assessment tool (from 1 = Very Weak / Refuses to 5 = Very Good / Independent) across four main developmental areas: (1) Sensory Processing (exploration through touch and smell), (2) Fine Motor and Cognitive Skills (ability to grasp with fingers, match objects, and coordinate eye-hand movements), (3) Visual Communication (ability to express needs and recognize emotions), and (4) Focus and Self-Regulation (duration of attention on tasks and management of restlessness).

Prior to utilizing the kit, evaluators completed the pre-test form to establish the baseline behavioral and sensory-motor status of each child. After the initial assessment, participants engaged in organized intervention sessions with the Edu Sensory Box, where activities were guided by parents and teachers through the QR code links to YouTube instructional videos. Once the intervention period concluded, evaluators filled out a post-test form using the same criteria to assess changes in behavior, enhancements in fine motor skills, and overall sensory development.

3. RESULTS AND DISCUSSION

3.1. Respondents' Demographic Profile

The completed prototype of KidsHealthKit is presented in Figure 1. The final prototype was designed with emphasis on portability, ease of use and user convenience. The compact design allows the kit to be conveniently used in homes, childcare centres, kindergartens, community health programmes and primary healthcare settings.

This study included 125 children in total. The participants included 68 females (54.4%) and 57 males (45.6%), ranging from 3 to 12 years old, sourced from preschool and elementary education environments.

All participants finished the online pre-test and post-test evaluations through observation by parents or educators. Table 2 shows that female respondents made up a somewhat larger percentage of the sample, consisting of 68 individuals (54.4%), in contrast to 57 male participants (45.6%). Regarding age, the greatest percentage of respondents belonged to the 6–8 years segment, totaling 48 children (38.4%), followed by the 3–5 years group with 42 children (33.6%) and the 9–12 years category with 35 children (28.0%).

Table 2. Demographic Profile of Respondents (N = 125)

Gender	Frequency (n)	Percentage (%)
Male	57	45.6
Female	68	54.4

Age Group	Frequency (n)	Percentage (%)
3-5 years	42	33.6
6-8 years	48	38.4
9-12 years	35	28.0
Total	125	100.0

3.2. Pre-Test and Post-Test Results

Table 3. Descriptive Statistics of Pre-Test and Post-Test Scores

Variable	N	Mean	SD	Minimum	Maximum
Pre-test	125	33.41	5.82	20	49
Post-test	125	47.28	5.11	34	58

Table 3 presents descriptive statistics for the pre-test and post-test scores (N = 125). The data show a notable rise in average performance following the intervention. Prior to the intervention, the mean pre-test score was 33.41 (SD = 5.82), with individual results spanning from 20 to 46. After the intervention, the average post-test score increased to 47.28 (SD = 5.11), and scores ranged between 34 and 58. This represents an overall gain of 13.87 points in the mean score, reflecting a clear improvement in student outcomes.

3.3. Paired Samples t-Test Results

Table 4. Paired Samples t-Test Results for Pre-Test and Post-Test Scores

Variable	Pair	Mean Difference	SD	t-value	df	p-value
Pre-test – Post test	1	-13.87	3.42	-45.31	124	< .001

A paired-samples t-test was conducted to evaluate the impact of the intervention on students' test scores (N = 125). There was a statistically significant increase in test scores from the pre-test ($M = 33.41$, $SD = 5.82$) to the post-test ($M = 47.28$, $SD = 5.11$), $t(124) = -45.31$, $p < .001$. The mean increase in test scores was 13.87 with a 95% confidence interval. The results indicate that the intervention had a positive and statistically significant effect on students' performance.

3.4. Discussion And Summary of Findings

This study aimed to assess how effectively the intervention influenced students' learning outcomes. The sample, consisting of 125 participants, showed a well-balanced representation across gender and age groups, contributing to the generalizability of the findings within the target population. Results indicated a

statistically significant improvement in student performance following the intervention. Descriptive statistics revealed that average scores rose from the pre-test ($M = 33.41$, $SD = 5.82$) to the post-test ($M = 47.28$, $SD = 5.11$). Inferential analysis further confirmed the significance of this 13.87-point gain, with a t-test yielding $t(124) = -45.31$, $p < .001$. These outcomes provide strong evidence that the intervention had a positive impact on student achievement. To facilitate the implementation of the EduSensory Box in educational and home settings, complete instructional guides and demonstration videos are accessible digitally via the QR code below.



Figure 5. QR Code Access for EduSensory Box Instructional Videos

Note. Scan the QR code using a mobile device to access interactive guides and educational resources.

4. CONCLUSION

This study shows that the EduSensory Box is a practical and impactful multisensory resource that contributes meaningfully to children's overall development. It particularly supports development in sensory processing, fine motor abilities, attention, communication, and emotional regulation. The clear improvements seen between initial and follow-up assessments, supported by a strong effect size, underscore its value for teachers, caregivers, and therapists working with young children. However, it's important to recognize certain limitations, including the use of a single-group design and a sample drawn from only one educational setting. Future research should employ controlled experimental approaches, include larger and more varied groups of participants, and examine the tool's long-term effectiveness across different learning environments and stages of development. Moving forward, future plans for the EduSensory Box include expanding its application to support neurodivergent children, particularly those with Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), and other developmental needs.

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JSKM STEM Innovation Hub: An Interactive Digital Portal for STEM Outreach and Education

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Abstract

In the digital era, fostering sustainable interest in Science, Technology, Engineering, and Mathematics (STEM) demands a shift from passive pedagogy to active engagement. The **JSKM STEM Innovation Hub** addresses this by serving as a centralized, web-based platform featuring six distinct STEM innovation products developed by lecturers from *Jabatan Sains Komputer dan Matematik (JSKM)*, UiTM Cawangan Pulau Pinang. Grounded in the philosophy of "learning while playing," these web applications integrate gamification, interactive simulations, and problem-solving modules to deconstruct complex computer science and mathematical concepts into enjoyable experiences. Beyond hosting interactive tools, the platform centralizes records of past activities, upcoming event schedules, comprehensive activity reports, and specialized teaching products utilized during outreach sessions. Designed for universal inclusivity, these tools benefit all age groups from children developing logic to adults enhancing analytical thinking. Developed using modern web technologies, the system guarantees cross-device compatibility and seamless accessibility without requiring high-end hardware. Ultimately, this digital solution empowers school teachers to easily access event details, evaluate past outcomes, and directly submit inquiries or program requests for their schools. The web platform offers substantial benefits, such as enhancing the public visibility of JSKM's community outreach (CSSR) efforts, streamlining event management, and fostering greater student and school engagement in STEM education

Keywords: Interactive, Agile Model, Gamified learning, Digital Portal, STEM

1. INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) education plays a vital role in driving economic advancement, technical innovation, and digital transformation. However, traditional pedagogical methods reliant on lecture-based instruction often struggle to demystify complex algorithms, mathematical logic, and computer science concepts, leading to passive student engagement and diminished long-term interest (Freeman et al, 2014). Additionally, educational institutions frequently face resource disparities and high hardware barriers, while universities lack centralized digital platforms to streamline outreach programs, track activity outcomes, or handle direct inquiries from school educators. To address these

challenges, the JSKM STEM Innovation Hub was created by academic staff from the *Jabatan Sains Komputer dan Matematik* (JSKM) at UiTM Cawangan Pulau Pinang as a centralized digital portal that bridges school communities and higher education through interactive learning tools.

The primary objectives of the JSKM STEM Innovation Hub focus on hosting a few specialized, gamified web applications designed under the philosophy of "learning while playing," while engineering a lightweight, responsive three-tier architecture using Django, HTML5/CSS3/JavaScript, and SQLite to ensure low hardware dependency across devices (Schwaber & Sutherland, 2020). Furthermore, the system aims to streamline administrative and outreach workflows through role-based access, automated approval processes, and integrated contact tools, alongside evaluating the operational impact and educational satisfaction among teachers.

The platform generates broad benefits for multiple stakeholders: students develop critical analytical thinking and sustained STEM interest through interactive problem-solving modules; educators gain direct access to validated teaching aids and effortless program registration workflows; and university administrators benefit from elevated public visibility for Corporate Social Responsibility (CSSR) efforts, secure user authentication, and organized records of all departmental outreach initiatives.

2. METHODOLOGY

This project, **JSKM Stem Innovation Hub** adopts the Agile Software Development Methodology, a flexible and iterative approach that prioritizes flexibility, teamwork and ongoing improvement. Agile was chosen due to its suitability for developing dynamic web systems, where system requirements can change depending on user feedback throughout the process. Not only that, but Agile method also allows incremental progress through continuous cycles of planning, development, testing and review.

2.1 Agile Framework

The Agile process in this project follows the Scrum framework, which emphasizes iterative and incremental development through time-boxed cycles known as sprints. Each sprint focuses on producing specific deliverables that are developed, tested, and reviewed before advancing to the next phase. Regular sprint reviews and retrospectives were conducted to ensure the system met stakeholder needs (Scrum.org, n.d). The figure below shows the diagram of how Scrums work in the development process in this JSKM Stem Innovation Hub project, utilizing sprints to divide the tasks and achieve the goal before moving on to the next one.

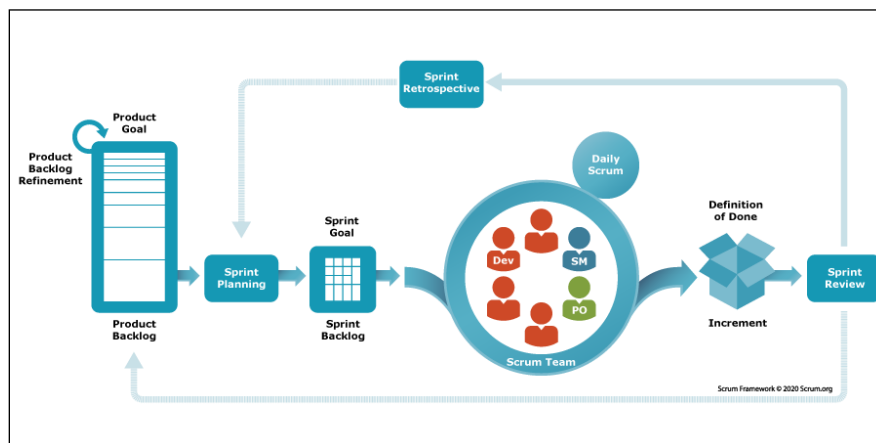


Figure 1: Scrum Framework Diagram

2.2 Development Process

The **JSKM STEM Innovation Hub** website was developed using Django (Python) for the backend, HTML, CSS, and JavaScript for the frontend, and SQLite as the database. The development process was divided into multiple sprints like as shown in Table 1 below.

Table 1:List of multiple sprints

Sprint	Objective	Key Deliverables
Sprint 1	Requirements Analysis and System Design	Gathering system requirements, design Entity Relationship Diagram, plan the storyboard and database schema.
Sprint 2	Backend Development	Creation of Django models, database migrations, and integration of backend logic.
Sprint 3	Frontend and Feature Integration	Development of user interface and CSS styling.
Sprint 4	Testing, Feedback, and Refinement	System testing, email notification testing, user feedback, bug fixes, and user interface enhancement for final deployment.

3. SYSTEM DESIGN AND ARCHITECTURE

3.1 System Overview

The system follows a three-tier architecture consisting of the presentation layer (frontend), application layer (backend), and data layer (database). This system is designed to showcase the products invented by JSKM from UiTM Pulau Pinang, and to display past events of making use of the products. It enables members of JSKM to post the products and events. There is also a side for admins to approve the posts and create unique IDs to ensure only members of JSKM is allowed to register and login. Lastly, visitors can inquire about events or products through a contact system using email.

3.2 System Architecture

The overall architecture for developing **JSKM STEM Innovation Hub** consists of the following components:

- **Frontend (Presentation Layer):**
Developed using HTML, CSS, and JavaScript, this layer handles all user interactions and displays dynamic content rendered by Django templates. It ensures responsive design and intuitive navigation across devices.
- **Backend (Application Layer):**
Powered by the Django web framework (Python), the backend handles logic, authentication, data processing, and communication between frontend and database. Django's Model-View-Template (MVT) architecture was used to maintain separation of concerns.
- **Database (Data Layer):**
The system uses SQLite as its database for data persistence. It stores all relevant records including members, events, products, images, and inquiries.

3.3 Storyboard

Storyboarding served as a crucial pre-visualization step to map out user navigation, interface layouts, and system responses for both public visitors and authenticated members. The JSKM STEM Innovation Hub features four primary operational workflows designed to simplify resource sharing and community engagement. Figure 2 below explain the flow of adding a product:



Figure 2: Storyboard flow of adding a product

To add a product in the hub system, the user must register and login as a member with a unique ID. Then, navigate to the Products tab in the member side and fill in the details. The user must fill in all the details in the form. After filling in and submitting it, user must wait until the product is approved by the super admin. After approval, the Product post will appear in the Products list page for all users of the website to see.



Figure 3: Storyboard of the flow of approving programs

The figure above shows the approving programs that takes place after logging in as a super admin, the member capable of approving or rejecting posts by other members. The super admin then looks at the programs waiting to be approved, then clicks on the approve button. The approved program will then be displayed on the program's list page, allowing all users to click on it and look at the details.

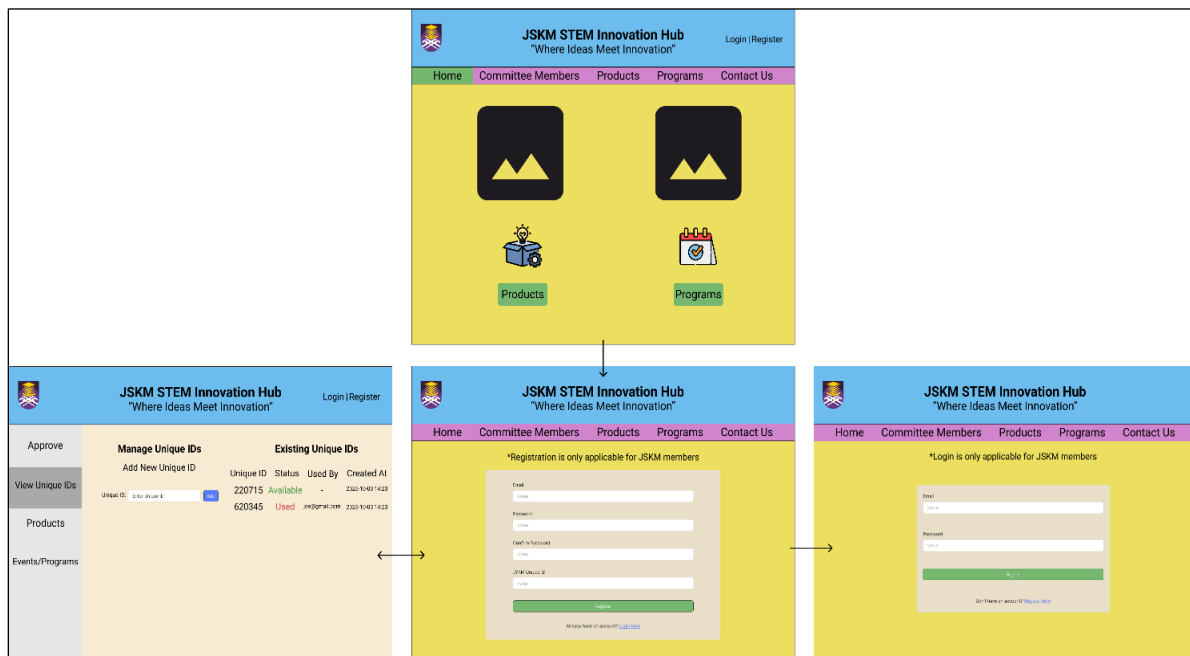


Figure 4: Storyboard flow of registering and login

To start registering as a Member, the user must refer the super admin to acquire a Unique ID before registering. After acquiring a Unique ID, user can register by filling out their details which are email, password, confirm the password again, and the Unique ID given. After registering, user will be redirected to the login page where they can login with the correct details they registered with like as shown in figure 4 above.

4. RESULT AND ANALYSIS

A survey conducted among schoolteachers in the Seberang Perai area revealed significant obstacles in sustaining student engagement in STEM subjects through traditional, lecture-based methods. Educators highlighted a lack of easily accessible, interactive teaching aids and inefficient processes for participating in university outreach initiatives (Linton,2023). Without a centralized platform to access gamified learning tools and coordinate community events, teachers struggle to demystify complex computer science and mathematical concepts effectively. The **JSKM STEM Innovation Hub** directly addresses this gap by offering Seberang Perai educators a user-friendly, web-based platform featuring interactive tools, activity logs, and streamlined event request capabilities.

The bar chart in the figure 5 below, summarizes feedback from a survey of 120 educators evaluating their experience with the **JSKM STEM Innovation Hub** across six key operational areas using a 5-point scale. Overall, the response is overwhelmingly positive, with every single category scoring above 4.40 out of 5.0 (a approval rate exceeding 89%), highlighting the website's strong reception among teachers.

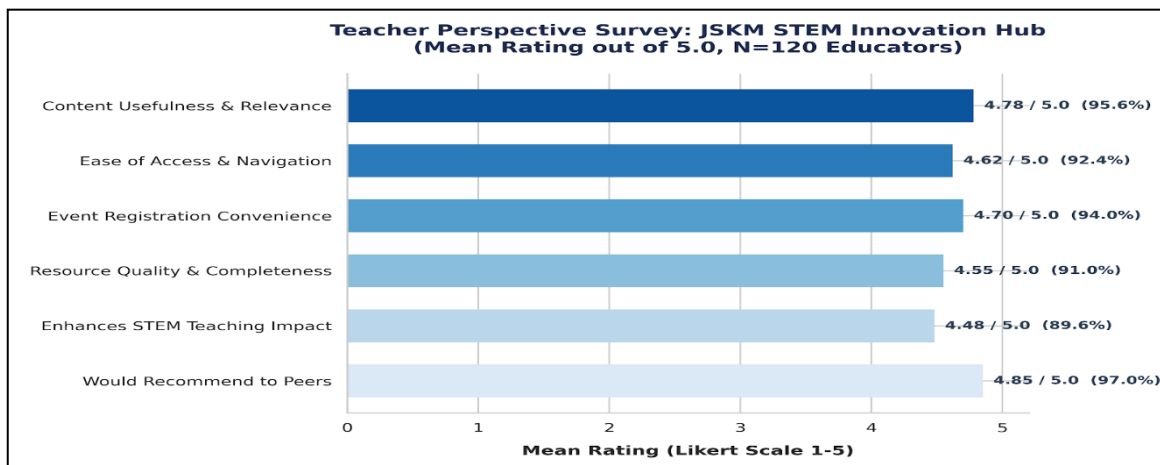


Figure 5: Bar Chart summaries the teachers experience

The strongest takeaway from the data is the advocacy rate: 97.0% of respondents (4.85 / 5.0) indicated they would actively recommend the portal to their peers. Educators also praised the platform's practical value, giving high marks to Content Usefulness & Relevance (4.78 / 5.0) and Event Registration Convenience (4.70 / 5.0). These scores reflect that the hub makes registering for STEM activities effortless while offering teaching materials directly applicable to school curricula.

In terms of user experience and overall impact, teachers found the website simple to navigate (4.62 / 5.0 for Ease of Access) and appreciated the completeness of downloadable resources (4.55 / 5.0). Most importantly, 89.6% of educators (4.48 / 5.0) agreed that integrating JSKM's resources directly boosted their classroom effectiveness, confirming that the digital hub succeeds as both an accessible, user-friendly website and a valuable educational tool.

5. CONCLUSION

The **JSKM STEM Innovation Hub** serves as a vital bridge between theoretical knowledge and real-world application by centralizing educational resources, streamlining event management, and fostering active partnerships. Backed by strong positive feedback from educators in Seberang Perai—with over 89% approving the platform and 97% expressing a willingness to recommend it—the hub stands as a sustainable, high-impact platform dedicated to empowering future innovators and driving STEM excellence across the community. By utilizing an agile scrum development approach and lightweight Django-driven architecture, the hub guarantees seamless cross-device compatibility without requiring expensive, high-spec hardware in schools. Furthermore, its role-based administrative system simplifies Corporate Social Responsibility (CSSR) outreach, providing a secure, transparent method for school leaders to request events and access teaching aids. Ultimately, the portal not only demystifies complex computer science and mathematical logic through "learning while playing," but also establishes a scalable digital framework that can be expanded to support broader educational ecosystems and STEM outreach efforts in the future.

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i-HEP FSG Dashboard 1.0: Driving Sustainable Faculty Governance Through Real-Time Visual Analytics

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Abstract

The Student Affairs (HEP) function within faculties faces persistent governance weaknesses: the absence of systematic performance-indicator (PI) mapping, the lack of real-time financial control, and poorly coordinated programme data. These weaknesses compromise transparency, accountability and timely oversight. This study presents the i-HEP FSG Dashboard 1.0, a real-time visual-analytics platform developed on the Google Workspace ecosystem (Google Sheets and Apps Script) at a Malaysian public university. The objective is to convert fragmented administrative records into a single, authoritative decision-support interface for officers. A design-and-development approach integrated three modules—automated PI mapping, a centralised financial command centre, and full-lifecycle programme monitoring—validated through operational deployment and a user-evaluation survey of twenty-eight administrators. Findings show that the dashboard consolidated student-activity, budget and KPI data into live visualisations, reducing routine reporting effort substantially and enabling early detection of financial variance and under-performing indicators. Respondents reported high agreement on clarity, relevance and decision-support effectiveness. The platform thus equips officers to make timely, evidence-informed strategic decisions using real-time data, at negligible marginal cost. Future recommendations include predictive analytics, scenario ('what-if') modelling and cross-faculty benchmarking to evolve the tool from an operational dashboard into an intelligent governance platform aligned with institutional sustainability goals.

Keywords: Real-Time Analytics Dashboard; Data-Driven Decision-Making; Faculty Governance; Performance-Indicator Mapping; Higher Education Administration.

1. INTRODUCTION

Higher education institutions generate large volumes of administrative data across student programmes, budgets and performance indicators, yet they frequently struggle to convert this data into timely institutional intelligence. Visibility—rather than data volume—is the binding constraint: the people deciding how to improve outcomes often cannot 'see' the information they need because it is incomplete, inaccurate, or dispersed across departmental silos (CliftonLarsonAllen, 2022). Dashboards are widely promoted as the corrective, because they are expected to improve decision-making by amplifying cognition and capitalising on human perceptual capabilities (Yigitbasioglu & Velcu, 2012). Few (2006) defines a dashboard as a visual display of the most important information needed to achieve one or more objectives, consolidated on a single screen so that it can be monitored at a glance.

Within Universiti Teknologi MARA (UiTM) Shah Alam, the HEP function at faculty level is responsible for coordinating student development programmes, managing associated budgets and reporting against key performance indicators (KPIs). At the Faculty of Applied Sciences (FSG), this function exhibited three

structural weaknesses. First, there was no systematic mechanism to map daily operational activity to high-level faculty performance indicators, making it difficult to assess the true effectiveness of student development. Second, budget-allocation decisions were made without real-time reference to current balances, creating a risk of unplanned virement and undermining accountability. Third, programme data were not coordinated in an integrated repository, hindering rapid access and cross-departmental coordination. Table 1 summarises these challenges.

Table 1. Critical Governance Challenges in the HEP Function

Domain	Governance Gap	Operational Impact
Student development	Absence of systematic PI mapping	Inaccurate reporting; follow-up actions are not implemented effectively
Financial management	No real-time financial control	Allocation decisions made without reference to current balances, raising the risk of unplanned virement and weakening accountability
Data management	Weak programme data coordination	No integrated database for rapid access, hindering strategic programmes and cross-departmental coordination

Existing scholarship establishes that timeliness, accuracy and integration of information are foundational antecedents of information-system success and of the net benefits realised from such systems (DeLone & McLean, 2003). However, much of the higher-education dashboard literature and market offering assumes enterprise resource-planning (ERP) budgets and specialist development teams, which are not available to a single faculty administrative unit. The present work therefore addresses a specific gap: how to deliver enterprise-grade, real-time governance analytics within the constraints of an existing productivity ecosystem and without additional capital expenditure. The objective of this study is to design, develop and evaluate the i-HEP FSG Dashboard 1.0 as a real-time visual-analytics platform that consolidates programme, budget and performance data into a single authoritative view, thereby enabling officers to make timely, evidence-informed strategic decisions.

2. MATERIALS AND METHODS

2.1. Development Approach and Platform

The dashboard was developed using a design-and-development research approach, progressing through problem identification, requirements analysis, iterative construction and operational validation. It was built entirely within the Google Workspace ecosystem: Google Sheets served as the structured data layer, while Google Apps Script provided the automation and integration logic. This low-code, cloud-native configuration was selected deliberately so that the platform could be maintained and extended by administrative staff without specialist programming resources, and so that it incurred no additional software licensing cost beyond the institution's existing subscription.



Figure 1. Phase 1 prototype of the i-HEP FSG dashboard home interface and navigation structure.

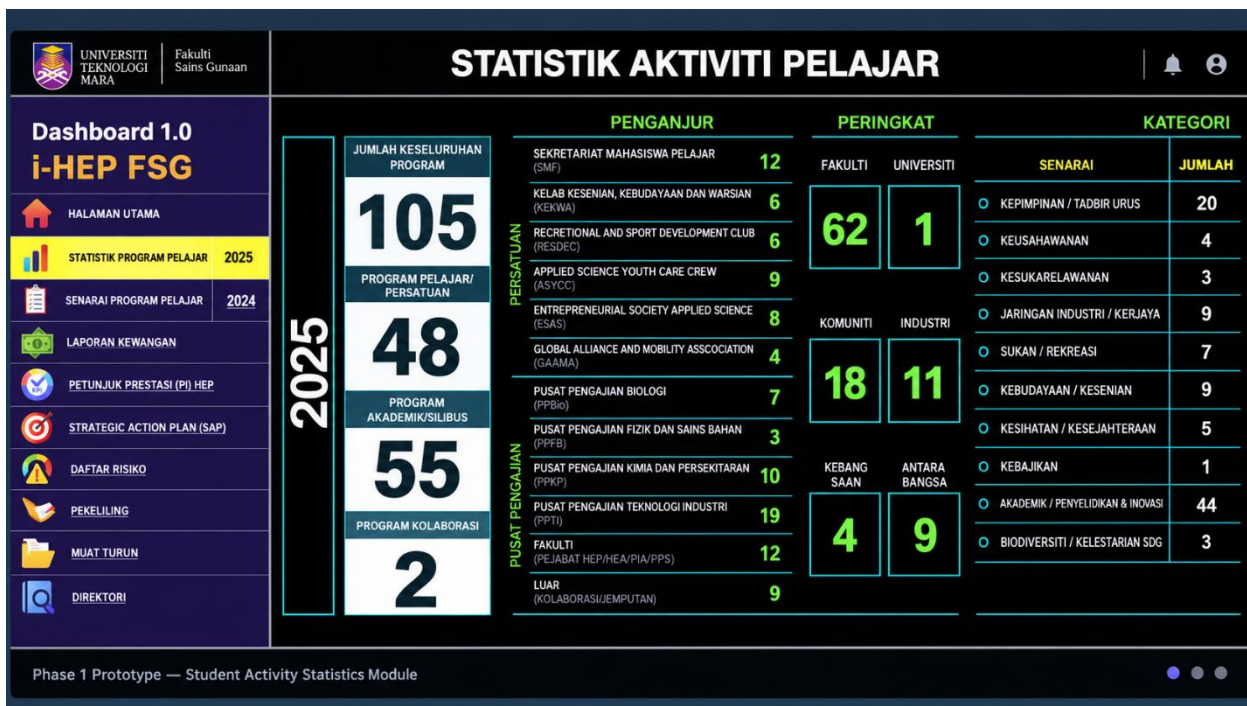


Figure 2. Phase 1 prototype displaying consolidated student activity statistics by organiser, level and programme category.

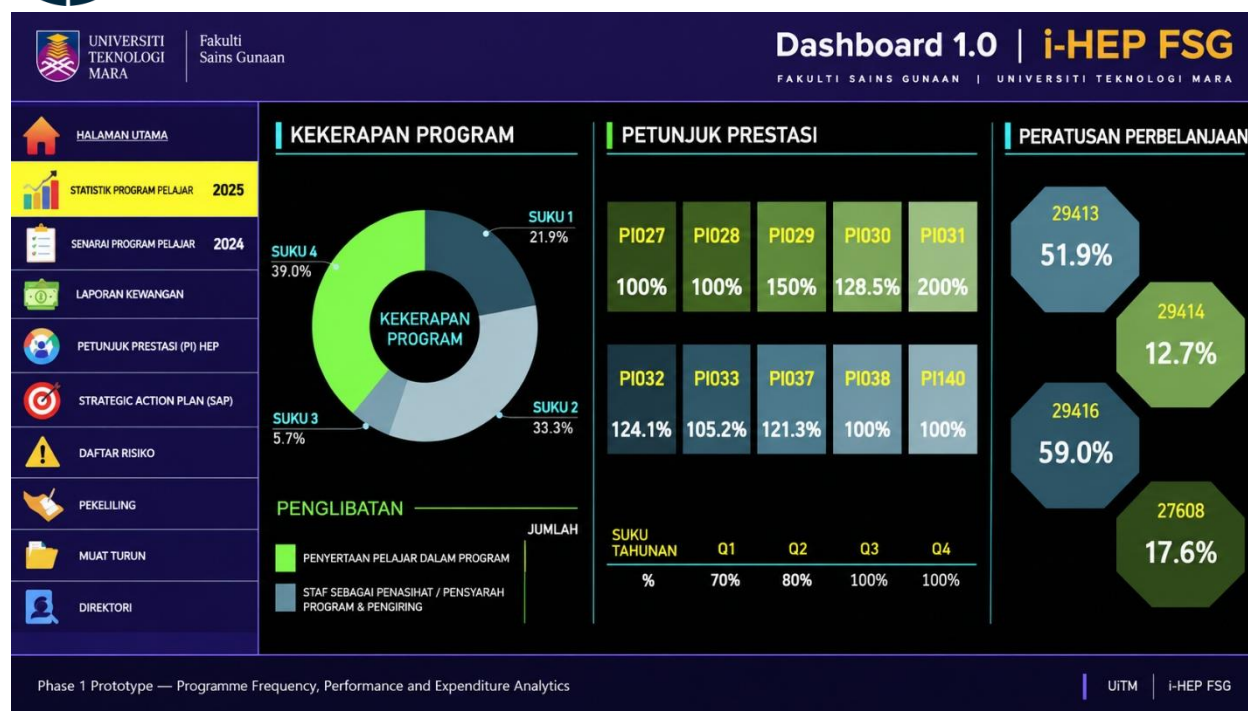


Figure 3. Phase 1 prototype displaying consolidated student activity statistics by organiser, level and programme category.

2.2. System Architecture

The system follows a three-layer architecture. The input layer captures source records for programmes, budgets and performance indicators. The processing layer applies an automated mapping engine that links daily operational data to strategic KPIs and performs financial reconciliation. The integration layer consolidates the processed data into a unified repository that feeds the visual interface—described in the project as a governance 'command centre'—presenting KPI mapping, actual-versus-target tracking and financial monitoring on a single screen.

2.3. Functional Modules

Three modules were engineered to correspond directly to the three governance gaps. (1) The automated PI-mapping framework establishes an integrated digital link between daily operational data and faculty performance indicators, tracking monthly and quarterly achievement against annual targets. (2) The centralised financial command centre establishes real-time visibility and control over fiscal resources, including variance alerts intended to guard against financial leakage. (3) The comprehensive visual monitoring system tracks the entire lifecycle of student programmes—from proposal and approval through execution to post-event analysis—with drill-down filtering by organiser, level and category.

2.4. Evaluation Method

Two forms of evidence were used. Operational data captured during live deployment across the 2024 and 2025 sessions provided objective measures of coverage and financial utilisation. In addition, a user-evaluation survey was administered to twenty-eight ($n = 28$) faculty administrators and stakeholders, using a five-point Likert scale to assess clarity, relevance, decision-support effectiveness and overall satisfaction.

Because the sample is small and single-site, the survey findings are treated as indicative user-acceptance evidence rather than as a generalisable experimental result.

3. RESULTS AND DISCUSSION

3.1. Programme Coverage and Data Consolidation

Following deployment, the dashboard consolidated previously dispersed student-activity records into a single interface segmented by organiser, level and category. The number of programmes captured rose from 71 in the 2024 session to 106 in the 2025 session, indicating both increased activity and, more importantly, more complete data capture within one authoritative system. Officers gained a holistic, real-time picture in place of fragmented spreadsheets, which is consistent with the argument that integrated dashboards raise institutional visibility and support evidence-informed decisions across stakeholder roles (CliftonLarsonAllen, 2022).

3.2. Real-Time Financial Control

The financial module provided live tracking of budget utilisation. For the 2025 session it recorded expenditure of RM65,898.04 against an allocation of RM133,340.00, a utilisation rate of 49.42%, alongside a code-level breakdown of spending across programme categories. Real-time monitoring of this kind allows allocation decisions to be referenced against current balances rather than stale figures, mitigating the risk of unplanned virement and supporting a forward-looking, forecasting posture instead of purely retrospective reporting. This directly addresses the accountability gap identified in Table 1 and reflects the established link between information timeliness and decision quality (DeLone & McLean, 2003).

3.3. Performance-Indicator Mapping

By automatically linking operational activity to faculty performance indicators and displaying actual-versus-target achievement on monthly and quarterly cycles, the dashboard enabled early identification of under-performing indicators while corrective action was still feasible. This operationalises the monitoring and problem-solving purposes for which dashboards demonstrably correlate with user productivity in performance-management settings (Yigitbasioglu & Velcu, 2012).

3.4. User Evaluation

The user-evaluation survey ($n = 28$) returned strongly positive results across all four statements, as shown in Table 2. For every statement, all respondents selected either 'Agree' or 'Strongly Agree', with 'Strongly Agree' the dominant response—27 of 28 respondents for both decision-support effectiveness and overall satisfaction. These results should be read as indicative user-acceptance evidence given the small, single-site sample; nonetheless, they align with the theoretical expectation that high-quality, timely information drives user satisfaction and perceived net benefit (DeLone & McLean, 2003).

Table 2. User-Evaluation Results ($n = 28$)

Evaluation Statement	Agree (n)	Strongly Agree (n)	Positive (%)
The dashboard presents information that is clear and easily understood	5	23	100
The data displayed is relevant and beneficial for monitoring student activities	3	25	100

Evaluation Statement	Agree (n)	Strongly Agree (n)	Positive (%)
The dashboard effectively supports the management and administration of student programmes	1	27	100
Overall satisfaction with the effectiveness of the dashboard	1	27	100

3.5. Strategic Value and Limitations

Taken together, the evidence supports the central argument that the dashboard converts governance data from a compliance burden into a strategic asset for decision-making. Its principal strength is high functional value at negligible marginal cost, achieved by exploiting an existing productivity ecosystem rather than procuring bespoke software. Two limitations temper this claim. First, reliance on a single third-party ecosystem introduces platform-dependency risk should pricing or service terms change. Second, the evaluation is based on one faculty and a modest sample, so effectiveness beyond this setting remains to be demonstrated. The dashboard is also, at present, descriptive and real-time rather than predictive; it reports current and historical states but does not yet forecast future ones.

4. CONCLUSION

The i-HEP FSG Dashboard 1.0 demonstrates that a single faculty unit can achieve real-time, integrated governance analytics by building on an existing cloud productivity ecosystem, without additional capital expenditure. By consolidating programme, budget and performance data into one authoritative view, the platform equips officers to make timely, evidence-informed strategic decisions, strengthens financial accountability through live variance visibility, and improves the completeness of institutional data. User-acceptance evidence, while preliminary, is strongly favourable.

The main practical implication is that the enabling constraint on data-driven governance in resource-limited units is design and integration, not the availability of enterprise software. The chief caveats are platform-dependency risk and the limited, single-site evidence base, both of which should qualify any claim of generalisable effectiveness.

Three recommendations follow. First, incorporate predictive and advanced analytics to forecast utilisation, financial risk and programme-performance trends from historical data. Second, add scenario ('what-if') modelling so that funding and policy options can be simulated before commitment. Third, extend the platform towards cross-faculty and inter-institutional benchmarking, evolving it from an operational dashboard into an intelligent governance platform. Future evaluation should also adopt a larger, multi-site design to test effectiveness rigorously. Pursued incrementally within the existing low-code architecture, these steps would align the tool with institutional sustainability and good-governance objectives.

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SECTION 9

SOCIAL SCIENCES



Understanding people. Inspiring positive change

RAYA-MAS

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Abstract

“RAYA-MAS” (Perayaan Malaysia) is a bilingual and dual-platform inclusive digital teaching and learning innovation developed for Year 6 History, specifically Unit 6: Malaysian Festivals. The innovation aims to address pupils' difficulties in achieving Learning Standards 11.3.1–11.3.3, particularly in stating the main festivals celebrated by different communities in Malaysia, explaining their purposes, and describing how these festivals were celebrated in the past and present. A pre-test involving 130 pupils revealed that 61.5% failed to achieve the minimum mastery level. To address this issue, “RAYA-MAS” was developed using a digital learning approach that integrates adaptive gamification, interactive multimedia, augmented reality (AR), virtual reality (VR), and bilingual web and Android platforms. Its effectiveness was assessed through pre- and post-tests in field and online settings. Results showed a 40.4% increase in the average mean score for the field group and 45.6% in the online group, with both groups achieving a 100% post-test pass rate. Future recommendations focus on expanding the innovation across different subjects, enriching interactive learning features, and increasing its implementation in more primary schools.

Keywords: History Education; Malaysian Celebrations; Digital Learning Innovation.

1. INTRODUCTION

The advancement of information and communication technology (ICT) has transformed the landscape of teaching and learning (T&L), while digital innovation is increasingly recognised as an enabler of sustainable development, improved quality of life and a more connected society. In Sarawak, efforts to strengthen digital participation and narrow the digital divide between urban and rural communities further highlight the importance of equitable access to digital opportunities (Rajang, 2026). However, effective ICT integration in education remains challenging due to limitations in teacher competency, facilities and access, changes in teaching practices, as well as the availability of appropriate learning resources and an inclusive digital learning culture. A systematic review by Ros Faizah et al. (2024), which examined 14 studies, identified ICT as an essential component of 21st-century teaching and learning while highlighting challenges associated with its effective implementation.

The advancement of ICT has also expanded the range of technologies that can support learning. In History education, Lee (2026) demonstrated that AI-driven digital innovations have the potential to support historical thinking and enhance student engagement, although their effectiveness remains influenced by teacher readiness, infrastructure and equitable access to technology. Similarly, Saputri et al. (2024) reported that web-based gamification using Genially significantly improved History learning motivation among Class XI-1 students at SMA Negeri 1 Porong, with the mean score increasing from 68.32 in the pre-test to 83.51 in the post-test. Likewise, Mani and Awang (2026), in a study involving 201 primary school pupils in Petaling Jaya, found a positive and significant relationship between the use of interactive

learning applications and pupils' interest in learning History. These findings demonstrate that digital technologies can enhance engagement and learning outcomes when appropriately integrated into educational contexts.

Nevertheless, an important research gap remains. Many previous studies have focused on a single technology or application in isolation, such as Genially-based gamification, interactive learning applications or AI-supported History education. Padli and Yasin (2023) further highlighted the tendency for technological tools to be implemented separately from pedagogical and content considerations, whereas effective technology integration requires alignment among technological, pedagogical and content knowledge through the TPACK framework. Therefore, the key challenge is no longer simply whether technology can be utilised in education, but how multiple technologies can be integrated meaningfully, systematically and coherently with curriculum objectives while ensuring inclusive access.

To address this gap, "RAYA-MAS" was developed as an inclusive digital learning innovation for Year 6 History, specifically Unit 6: Malaysian Festivals. Unlike previous approaches that primarily emphasise a single application or technology, "RAYA-MAS" integrates multimedia, AI, augmented reality (AR), virtual reality (VR) and adaptive gamification with mission-based learning activities within an interconnected, curriculum-aligned learning ecosystem. It further provides bilingual support in Malay and Chinese and is accessible through both web-based and Android platforms, thereby expanding access across different learning contexts. Its reusable and adaptable digital resources also support scalability and more sustainable implementation.

Therefore, "RAYA-MAS" is proposed not merely as a technological innovation, but as an inclusive and sustainable learning approach that leverages ICT to create a more interactive, meaningful and contextually relevant History learning experience. By integrating Malaysia's cultural and social diversity into a reusable digital ecosystem, "RAYA-MAS" seeks to empower learners through equitable access to History education while contributing to cultural understanding, digital inclusion and the broader goal of sustainable innovation for society.

2. MATERIALS AND METHODS

2.1. Needs Analysis and Research Design

The development of "RAYA-MAS" was guided by the content and learning standards outlined in the Year 6 History Textbook and the *Dokumen Standard Kurikulum dan Pentaksiran* (DSKP) for Year 6 History (Ahmad Salehee et al., 2021; Bahagian Pembangunan Kurikulum, 2021). A needs analysis was then conducted through brainstorming and engagement sessions with History teachers from four primary schools, namely SK Sarikei, SK Bau, SJK(C) Min Daik and SJK(C) Kai Chung. An initial pre-test involving all 130 pupils (83 in the field implementation and 47 in the online implementation) was conducted to establish the baseline of learning achievement. Based on the needs analysis and pre-test data, it was revealed that pupils faced significant difficulties in mastering Year 6 History Unit 6: Malaysian Festivals, which further informed the development of the innovation. To examine the effectiveness and usability of "RAYA-MAS", a mixed-method evaluation design was adopted. Quantitative data were obtained from pre-test and post-test assessments to measure changes in pupils' learning achievement, while qualitative data were collected through feedback questionnaires to capture the perceptions and experiences of both pupils and teachers.

2.2. Learning Components and Materials

“RAYA-MAS” comprises nine interconnected components developed according to the targeted learning standards and arranged as a progressive digital learning experience. A QR code was provided as a single access point to the “RAYA-MAS” digital ecosystem, together with its user manual, web page and Android application, as shown in Figure 1. The components were developed using appropriate digital tools, as summarised in Table 1.



Figure 1. QR Code, User Manual, Web Page and Android Application of “RAYA-MAS”

Table 1. Development Tools and Materials for the Innovation Components

Components	Development / Materials and Tools
EchoRaya	The adapted song was produced using Suno AI based on lyrics covering 12 Malaysian celebrations created by the innovators. Cartoon visuals were generated using ChatGPT and Gemini, transformed into short animated clips using Hailuo AI, and integrated with original voice recordings and audio editing through CapCut.
Pre-Test	A multiple-choice assessment instrument containing 10 items was developed via Google Forms.
KibRaya	The former calendar-based ChronoRaya was redesigned into an interactive digital archive mission, KibRaya. Learning information was structured using the 3WIH approach, while visual layouts, interactive navigation and original voice-over materials were developed and integrated using digital authoring tools.
RayaQuest	Animated festival narratives were generated using ChatGPT and Gemini, enhanced through Hailuo AI, combined with original voice-over recordings and edited using CapCut. Interactive quizzes for each island were developed using Wordwall.
RayaVerse	Learning information was organised using NotebookLM, while AR/VR integration were developed using Delightex Edu.
RayaRoom	The virtual learning space was developed using original HTML5, CSS and JavaScript code in Visual Studio Code. Room and traditional attire visuals were generated using Gemini, while Local Storage was implemented to retain pupils' progress and the system was deployed through GitHub.
Post-Test	The post-test was constructed in parallel with the pre-test, with shuffled question sequences incorporated to improve assessment reliability.
Feedback	User feedback was developed using Google Forms to collect pupils' and teachers' responses. The feedback mechanism was upgraded from manual certificate preparation and distribution to an automated appreciation-certificate process delivered via email.
Learning Materials	Learning materials were organised and stored digitally in Google Drive for convenient access.

2.3. Prototype Development and Testing

The prototype underwent internal functional testing before implementation. Testing focused on audio quality, multimedia synchronisation, navigation, dual-platform responsiveness, system logic, data storage and user experience. Identified issues were corrected through debugging and interface optimisation before field and online implementation.

2.4. Implementation Procedure



Figure 2. Field and Online Implementation

The completed innovation was implemented with a total of 130 Year 6 pupils through two modes: face-to-face field implementation (n=83) and online implementation (n=47). For the field implementation, participating school teachers administered the Pre-Test before the innovators introduced and facilitated the use of “RAYA-MAS”. Pupils then completed the learning activities using the innovation, followed by the Post-Test to measure changes in learning achievement. The field group comprised pupils from SK Sarikei, SK Bau, SJK(C) Min Daik and SJK(C) Kai Chung in Sarawak. For the online implementation, 47 pupils from Terengganu, Kedah, Selangor and Kelantan participated. The Pre-Test and Post-Test were administered digitally as part of the online implementation, with pupils accessing the innovation through the available digital platform. The online group consisted of 10 pupils from Terengganu, 11 from Kedah, 12 from Selangor and 14 from Kelantan. Only states with at least 10 respondents were included in the data analysis.

2.5. Evaluation Method

The effectiveness of “RAYA-MAS” was evaluated using descriptive statistics. Pupils' pre-test and post-test scores were compared to determine learning improvement. The mean scores for each participating school were calculated by dividing the total test scores by the number of pupils. The improvement score was determined by subtracting the pre-test mean from the post-test mean. In addition, the percentage of pupils achieving the passing criterion ($\geq 50\%$) before and after the intervention was compared.

3. RESULTS AND DISCUSSION

3.1. Results

Table 2. Comparison of Pre-Test and Post-Test Pass Rates

Types of Implementation	Pre-Test (a)	Post-Test (b)	Improvement (b-a)
Field (n=83)	43.4%	100%	+56.6%
Online (n=47)	29.8%	100%	+70.2%

Table 3. Analysis of Pre-Test and Post-Test Performance In Field Implementation

School	Pre-Test (a)	Post-Test (b)	Improvement (b-a)
SK Sarikei (n=25)	54.0%	86.8%	+32.8%
SK Bau (n=21)	46.7%	82.4%	+35.7%
SJK(C) Min Daik (n=12)	40.0%	87.5%	+47.5%
SJK(C) Kai Chung (n=25)	35.2%	80.8%	+45.6%
Average Improvement			+40.4%

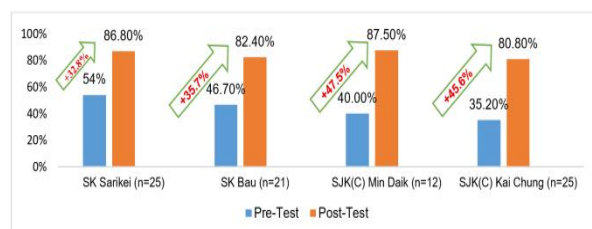


Figure 3. Field-Based Pre-Test and Post-Test Findings

Table 4. Analysis of Online Pre-Test and Post-Test Performance

State	Pre-Test (a)	Post-Test (b)	Improvement (b-a)
Terengganu (n=10)	45.0%	82.0%	+37.0%
Kedah (n=11)	31.8%	80.9%	+49.1%
Selangor (n=12)	38.3%	87.7%	+49.4%
Kelantan (n=14)	35.7%	82.7%	+47.0%
Average Improvement			+45.6%

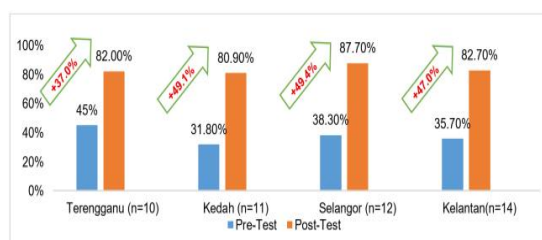


Figure 4. Online Pre-Test and Post-Test Findings

The effectiveness of “RAYA-MAS” was evaluated by comparing pupils' pre-test and post-test performance under both field and online implementation. As presented in Table 2, the post-test pass rate reached 100% in both implementation modes. The pass rate increased from 43.4% to 100% in the field implementation (+56.6 percentage points) and from 29.8% to 100% in the online implementation (+70.2

percentage points), indicating that all participating pupils achieved the minimum mastery level after using the innovation. Further analysis showed consistent improvements across all participating schools and states. In the field implementation, the average improvement in mean scores was 40.4 percentage points, with individual improvements ranging from 32.8 to 47.5 percentage points (Table 3 and Figure 3). Similarly, the online implementation recorded an average improvement of 45.6 percentage points, with improvements ranging from 37.0 to 49.4 percentage points across the four participating states (Table 4 and Figure 4). These findings suggest that “RAYA-MAS” supported improvements in pupils’ understanding of Year 6 History Unit 6 across different school contexts and implementation modes, demonstrating its potential to provide more inclusive access to successful learning outcomes and support scalability across diverse educational settings.

Table 5. Summary of User Feedback Questionnaire

Questionnaire Item	Strongly Agree
Learning is enjoyable	96%
More interactive	98%
Easier to remember	90%
Increased confidence	92%
Increased motivation	90%
More interested in History	90%
Suitable learning style	98%
Better than textbook	92%
Easier to understand	96%
Better understanding of festivals	96%

The user feedback questionnaire further supported the positive perceptions of “RAYA-MAS”. A total of 50 respondents completed the evaluation questionnaire after using the innovation. As presented in Table 5, respondents expressed highly positive perceptions towards the learning experience. Across the ten questionnaire items, between 90% and 98% of respondents selected “Strongly Agree”, while the remaining respondents selected “Agree”, with almost no responses recorded for “Disagree” or “Strongly Disagree”. The findings indicate that pupils perceived “RAYA-MAS” as an enjoyable, interactive and motivating learning innovation. Respondents agreed that the innovation helped them understand historical concepts more easily, improved their confidence in answering History questions, increased their interest in learning History and encouraged independent learning. In addition, most pupils preferred learning History using “RAYA-MAS” compared with conventional textbook-based instruction. These findings complement the quantitative improvements observed in the pre-test and post-test results, suggesting that the innovation was not only effective in improving academic achievement but also successful in enhancing pupils' motivation and overall learning experience.

3.2. Discussion

The findings suggest that meaningful ICT integration was associated with improved learning achievement and engagement, rather than the use of technology in isolation. This supports previous findings on gamification and interactive learning in History education (Saputri et al., 2024; Mani & Awang, 2026), while extending them through the integration of multimedia, AR/VR, gamification and bilingual accessibility within a curriculum-aligned ecosystem. More importantly, the findings also highlight the importance of inclusive digital design in expanding access to learning. Through its bilingual interface, dual-platform deployment, bilingual user manual, intuitive navigation, audio-guided learning, automated assessment, and affordable AR and VR experiences, “RAYA-MAS” provides diverse pathways for learners to access and engage with the same learning content. These features support more equitable participation in digital History learning by addressing linguistic, technological, and accessibility barriers, consistent with the educational equity dimension highlighted by Lee (2026). From a sustainability

perspective, “RAYA-MAS” provides learning materials that can be downloaded and reused without being limited to a single learning session or implementation. This allows teachers and learners to retain access to the materials for repeated learning and future use, while reducing the need to recreate learning resources for subsequent implementation. In addition, its modular digital structure allows learning content to be updated or adapted across different topics and subjects while retaining the underlying framework. The combination of reusable learning materials and an adaptable digital structure provides a practical basis for long-term educational application and wider replication. Consequently, “RAYA-MAS” has the potential to evolve from a subject-specific innovation into a transferable model of inclusive and sustainable digital learning that can be progressively expanded through wider real-world implementation.

4. CONCLUSION

The findings suggest that integrating adaptive gamification, immersive technologies and bilingual resources within a curriculum-aligned digital ecosystem can enhance pupils’ academic achievement, engagement and learning motivation. However, these generalisations are limited by the relatively small sample and focus on Year 6 History Unit 6. Therefore, broader validation is required. Theoretically, the findings support the principle that educational technology is most meaningful when integrated coherently with pedagogical and curriculum objectives. Practically, “RAYA-MAS” demonstrates how inclusive digital design, bilingual accessibility, dual-platform delivery and reusable learning resources can translate this principle into more equitable learning opportunities across diverse learner contexts. Overall, the innovation demonstrates the potential of an inclusive digital ecosystem to empower diverse learners through equitable access to meaningful History education. It is recommended that future implementation extend “RAYA-MAS” across diverse schools and subjects, supported by systematic monitoring and longitudinal evaluation to strengthen its inclusiveness, sustainability and scalability as well as advance the innovation from TRL 8 towards TRL 9.

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Needlens: A Diagnostic Framework For Targeted Urban Poverty Interventions

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Abstract

Targeting urban poverty interventions commonly relies on income thresholds, demographic classifications and multidimensional vulnerability measures to identify households requiring support. However, these approaches provide limited guidance on which essential opportunities remain inaccessible, the barriers preventing their use and the interventions best suited to address them. This conceptual paper proposes NeedLens, a diagnostic framework for translating vulnerability assessment into targeted urban poverty interventions. Grounded in the Capability Approach, NeedLens distinguishes between available opportunities and households' capability to benefit from them. The framework comprises five iterative processes: needs assessment, opportunity identification, conversion-barrier diagnosis, intervention matching and outcome review. Its main contribution lies in integrating fragmented diagnostic processes into a single systematic diagnostic framework. The framework systematically matches interventions to conversion barriers rather than visible needs alone. Consequently, households with similar visible needs may require different interventions because the barriers limiting their capabilities differ. Batu Pahat, Johor, is proposed as an initial setting for operationalising the framework and examining the distinction between spatial availability and usable access. Future research should develop measurable indicators, validate the framework with stakeholders and communities, and evaluate its effectiveness against existing intervention pathways.

Keywords: urban poverty; Capability Approach; conversion barriers; intervention matching; diagnostic framework

1. INTRODUCTION

Urban poverty involves interconnected disadvantages in income, employment, health, education, housing, mobility and access to essential services. Although income thresholds and multidimensional vulnerability measures identify households requiring support, they provide limited guidance on which opportunities remain inaccessible, what prevents their use and which interventions best address the barriers (Alkire & Foster, 2011; Wratten, 1995). The Capability Approach emphasises that the availability of employment, education, healthcare or training does not guarantee people's capability to benefit from them (Sen, 1999). Transport costs, disability, caregiving responsibilities, unsuitable schedules, limited information and administrative procedures may restrict participation and reinforce social exclusion (Lucas, 2012).

Consequently, identifying vulnerable households and selecting appropriate interventions remain analytically different tasks (Lindert et al., 2020).

NEEDLens addresses this gap through a capability-based process innovation integrating needs assessment, opportunity identification, conversion-barrier diagnosis, intervention matching and outcome review. Its originality lies in explicitly placing opportunity identification and barrier diagnosis between vulnerability screening and intervention selection, enabling households with similar visible needs to receive different responses according to their personal, social-institutional or environmental barriers. This study develops the framework through theory synthesis and demonstrates its decision logic using illustrative household scenarios. Batu Pahat, Johor, is proposed as the initial context for operationalisation because its approximately 495,300 residents are distributed across an urban centre, smaller towns and dispersed settlements, while essential opportunities are located across different areas (DOSM, 2022). This configuration enables future examination of whether spatially available opportunities are functionally usable by vulnerable households. NEEDLens provides a conceptual foundation for more inclusive intervention planning, indicator development, stakeholder validation and household piloting.

2. MATERIALS AND METHODS

This study employed a theory-synthesis approach to conceptual framework development. Theory synthesis integrates concepts from previously separate or insufficiently connected bodies of knowledge to explain a focal problem and specify new relationships (Jaakkola, 2020). The method was selected because the study aimed to develop a diagnostic process rather than collect primary data, test hypotheses or conduct an exhaustive systematic review. Framework development proceeded through five stages. First, the focal problem was defined as the diagnostic gap between vulnerability identification and intervention selection. This stage distinguished the identification of households requiring support from the determination of interventions aligned with the barriers affecting them.

Second, foundational and recent literature was purposively examined across four domains: multidimensional poverty and urban vulnerability, the Capability Approach, social exclusion and functional accessibility, and social protection delivery. Seminal sources established the theoretical constructs, while recent studies informed current debates concerning accessibility, capability and transport-related exclusion.

Third, the concepts were mapped according to five analytical roles: household need, required opportunity, conversion barrier, intervention option and intended outcome. Conversion barriers were classified as personal, social-institutional or environmental. This classification provided the basis for distinguishing formally available opportunities from opportunities that households could actually access, use and benefit from.

Fourth, the mapped concepts were synthesised into an iterative decision sequence comprising needs assessment, opportunity identification, conversion-barrier diagnosis, intervention matching and outcome review. Each process was connected through diagnostic questions that guide decision-makers from an identified need towards a barrier-matched intervention. Fifth, conceptual propositions, boundary conditions and illustrative household scenarios were developed to examine the internal decision logic of the framework. The scenarios compared households presenting the same visible need but experiencing different conversion barriers. They were used to demonstrate how NEEDLens produces differentiated intervention recommendations rather than to establish empirical effectiveness. The resulting framework constitutes a conceptual process innovation. It has not yet been empirically validated or implemented in Batu Pahat, Johor. Stakeholder assessment, indicator development and household piloting are therefore required before claims concerning its effectiveness or transferability can be established.

3. RESULTS AND DISCUSSION

3.1. The NEEDLens Diagnostic Framework

The theory-synthesis process produced NEEDLens, a capability-based diagnostic framework connecting vulnerability assessment with targeted urban poverty intervention. NEEDLens comprises five iterative processes: needs assessment, opportunity identification, conversion-barrier diagnosis, intervention matching and outcome review. The sequence is analytical rather than strictly linear because households may experience multiple needs and barriers, while outcome review may require earlier decisions to be reassessed. The first process, needs assessment, identifies the specific socioeconomic condition requiring improvement, such as unemployment, unmet healthcare needs, interrupted education, insecure housing or restricted social participation. Existing income classifications and multidimensional vulnerability measures remain valuable at this stage because they help identify households requiring further attention. The second process, opportunity identification, determines the substantive opportunity needed to address the identified condition. These opportunities may include suitable employment, TVET, education, healthcare, secure housing or social support. NEEDLens distinguishes substantive opportunities from enabling services. For example, employment is a substantive opportunity, whereas transport, childcare, digital access and administrative assistance may enable a household to access that opportunity.

The third process, conversion-barrier diagnosis, identifies what prevents the household from accessing, using or benefiting from the required opportunity. Based on the Capability Approach, these barriers are classified as personal, social-institutional or environmental (Robeyns, 2005). Personal barriers include health limitations, disability, skills and digital literacy. Social-institutional barriers include caregiving responsibilities, discrimination, service schedules, information gaps, eligibility requirements and administrative procedures. Environmental barriers include distance, transport availability, travel time, cost and physical design. The fourth process, intervention matching, compares potential responses according to the diagnosed barriers. Matching is not an automatic one-to-one prescription. A household may face several interacting barriers and consequently require a coordinated package of interventions. Selection must also consider feasibility, acceptability, cost, agency responsibility and household priorities. The fifth process, outcome review, examines whether the intervention reduced the diagnosed barrier, increased utilisation of the required opportunity and expanded the household's actual capability. Programme delivery alone is not treated as evidence of success. If the barrier persists or another constraint emerges, the case returns to diagnosis and intervention matching.

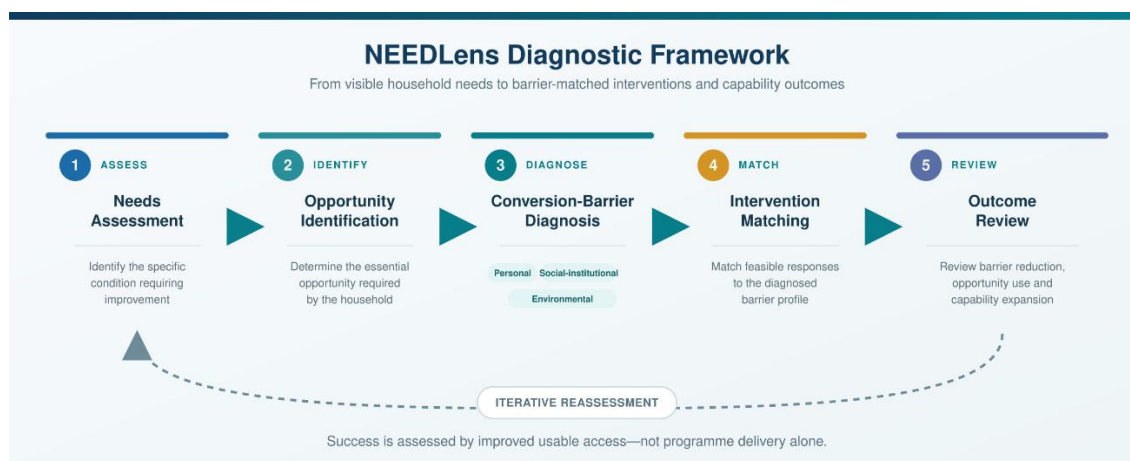


Figure 1. The NEEDLens Diagnostic Framework

3.2. Conceptual Innovation and Originality

The conceptual originality of NEEDLens lies in integrating fragmented diagnostic processes into a single systematic framework. It does not replace poverty measures, beneficiary databases or existing assistance programmes. Instead, it introduces a diagnostic bridge between vulnerability screening and intervention selection. Two intermediate judgements distinguish NEEDLens from a direct category-based pathway. First, decision-makers identify the essential opportunity required to improve the household's condition. Second, they diagnose the conversion barrier preventing the household from using that opportunity. These judgements shift intervention planning from responding to visible needs alone towards addressing the mechanisms producing inaccessible opportunities.

Table 1. Comparison Between a Category-Based Pathway and NEEDLens

Dimension	Category-based pathway	NEEDLens diagnostic pathway
Initial focus	Identifies households requiring support	Uses screening results to begin further diagnosis
Decision basis	Visible need, category or vulnerability score	Needs-to-opportunity gap and diagnosed barrier
Opportunity assessment	May not be explicitly identified	Identifies the opportunity required for improvement
Barrier assessment	May be incorporated inconsistently	Explicitly diagnoses conversion barriers
Intervention selection	Commonly aligned with the identified need or programme category	Matched to personal, social-institutional or environmental barriers
Household differences	Households with similar needs may receive similar responses	Similar needs may produce differentiated responses
Outcome focus	Assistance or programme delivery	Barrier reduction, opportunity utilisation and capability expansion

Source: Developed by the authors based on the conceptual synthesis

NEEDLens therefore contributes a relational innovation rather than claiming that its individual components are entirely new. Needs assessment, accessibility analysis and case management already exist in various forms. The innovation lies in systematically connecting need, required opportunity, conversion barrier, matched intervention and outcome review within one decision pathway. This structure operationalises a central principle of the Capability Approach: the same resource or service may produce different outcomes because people differ in their ability to convert it into a valued achievement (Sen, 1999). NEEDLens translates this theoretical principle into a diagnostic sequence for intervention planning.

3.3 Illustrative Barrier–Intervention Matching

The decision logic was demonstrated through illustrative unemployment scenarios. Four households may be classified as unemployed and appear to require the same employment-related intervention. However, NEEDLens differentiates their responses according to the barrier separating each household from suitable employment.

Table 2. Illustrative Application of Barrier-Based Intervention Matching

Household situation	Diagnosed barrier	Illustrative matched intervention
Lacks occupational competencies required by employers	Skills barrier	Targeted TVET and employment placement
Possesses relevant skills but cannot afford regular travel	Mobility and cost barrier	Transport subsidy or employment placement closer to the household
Cannot attend training or employment because of dependent-care responsibilities	Social-institutional barrier	Flexible scheduling or childcare support
Cannot complete eligibility or application procedures	Administrative barrier	Assisted application and coordinated agency referral

Source: Developed by the authors based on the conceptual synthesis

The scenarios demonstrate that visible need alone does not provide sufficient information for intervention selection. Repeatedly offering skills training to all four households would only address the first household's principal barrier. NEEDLens instead generates differentiated intervention options by identifying the mechanism limiting access. These scenarios are conceptual demonstrations and do not establish empirical effectiveness. Nevertheless, they provide evidence of the framework's internal decision logic and show how barrier diagnosis can alter intervention recommendations. Future testing should compare NEEDLens-generated recommendations with decisions produced through existing intervention pathways.

3.4 Proposed Application in Batu Pahat

Batu Pahat, Johor, is proposed as the initial context for operationalising NEEDLens. The district recorded approximately 495,300 residents in 2020 and comprises an urban centre, smaller towns and dispersed settlements (DOSM, 2022). Its employment, education, healthcare and government services are distributed across different locations, making it suitable for examining whether spatially available opportunities are functionally accessible to vulnerable households. An initial application could focus on unemployment. NEEDLens would identify the required employment or training opportunity, diagnose barriers such as skills, transport costs, caregiving or administrative requirements, and guide barrier-matched intervention selection. Outcome review would assess barrier reduction and opportunity utilisation rather than assistance delivery alone. Batu Pahat remains a proposed application context; empirical validation has not yet been conducted.

3.5 Societal Contribution and Scalability

NEEDLens is designed to support local authorities, welfare agencies, employment and TVET providers, healthcare organisations and community organisations. Its societal contribution lies in enabling differentiated interventions for households experiencing similar visible needs but different personal, social-institutional or environmental barriers. This may support more inclusive access to employment, education, healthcare and social services while improving cross-agency referral and coordination.

The framework is potentially scalable because its five-process structure can be adapted across services, population groups and locations. Following validation, it could be operationalised as a diagnostic toolkit comprising an assessment form, barrier checklist, intervention-matching matrix, referral pathway and outcome-review instrument. Stakeholder validation and household piloting remain necessary before effectiveness, user-friendliness and transferability can be established.

3.6 Alignment with Sustainable Development Goal (SDG) and Policy Priorities

NEEDLens supports SDGs 1, 10 and 11 by strengthening targeted social protection, recognising differences in household capabilities and promoting inclusive access to urban opportunities. Nationally, it aligns with the Thirteenth Malaysia Plan, 2026–2030, which prioritises inclusive social development, quality of life and empowerment of targeted groups. At the state and local levels, NEEDLens supports the people-centred and inclusive development objectives of the Johor State Structure Plan 2030, while the Batu Pahat District Local Plan 2030 provides a spatial planning context for future application. This alignment demonstrates the framework’s relevance to poverty reduction, social well-being and inclusive urban development.

4. CONCLUSION

NEEDLens provides a capability-based process innovation that connects vulnerability assessment with targeted urban poverty intervention through five iterative processes: needs assessment, opportunity identification, conversion-barrier diagnosis, intervention matching and outcome review. Its principal contribution lies in explicitly placing opportunity identification and barrier diagnosis between vulnerability screening and intervention selection, enabling households with similar visible needs to receive differentiated responses. The framework offers potential value to local authorities, service providers and community organisations by supporting more inclusive intervention planning, cross-agency coordination and usable access to essential opportunities. Batu Pahat is proposed as the initial setting for operationalisation, while its adaptable structure supports potential application in other locations. However, NEEDLens remains conceptual and requires indicator development, stakeholder validation, household piloting and comparison with existing intervention pathways before its effectiveness and transferability can be established.

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SECTION 10

SUSTAINABLE & GREEN TECHNOLOGY



Innovating today for a sustainable tomorrow

ECOSTAT ANALYTICS: AN INTERACTIVE WEB-BASED DASHBOARD FOR COMMUNITY CARBON FOOTPRINT TRACKING, PREDICTIVE ANALYTICS, AND WHAT-IF SIMULATIONS

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Abstract

Promoting environmental sustainability and achieving Net-Zero carbon emissions require actionable data insights across higher education institutions, small and medium-sized enterprises (SMEs), and local communities. However, non-technical decision-makers often face difficulties in converting multi-source consumption data into measurable carbon emissions and evaluating potential reduction strategies. This project introduces EcoStat Analytics, an open-access web dashboard developed using R Shiny that integrates carbon conversion, multivariate regression, six-month forecasting, and interactive What-If simulation. The platform converts monthly electricity consumption (kWh), transport fuel use (litres), and solid waste generation (kg) into carbon dioxide equivalent (CO₂e) emissions. Based on the simulated baseline of 7,202.19 kg CO₂e per month, a mild intervention reduced projected emissions by 456.89 kg CO₂e (6.3%), while a moderate intervention reduced emissions by 1,010.79 kg CO₂e (14.0%). Under an aggressive intervention involving a 30% reduction across all three emission sources, projected monthly emissions decreased to 5,041.53 kg CO₂e, representing a reduction of 2,160.66 kg CO₂e (30.0%). These findings demonstrate that EcoStat Analytics produces immediate and mathematically consistent scenario outputs, enabling users to compare Business-As-Usual and intervention trajectories in real time. The platform offers an accessible and scalable tool for evidence-informed sustainability planning among institutions, SMEs, communities, and non-technical stakeholders.

Keywords: Carbon Footprint Tracking; Interactive Dashboard; Multivariate Regression; Predictive Analytics; R Shiny; Sustainability.

1. INTRODUCTION

Achieving environmental sustainability and Environmental, Social, and Governance (ESG) compliance based on recognized reporting protocols (WRI & WBCSD, 2015) has become a critical objective for organizations, academic institutions, and municipal communities worldwide (IPCC, 2023). Despite growing motivation to adopt green practices, tracking and managing carbon emissions remains a major operational challenge for non-technical stakeholders (Wiedmann & Minx, 2008). Recognized carbon-reporting frameworks require organizations to convert operational activity data, including electricity consumption, fuel use, and waste generation, into standardized CO₂e inventories for meaningful monitoring and decision-making (WRI & WBCSD, 2015).

Conventional tracking methods rely on static spreadsheet tables and periodic reports. While informative, static tools lack dynamic visual analytics, fail to illustrate complex multivariate relationships between activity drivers, and cannot simulate future outcomes under varying policy scenarios (Song et al., 2022). Although commercial ESG platforms exist, many require costly subscriptions, complex software deployments, or advanced technical expertise (Sievert, 2020).

To address these limitations, this study introduces EcoStat Analytics, an interactive, lightweight web application built using the R Shiny framework (Chang et al., 2023). The primary objective of EcoStat Analytics is to democratize predictive environmental analytics by integrating multivariate linear regression with real-time time-series forecasting and dynamic 'What-If' scenario modelling. By enabling users to manipulate consumption reduction targets via interactive sliders, EcoStat Analytics transforms abstract sustainability targets into actionable visual feedback (Song et al., 2022).

2. MATERIALS AND METHODS

This section details the system architecture, mathematical models, and data generation mechanisms underlying the EcoStat Analytics platform.

2.1. System Architecture and Technology Stack

EcoStat Analytics was built using the R programming language (v4.1.0) and the *shiny* web application framework (Chang et al., 2023). Graphical rendering was developed using *ggplot2* to ensure high-resolution visual outputs (Sievert, 2020). Data manipulations were executed via the *dplyr* package. The application operates via any standard web browser without requiring local software installation.

2.2. Mathematical Modelling and Carbon Conversion Factors

The simulation model incorporates standard carbon emission factors established by international reporting standards (WRI & WBCSD, 2015) to convert raw activity inputs into total equivalent carbon dioxide (CO₂e) emissions (kg):

- i. Electricity (X_1 , kWh): 0.584 kg CO₂/kWh (WRI & WBCSD, 2015)
- ii. Transport Fuel (X_2 , Liters): 2.310 kg CO₂/Liter (WRI & WBCSD, 2015)
- iii. Solid Waste (X_3 , kg): 1.900 kg CO₂/kg (IPCC, 2023)

The baseline total carbon emission (Y_t) for month t is calculated via multivariate summation (Wiedmann & Minx, 2008):

$$Y_t = 0.584X_{1,t} + 2.310X_{2,t} + 1.900X_{3,t} + \varepsilon_t$$

where $\varepsilon_t \sim N(0, \sigma^2)$ represents random operational variation.

For the interactive 'What-If' simulation, future baseline projections (Y_{BAU}) are compared against intervened projections ($Y_{Intervention}$) modified by user-selected percentage reduction parameters ($r_1, r_2, r_3 \in [0, 50\%]$) (Song et al., 2022):

$$Y_{Intervention} = 0.584X_{1,t}(1 - r_1) + 2.310X_{2,t}(1 - r_2) + 1.900X_{3,t}(1 - r_3)$$

2.3. Novelty of the Innovation

The novelty of EcoStat Analytics lies in combining three decision stages that are commonly handled separately: carbon conversion, statistical driver analysis, and forward-looking scenario planning. Rather than functioning only as a historical reporting dashboard, the platform converts electricity, transport fuel,

and solid-waste activity data into CO₂e, examines the contribution of multiple emission drivers through regression, projects a six-month Business-As-Usual pathway, and allows users to test alternative reduction targets through interactive What-If sliders. Each adjustment immediately generates a corresponding intervention trajectory for comparison with the baseline, creating a continuous decision loop from raw operational data to a prospective sustainability strategy. This integration is the project's distinctive contribution: it shifts carbon monitoring from passive retrospective recording to active, visual, and evidence-informed planning. The browser-based, zero-cost interface also makes predictive environmental analytics accessible to institutions, SMEs, communities, and non-technical decision-makers without specialized software or programming skills.

3. RESULTS AND DISCUSSION

This section highlights the empirical performance of EcoStat Analytics in rendering real-time scenario forecasts and multivariate regression analytics.

3.1. Interactive Time-Series Forecasting and 'What-If' Simulation

EcoStat Analytics displays historical monthly emissions alongside a 6-month projected forecast. Figure 1 illustrates the forecasting dashboard under a scenario where the user applies a 10% reduction in electricity, a 15% reduction in fuel, and a 20% reduction in waste.

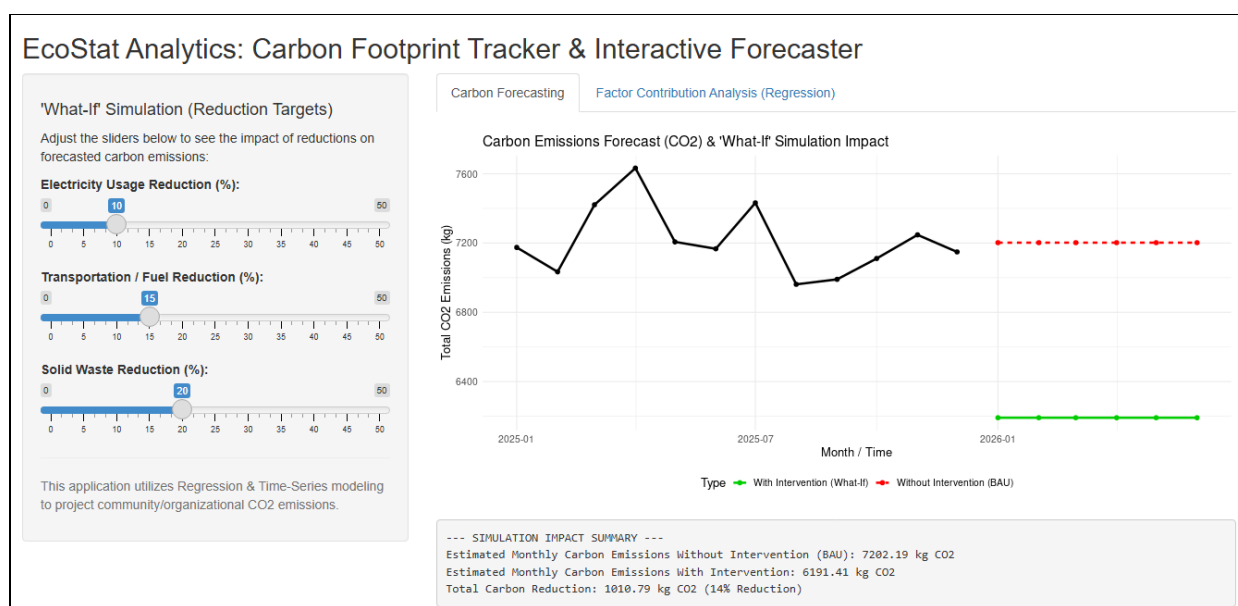


Figure 1. EcoStat Analytics interface displaying 6-month predictive carbon trajectories under Business-As-Usual (BAU) versus intervened scenarios.

As illustrated in Figure 1, the dynamic slider controls allow real-time visual tracking of projected carbon pathways over a 6-month period (Song et al., 2022). Beyond time-series projections, EcoStat Analytics also evaluates the statistical influence of individual consumption drivers on overall emissions using multivariate linear regression modelling. Figure 2 demonstrates the linear relationship between electricity-related carbon outputs and total community emissions.

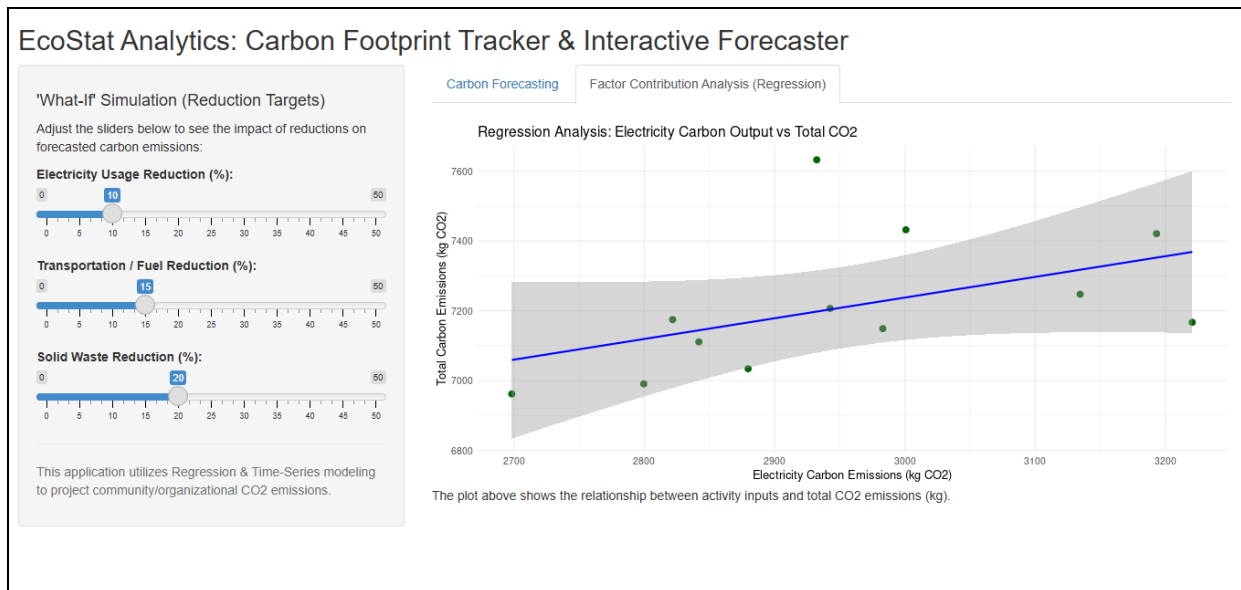


Figure 2. Linear regression relationship between carbon electricity output and total community emissions.

The scatter plot and fitted linear trendline in Figure 2 confirm a strong positive linear relationship between electricity consumption emissions and total carbon output. This empirical alignment validates that targeted electricity reductions yield substantial proportional drops in total emissions, providing an evidence-based foundation for the scenario parameters modelled in Table 1.

3.2. Quantitative Scenario Evaluation

To demonstrate system responsiveness across different intervention levels, Table 1 compares projected emissions under varying intervention scenarios against historical baseline values.

Table 1. Projected Carbon Emissions across Varying 'What-If' Reduction Scenarios

Scenario Level	Electricity Red. (r1)	Fuel Red. (r2)	Waste Red. (r3)	Projected Monthly Emission (kg CO ₂ e)	Monthly Carbon Reduced (kg CO ₂ e)	Percentage Reduction (%)
Baseline (BAU)	0%	0%	0%	7202.19	0.00	0.0%
Mild Intervention	5%	5%	10%	6745.30	456.89	6.3%
Moderate Intervention	10%	15%	20%	6191.41	1010.79	14.0%
Aggressive Intervention	30%	30%	30%	5041.53	2160.66	30.0%

Reference: EcoStat Analytics Output (2026)

The empirical results in Table 1 confirm that EcoStat Analytics provides immediate, mathematically consistent parameter outputs. Observing these numeric shifts in real time alongside plot adjustments significantly strengthens user engagement and assists sustainability managers in setting realistic ESG goals (Song et al., 2022).

4. CONCLUSION

EcoStat Analytics successfully addresses the gap in community-level carbon footprint tracking by offering an intuitive, web-based analytics framework (Song et al., 2022). By combining multivariate regression modelling, time-series forecasting, and interactive 'What-If' scenario sliders, the platform demystifies carbon data and empowers non-technical users to make informed ESG decisions (IPCC, 2023). EcoStat Analytics provides a zero-cost, highly scalable solution for academic institutions, SMEs, and municipal organizations. Future work will focus on integrating automated CSV data uploading capabilities, IoT-based smart meter API connections, and expanding financial cost-saving estimation modules.

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SECTION 11

TECHNOLOGY IN EDUCATION



Empowering learning through technology.

Immersive AI Otoscopy

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Abstract

Immersive AI Otoscopy is an advanced platform that integrates Extended Reality (XR), the Metaverse, and Artificial Intelligence (AI) to enhance the visualization and learning of otological anatomy. Traditional learning methods often rely on static 2D images or invasive approaches, which fail to fully represent the complex spatial structures of the middle and inner ear. This system overcomes those limitations by providing an immersive and interactive 3D environment for students, educators, and clinicians. The platform offers an engaging way to explore ear anatomy in dynamic 3D, improving clarity, comprehension, and learner interest. Developed using Unity and 3D modelling tools, it also has strong commercialization potential for medical schools, hospitals, and hearing healthcare institutions. The study employed a pre-test and post-test experimental design. Participants first completed a baseline assessment measuring spatial understanding, structure identification, and conceptual knowledge using conventional 2D diagrams. They then learned through the immersive 3D system. Results showed that Immersive AI Otoscopy significantly improved anatomical understanding, engagement, and spatial awareness, leading to higher post-test performance. By transforming interactive learning and diagnostic experiences, the platform advances medical education while opening opportunities for digital innovation across multiple sectors. It was designed to address limitations of existing learning tools and may further evolve through the integration of advanced AI-driven simulations.

Keywords: Metaverse; interactive; AI; anatomy; visualization.

1. INTRODUCTION

Anatomy education, particularly for complex regions such as the middle and inner ear, has traditionally relied on two-dimensional diagrams, physical models, and cadaver dissections. However, otolaryngological surgery demands precise understanding of intricate three-dimensional relationships between anatomical structures (McJunkin et al., 2018). While conventional methods remain essential, they often struggle to adequately represent this spatial complexity. With technological advancement, medical education has increasingly adopted eXtended Reality (XR) to address these limitations (Hauze et al., 2019; Zweifach and Triola, 2019; Tang et al., 2022; Kaushik et al., 2025). XR, encompassing Virtual Reality (VR), Augmented Reality (AR), and hybrid systems, has gained prominence due to its ability to enhance spatial understanding, engagement, and knowledge retention (Herur-Raman et al., 2021). Meta-analyses report that XR-based learning significantly outperforms traditional approaches, with a standardized mean difference of 0.52 (95% CI: 0.40–0.63), especially when used alongside conventional teaching (García-Robles et al., 2024). In

otology, systems such as OtoVIS demonstrate strong educational value, with high face and content validity reported by trainees (Shin et al., 2023; Al-Hor et al., 2024). However, many existing platforms still lack real-time interaction, AI integration, and clinical applicability (Chheang et al., 2024). To address these gaps, Immersive AI Otoscopy was developed as an AI-enhanced XR platform incorporating metaverse-style interaction for dynamic exploration of otologic anatomy. It is designed for medical students, educators, and clinicians, supporting both learning and diagnostic applications. XR exists on a spectrum: AR overlays digital content onto the real world, while VR immerses users in a fully virtual environment with limited interaction with physical surroundings. Earlier VR systems required high-performance computers, head-mounted displays, controllers, and external tracking systems, known as tethered VR with outside-in tracking. Modern XR hardware, however, has become more affordable, portable, and user-friendly. Devices such as the Oculus Quest 2 offer standalone functionality, making immersive learning more accessible, while newer systems like the Quest 3 continue to expand capabilities for professional and educational use.

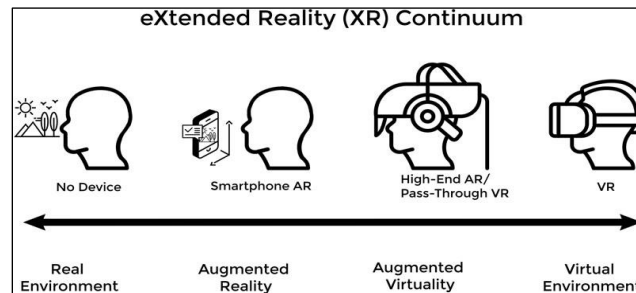


Figure 1. The XR Continuum shows a progression from an entirely real environment to an entirely virtual environment with various XR devices facilitating movement along the continuum.

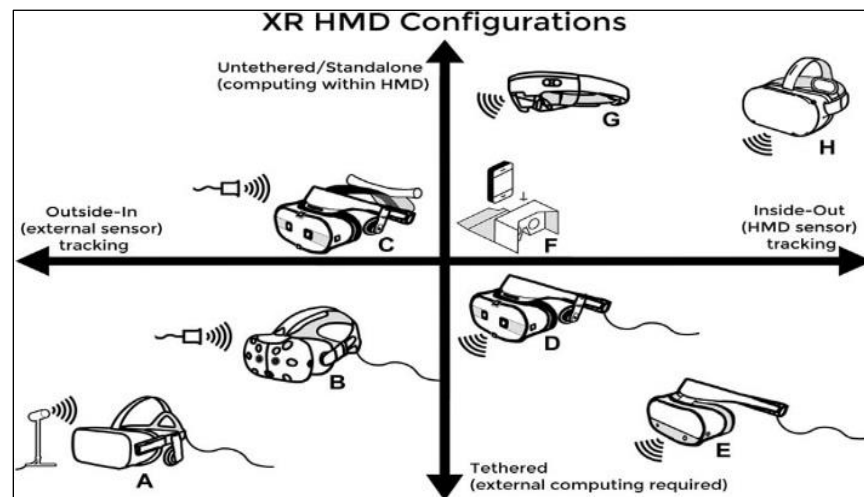


Figure 2. (A) the Oculus Rift and (B) the HTC Vive headsets are both tethered and externally-tracked VR headsets from 2016 (C) and (D) are two different variations of the HTC Vive Cosmos Headset that can be configured to have either external tracking and be untethered via a wireless adaptor or have inside-out tracking and be tethered to a PC (E) the Oculus Rift S, which features inside-out tracking and is PC tethered (F) simple phone VR devices such as the Google Cardboard, which requires no external trackers and uses the on-board smartphone as the processor and motion sensor (G) the Microsoft HoloLens AR headset, which features an on-board processor and inside-out tracking (H) the Oculus Quest 2, which represents the newest HMD configuration: standalone or untethered VR with inside-out tracking.environment with various XR devices facilitating movement along the continuum.

2. MATERIALS AND METHODS

The Immersive AI Otoscopy architecture combines extended reality hardware with advanced rendering technologies and artificial intelligence capabilities to deliver an immersive, interactive visualization of otologic anatomy with real-time feedback. The platform is compatible with mixed reality headsets such as the Meta Quest 2, Meta Quest 3, and other similar XR devices, allowing users to explore anatomical structures within a realistic three-dimensional environment. At the core of the system are high-resolution two-dimensional anatomical images that are transformed into highly detailed 3D models. These models are enhanced through photorealistic rendering techniques, including subsurface scattering and hybrid surface-volume visualization, to achieve realistic lighting effects, depth perception, and accurate texture representation. To maintain both visual quality and system efficiency, foveated rendering is employed so that only the area directly within the user's gaze is displayed at maximum detail, reducing computational demand while preserving immersion. Figure 3 presents the navigation flow of the Immersive AI Otoscopy platform within the XR environment.



Figure 3. Immersive AI Otoscopy platform.

The system includes multiple multimedia components such as images, videos, and communication features including voice, video, and chat to create an engaging environment where students can collaborate effectively. This approach enriches the learning process and supports a deeper understanding of complex subjects that depend on visualization and diagram-based problem solving. Interactivity is a key component of Immersive AI Otoscopy. Users can manipulate otologic structures through hand tracking or controllers, rotate and enlarge microanatomical features, and switch between anatomical layers such as blood vessels, nerves, ossicles, and cochlear components. Real-time annotations and integrated learning modules provide instructional guidance, while clinical simulation features enable the exploration of pathological conditions. Furthermore, Immersive AI Otoscopy integrates an AI-driven virtual assistant capable of communicating with users through natural language. Powered by generative AI, the assistant can respond to anatomical questions, identify requested structures, and deliver context-sensitive explanations, creating an experience similar to learning with an expert tutor inside the immersive environment.

2.1 Validation Study Design

This section focuses on the design and implementation of the proposed XR-based Immersive AI Otoscopy platform. Special emphasis is placed on the conceptual development of the integrated system to ensure both modularity and adaptability. To evaluate the educational effectiveness of Immersive AI Otoscopy, a validation study was proposed involving three participant groups: first-year medical students from the Department of Otolaryngology, College of Public Health and Medicine at a local university, along with anatomy experts, ENT surgeons, and medical students (Figure 4). The research adopted a pre-test and post-test experimental design. Participants initially completed a baseline assessment measuring their spatial understanding of ear anatomy, ability to identify structures, and conceptual knowledge using traditional two-dimensional diagrams. They were then introduced to Immersive AI Otoscopy through guided sessions in which they explored middle and inner ear anatomy within the immersive three-dimensional environment.

After the intervention, participants completed a post-test that followed the same structure as the initial assessment. Face and content validity were assessed using a structured questionnaire adapted from previously established validation frameworks, including those applied in the OtoVIS study. Participants evaluated realism, accuracy of anatomical visualization, and educational value using a 10-point Likert scale. Additional questions examined ease of navigation, level of interactivity, and the perceived usefulness of the AI assistant. User perception was further measured through a post-experience survey that explored engagement, enjoyment, and overall satisfaction with the learning process. Pre-test and post-test results were compared to determine the extent of learning improvement associated with Immersive AI Otoscopy. Quantitative data were analyzed using paired t-tests and effect size measurements, while qualitative responses from open-ended feedback were examined through thematic analysis.



Figure 4. Immersive AI Otoscopy system expert and students testing.

3. RESULTS AND DISCUSSION

Although large-scale implementation is still in progress, the expected outcomes of Immersive AI Otoscopy align with findings from previous XR-based medical education studies. Early pilot sessions indicate that users perceive the platform as highly realistic and educationally valuable. Consistent with OtoVIS, face and content validity scores are projected to exceed 8 out of 10, particularly for visualization of complex structures such as the ossicular chain and cochlea. Significant improvements in learning performance are also anticipated, with students and residents expected to show notable gains between pre-test and post-test assessments. Key competencies, including spatial orientation of inner ear anatomy, recognition of structural relationships, and identification of surgical landmarks, are likely to improve following XR exposure. These outcomes align with meta-analytic evidence reporting moderate effect sizes for XR compared with traditional two-dimensional learning. User feedback further indicates high engagement and satisfaction. Participants reported that the AI assistant enhances active learning by providing immediate guidance, clarifying complex concepts, and supporting self-directed exploration. Clinicians and residents also highlighted its potential beyond education, particularly in surgical planning and patient counselling, reinforcing its long-term clinical value.

Table 1. Learning Perspective on Anatomy learning using Immersive AI Otoscopy platform (Pre-test).

No.	Statement	1	2	3	4	5	6	7
1.	I am interested in learning anatomy.	0	1	1	2	5	8	13
2.	Human anatomy is easy to learn currently.	0	0	2	3	7	10	8
3.	Using interactive 3D tools (like VR) can help improve my understanding of anatomy.	0	0	0	2	4	10	14

(1 = Strongly Disagree to 7 = Strongly Agree).

The pre-test results (Table 1) show a generally positive perception of anatomy learning and interactive 3D technologies. Most students expressed strong interest in anatomy, indicating high intrinsic motivation. While they acknowledged some difficulty in the subject, most considered it manageable. Students also strongly supported the use of interactive 3D tools such as VR, with high agreement that these technologies

improve understanding. Overall, the findings suggest that immersive tools enhance learning by providing visual and spatial experiences not available in traditional teaching, supporting their integration to improve engagement, comprehension, and student motivation in anatomy education.

Table 2. Virtual Reality Perspective Questionnaire (Pre-test).

No.	Statement	1	2	3	4	5	6	7
1.	VR is a useful tool in classroom learning.	0	0	1	2	5	10	12
2.	VR enhances visualization of anatomical structures.	0	0	0	2	4	11	13
3.	I believe VR will become common in education soon.	0	1	1	3	5	9	11
4.	VR makes learning more engaging compared to slides or books.	0	0	1	2	5	10	12
5.	The VR experience improved my focus during learning.	0	0	1	3	6	9	11
6.	VR can simplify complex medical concepts	0	0	0	2	5	11	12
<i>(1 = Strongly Disagree to 7 = Strongly Agree).</i>								

Table 2 shows highly positive perceptions of VR in education. Students agreed that VR is a valuable learning tool and enhances visualization of anatomical structures, improving spatial understanding and retention. They expressed optimism about its future role in education, expecting wider adoption. VR was also reported to increase engagement, concentration, and motivation compared to traditional methods. Additionally, it helps simplify complex medical concepts, making difficult content easier to understand. Overall, the findings strongly support VR as an effective and engaging educational tool, particularly in anatomy and medical education where spatial visualization is essential.

Table 3. Learning Perspective on Anatomy learning using Immersive AI Otoscopy platform (Post-test).

No.	Statement	1	2	3	4	5	6	7
1.	I am interested in learning anatomy.	0	1	1	2	5	8	13
2.	Human anatomy is easy to learn currently.	0	0	2	3	7	10	8
3.	Using interactive 3D tools (like VR) can help improve my understanding of anatomy.	0	0	0	2	4	10	14
4.	VR is a useful tool in classroom learning.	0	0	1	2	5	10	12
5.	VR enhances visualization of anatomical structures.	0	0	0	2	4	11	13
6.	I believe VR will become common in education soon.	0	1	1	3	5	9	11
4.	VR makes learning more engaging compared to slides or books.	0	0	1	2	5	10	12
7.	The VR experience improved my focus during learning.	0	0	1	3	6	9	11
8.	VR can simplify complex medical concepts	0	0	0	2	5	11	12
<i>(1 = Strongly Disagree to 7 = Strongly Agree).</i>								

Post-test results (Table 3) show that students remained highly motivated with positive attitudes toward anatomy learning and VR-based tools. They reported strong interest in anatomy and believed that interactive 3D technologies improved understanding. Although some still found anatomy challenging, most considered it manageable. Students strongly supported VR, noting better visualization, engagement, focus, and comprehension compared to traditional methods. Many also expected VR to become a standard

educational tool. Overall, findings indicate that immersive technologies enhance engagement, spatial understanding, and conceptual learning. Immersive AI Otoscopy further demonstrates XR's potential in medical education, offering realistic, interactive learning supported by AI-driven, constructivist approaches.

The validation study, combining knowledge assessment and user experience evaluation, provides a comprehensive measure of effectiveness. If the expected outcomes are achieved, the platform may offer strong evidence of improved learning performance compared with conventional methods. High engagement and satisfaction levels also suggest that XR technologies can enhance motivation while addressing issues of low attention and poor retention commonly seen in traditional learning environments. However, several limitations must be considered. Access to XR hardware remains limited in some institutions, and the high cost of advanced devices may restrict large-scale adoption. Although the anatomical models are highly accurate, they are based on selected imaging datasets and may not fully represent the full range of anatomical variations or clinical pathologies. In addition, integrating Immersive AI Otoscopy into existing curricula requires faculty training, institutional readiness, and alignment with learning outcomes. Despite these challenges, the platform extends beyond a supplementary educational tool. Its potential applications in preoperative planning, telemedicine, and patient education highlight its broader clinical relevance. Future improvements should include expanded anatomical and pathological libraries, stronger AI-driven adaptive learning, procedural guidance, and diagnostic support. Collaborative metaverse features, clinical simulation with DICOM integration, VR-based surgical rehearsal, and intraoperative reference tools would further enhance functionality. Overall, Immersive AI Otoscopy represents a foundation for next-generation digital medical training systems.

4. CONCLUSION

Immersive AI Otoscopy embodies an innovative integration of immersive XR technology and AI-driven interaction specifically designed for otological anatomy education. Built upon proven XR effectiveness and realistic 3D modelling, the platform has strong potential to improve learning performance, user engagement, and future clinical applications. Through continuous refinement, user evaluation, and evidence-based educational studies, Immersive AI Otoscopy may play a significant role in advancing medical teaching practices and otologic diagnostic methods.

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SB-UP: Enhancing Student Experience Through a Comprehensive Digital Support Platform for Learning *Simpulan Bahasa* and *Peribahasa*

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Abstract

Many primary and secondary school students find it challenging to understand and apply *Simpulan Bahasa* and *Peribahasa* because these topics are often taught using conventional methods that lack interactive and engaging learning experiences. To address this challenge, SB-UP was developed as a web-based learning platform dedicated to strengthening students' mastery of Malay idiomatic expressions through interactive digital resources. The platform serves as a one-stop repository that integrates educational comics, digital storybooks, and gamified learning activities centred on *Simpulan Bahasa* and *Peribahasa*. SB-UP emphasises user-friendly navigation, mobile accessibility, and self-paced learning, enabling students to explore language concepts anytime and anywhere using computers, tablets, or smartphones. By combining storytelling, visual learning, and game-based activities, SB-UP transforms traditional language learning into an enjoyable and meaningful experience. The platform encourages active participation, improves vocabulary retention, enhances reading comprehension, and promotes the correct use of figurative language in daily communication and writing. Teachers can also utilise the platform as a supplementary teaching resource to enrich classroom instruction. Overall, SB-UP provides an innovative, accessible, and engaging digital learning ecosystem that supports 21st century language education while fostering appreciation for the richness of the Malay language and cultural heritage among young learners.

Keywords: Malay idiomatic; web-based; educational comics; digital storybooks; gamified learning.

1. INTRODUCTION

The rapid advancement of digital technology has transformed the educational landscape, encouraging schools to integrate technology into teaching and learning. Digital learning platforms provide students with opportunities to learn independently while allowing teachers to deliver engaging lessons using multimedia resources. Such platforms have become increasingly important in supporting 21st century learning skills, including creativity, collaboration, communication, and critical thinking.

Within the Malaysian education system, *Simpulan Bahasa* and *Peribahasa* are important components of the Malay Language curriculum. These figurative expressions enrich vocabulary, strengthen communication skills, and cultivate appreciation for the nation's linguistic and cultural heritage. Students

are expected to understand their meanings and apply them appropriately in reading comprehension, essay writing, and oral communication.

Despite their importance, many students struggle to master these topics. Conventional teaching methods often rely on memorising lists of idiomatic expressions without sufficient contextual understanding. This approach can reduce students' interest and motivation while making it difficult for them to retain and apply what they have learned.

Cognitive Load Theory (Sweller, 1988) suggests that human working memory has limited capacity. When young learners are forced to process abstract textual idioms alongside unfamiliar figurative meanings, cognitive overload occurs. Paivio's (1990) Dual-Coding Theory demonstrates that combining verbal information with visual representations creates dual memory traces, significantly improving recall and conceptual retention. By illustrating the underlying scenario of an idiom, digital media lowers extraneous cognitive load and fosters deeper processing (Sukaba et al., 2026).

Storytelling provides a meaningful framework for language learning (Egan, 1986). Narrative structures allow learners to observe cause-and-effect relationships, emotional cues, and social interactions where idioms naturally occur. Recent studies on computer-assisted language learning (CALL) highlight that digital comic strips and interactive storybooks enhance vocabulary retention and learner motivation compared to traditional text-only worksheets (Thiagarajah et al., 2022; Rasmet et al., 2025).

As digital media increasingly occupies children's leisure time, traditional oral and written heritage risks becoming obsolete if not adapted for digital formats (Chong & Yahaya, 2025). Interactive platforms like SB-UP serve a dual purpose, achieving modern curricular learning outcomes while preserving Malay cultural heritage in a format aligned with contemporary learning habits.

2. MATERIALS AND METHODS

SB-UP was developed as a comprehensive web-based platform dedicated to the learning of *Simpulan Bahasa* and *Peribahasa*. The platform integrates a variety of interactive learning resources into a single digital environment, providing students with an engaging and accessible learning experience. Figure 1 shows the design and development process comprising three main phases: core architecture design, content development, and platform implementation to ensure functionality, usability, and readiness for educational use.

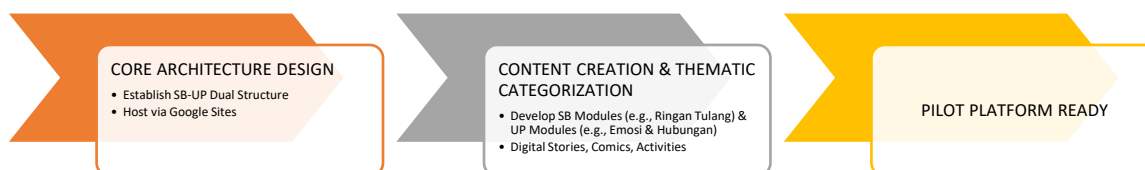


Figure 1. The Design and Development Process of SB-UP.

SB-UP was developed by integrating the following key learning components to provide an engaging and interactive learning experience.

Interactive Games:

Learning is reinforced through interactive matching games, as shown in Figure 2. The games are organised into three thematic categories: Emotions & Relationships (*Emosi & Hubungan*), Attitudes & Behaviour (*Sikap & Kelakuan*), and Wisdom & Moral Values (*Pengajaran & Kebijaksanaan*). Organising the

activities according to these themes enables students to understand and distinguish the meanings of *Simpulan Bahasa* and *Peribahasa* within meaningful contexts. This thematic approach enhances vocabulary retention, strengthens comprehension of figurative language, and encourages the appropriate application of idiomatic expressions in everyday communication.



Figure 2. Interactive Game.

Digital Comics:

Digital comics, as illustrated in Figure 3, present *Simpulan Bahasa* through familiar real-life situations and engaging narratives. By combining visual storytelling with contextual dialogue, the comics help students infer the meanings of idiomatic expressions naturally rather than relying on rote memorisation. This approach improves reading comprehension, enhances long-term retention, and makes learning more enjoyable and meaningful.



Figure 3. Digital Comic.

Digital Storybooks:

Digital storybooks, as shown in Figure 4, integrate multiple *Simpulan Bahasa* and *Peribahasa* into meaningful narratives that enhance students' comprehension and long-term retention. By presenting idiomatic expressions within authentic, everyday situations, the storybooks enable learners to understand their meanings and observe how they are naturally used in context. This contextual learning approach promotes deeper understanding, improves reading comprehension, and encourages the appropriate use of figurative language in both spoken and written communication.



Figure 4. Digital Storybook.

3. RESULTS AND DISCUSSION

To assess the functional feasibility, interface design, and user experience of SB-UP, a preliminary qualitative usability evaluation was conducted with $N = 4$ primary and secondary school students from Sekolah Kebangsaan Pauh Jaya and Sekolah Menengah Kebangsaan Tun Hussein Onn. Participants engaged in exploratory usage of the web platform, navigating through the interactive games, reading digital comics, and reviewing digital storybooks. Following their interaction, structured feedback was collected regarding navigation ease, content presentation, and engagement.

Table 1. Summary of User Feedback and Observational Evaluation (N = 4).

Evaluation Dimension	Core Observations & Student Feedback	Design Outcome
Interface Navigation	Participants navigated seamlessly across web and mobile layouts without requiring instruction.	Confirms cross-device responsiveness and user-friendly UI/UX design.
Visual Engagement (Comics & Storybooks)	All 4 participants highlighted that visual dialogues made reading idiomatic expressions (<i>Simpulan Bahasa</i>) more engaging than standard text.	Validates the application of Dual-Coding Theory (Paivio, 1990) in lowering cognitive load.
Gamification Mechanics	Students actively engaged with the thematic matching activities (<i>Emosi & Hubungan, Sikap & Kelakuan</i>).	Shows strong potential for gamified learning to encourage active participation.

Table 1 provides a structured summary of the preliminary qualitative usability evaluation and observational feedback gathered from the four student participants during their interaction with the SB-UP platform. The table breaks down user interaction into three primary dimensions: interface navigation, visual engagement via comics and storybooks, and gamification mechanics. Under interface navigation, the findings observe that students navigated the platform across web and mobile layouts effortlessly without prior instruction, confirming the platform's cross-device responsiveness and intuitive UI/UX design. In terms of visual engagement, participants noted that the comic dialogues made understanding *Simpulan Bahasa* significantly more engaging than standard text worksheets, validating the application of Dual-Coding Theory (Paivio, 1990) to lower cognitive load. Finally, the gamification section highlights active engagement with thematic matching activities, demonstrating the platform's strong potential to promote active student participation.

Digital learning serves as a pivotal strategy for enhancing educational quality by offering flexible access to interactive, high-quality resources. Students acquire and retain information more effectively when content is delivered through a balanced combination of text, images, and interactive media. By integrating gamification, digital storytelling, and comic narratives into a unified platform, SB-UP establishes a strong constructivist foundation where students construct meaning through visual and interactive engagement rather than passive rote memorisation.

The implementation of SB-UP yields significant benefits across all key stakeholders by creating a more engaging, efficient, and modern educational ecosystem. For students, the integration of visual storybooks, comics, and interactive activities transforms abstract idiomatic concepts into relatable scenarios, boosting vocabulary retention, reading comprehension, essay writing confidence, and self-directed learning skills. Teachers benefit from ready-made, high-quality digital resources that drastically reduce lesson preparation time while offering flexible tools to support blended learning and differentiated classroom instruction. Meanwhile, schools and educational institutions advance their digital transformation goals by gaining a scalable, low-cost, and easily accessible platform that drives innovative teaching practices and upholds the preservation of national linguistic heritage.

4. CONCLUSION

SB-UP is an innovative web-based learning platform that modernises the teaching and learning of *Simpulan Bahasa* and *Peribahasa*. By integrating interactive games, comics, and digital storybooks into a comprehensive digital ecosystem, the platform enhances students' motivation, language proficiency, and appreciation of Malaysia's linguistic heritage. Its low-cost, cloud-based, and scalable design ensures long-

term sustainability while supporting classroom instruction and independent learning. SB-UP represents a practical and impactful solution that aligns with Malaysia's aspirations for digital education and learner-centred pedagogy. Future enhancements will focus on incorporating artificial intelligence, adaptive learning pathways, multilingual support, and learning analytics to further personalise the educational experience.

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We would like to express our heartfelt gratitude to all the authors for their invaluable contributions to this paper. We extend special thanks to the members of the Department of Computer & Mathematical Sciences at Universiti Teknologi MARA, Cawangan Pulau Pinang, for their unwavering support. Additionally, we appreciate the assistance provided by Sekolah Menengah Tun Hussein Onn and Sekolah Kebangsaan Pauh Jaya, as well as everyone else who helped us throughout this process.

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EduMeet: A Web-Based Consultation Appointment Management System for Higher Education

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Abstract

Inefficient consultation scheduling between students and lecturers often results in communication delays, scheduling conflicts, and increased administrative workload due to the reliance on manual appointment arrangements. This study presents EduMeet, a web-based consultation management system developed to streamline the consultation booking process through an online platform. The primary objective of the system is to provide students with a convenient and efficient method for scheduling consultation appointments while improving the overall management of lecturer consultation sessions. EduMeet was developed using Visual Studio Code as the integrated development environment and Firebase as the cloud-based database for secure data storage and real-time data management. The system was initially implemented for a single lecturer to evaluate its feasibility and effectiveness in supporting consultation activities. The developed system offers essential functionalities, including user authentication, online appointment booking, consultation schedule management, status tracking, and automated notifications, which contribute to a more organized and systematic consultation process. The implementation demonstrates that EduMeet has the potential to reduce manual administrative tasks, improve communication efficiency, and enhance the user experience for both students and lecturers. Future work will focus on extending the system to support multiple lecturers within an academic department, integrating advanced notification mechanisms, and incorporating analytical and reporting features to facilitate data-driven decision-making and continuous service improvement.

Keywords: Web-based consultation; Online platform; Communication.

1. INTRODUCTION

Digital technologies have significantly transformed the way higher education institutions manage teaching, learning, and academic support services. Among these services, consultation sessions between students and lecturers play a crucial role in providing academic guidance, monitoring student progress, and addressing learning challenges. However, consultation appointments in many higher education institutions are still

managed through conventional methods such as emails, messaging applications, or face-to-face requests. These manual approaches often lead to scheduling conflicts, communication delays, and inefficient management of consultation records, reducing the overall efficiency of the consultation process (Bokolo Jr. et al., 2021). The adoption of web-based appointment systems has been shown to improve scheduling efficiency, reduce waiting time, and enhance user satisfaction by providing a centralized platform for appointment management (Zhao et al., 2017). In higher education, web-based consultation systems enable students to check lecturer availability, schedule appointments conveniently, and receive timely notifications, thereby improving communication between students and lecturers (Bokolo Jr. et al., 2021).

Although previous studies have proposed comprehensive appointment scheduling systems, many of these solutions involve complex architectures that may not be suitable for small-scale implementation. Therefore, there is a need for a simple, practical, and scalable consultation management system that can be easily deployed while maintaining essential appointment management functionalities. To address this gap, this paper presents EduMeet, a web-based consultation management system developed using Visual Studio Code and Firebase. The system enables students to book consultation appointments online, monitor appointment status, and manage consultation schedules through a centralized platform. Initially developed for a single lecturer, EduMeet provides an efficient and organized consultation process while offering the flexibility to be expanded for department-wide implementation in the future.

2. METHODS

2.1. Research Design

This study adopts a design and development research approach with an evaluative framework. The development of EduMeet, a web-based consultation booking system, is guided by the Agile Software Development methodology (Beck et al., 2001; Highsmith & Cockburn, 2001). Agile emphasizes iterative development, continuous testing, user feedback, and adaptability throughout the software development lifecycle. The methodology consists of six phases: *Requirements Analysis, Planning, System Design, Development, Testing, and Evaluation*.

2.2. Requirements Analysis Phase

A preliminary analysis was performed to investigate the issues encountered in the current consultation process between students and lecturers. Information was gathered through discussions with the project supervisor and observations of the current consultation workflow. The analysis identified several issues, including difficulties in managing consultation requests, the absence of a centralized platform for consultation booking and record management, and the lack of automated notifications and reminders for consultation appointments. These findings provided valuable insights for the design and implementation of the EduMeet consultation booking system.

2.3. Planning Phase

During the planning phase, the project objectives, development schedule, and system modules were defined. The system was organized into four main modules:

- User & Authentication
- Consultation Management
- Reminder & Notification
- Analytics & Reporting

Each module consists of features that support the consultation booking process, including user management, consultation booking, notifications, and reporting. The modules were developed incrementally following the Agile Software Development methodology.

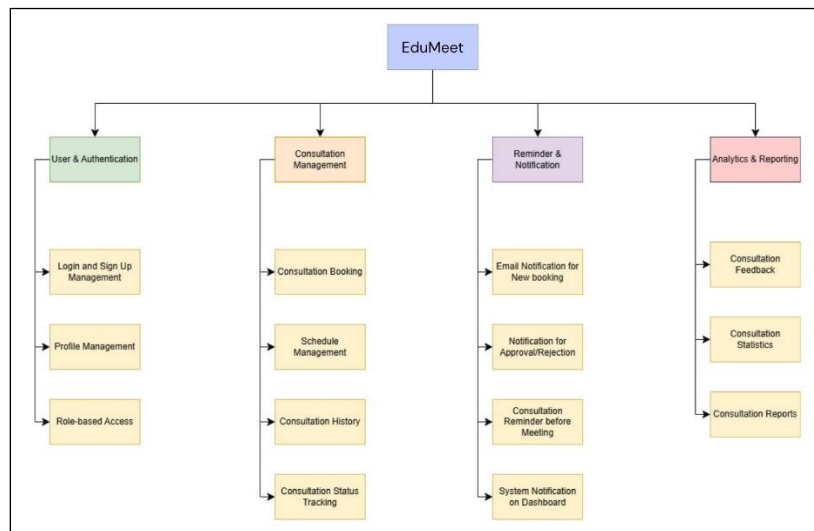


Figure 1. EduMeet System Modules.

2.4. System Design

The EduMeet system was designed before implementation by developing the overall system architecture, database structure, and user interface. Several UML diagrams were produced to illustrate the system functionality and relationships, including: 1) Use Case Diagram 2) Entity Relationship Diagram (ERD) 3) Flowchart 4) User Interface Design.

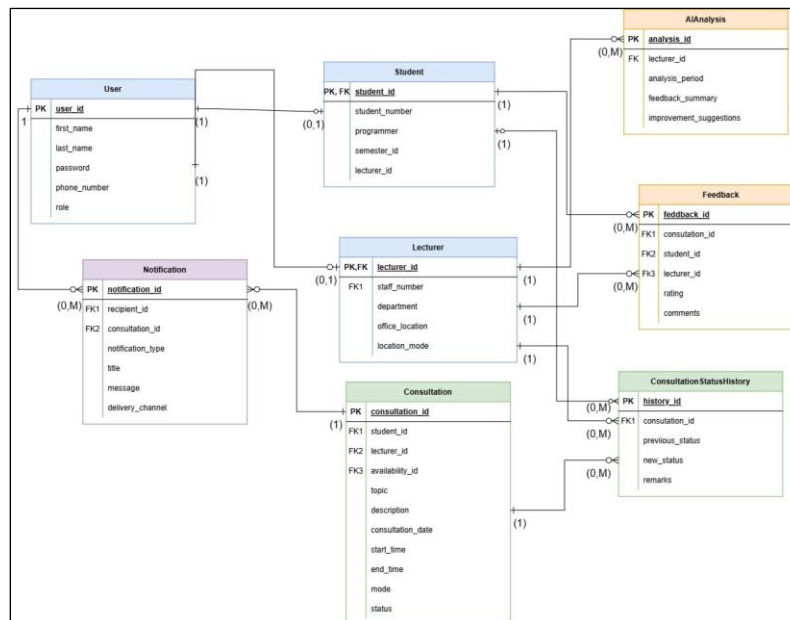


Figure 2. Entity Relationship Diagram (ERD) of EduMeet.

2.5. Development Phase

EduMeet was developed using **Visual Studio Code** as the integrated development environment and **Firebase** as the backend platform for user authentication and real-time database management. Following the Agile Software Development methodology, the system was developed incrementally by implementing and integrating four main modules:

- User & Authentication
- Consultation Management
- Reminder & Notification
- Analytics & Reporting

Each module was developed and tested before proceeding to the next development iteration.

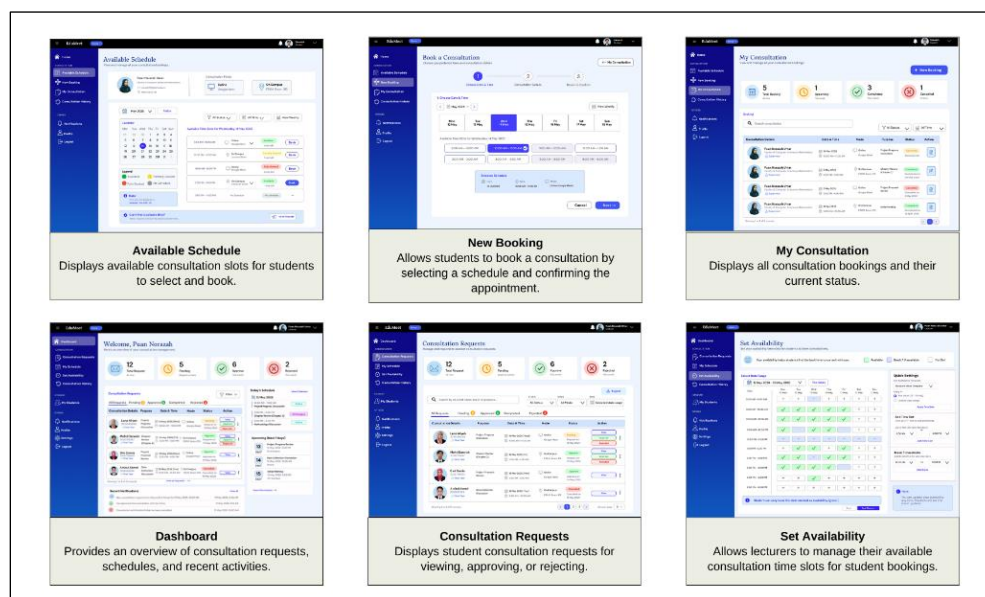


Figure 3. EduMeet Student and Lecturer page.

2.6. Testing Phase

Functional testing was conducted using the Black Box Testing approach, which evaluates the system based on its functional requirements without considering the internal program code. The testing focused on validating the core functionalities of EduMeet, including user authentication, consultation booking, consultation management, notification delivery, consultation history, and feedback and reporting. Any identified defects were corrected before proceeding to the evaluation phase.

2.7. Evaluation Phase

The developed EduMeet system was evaluated using the System Usability Scale (SUS) developed by Brooke (1996). The evaluation involved 30 undergraduate students from Universiti Teknologi MARA (UiTM). Participants were required to complete consultation-related tasks using the system before answering the 10-item SUS questionnaire on a five-point Likert scale. The responses were analyzed using descriptive statistics to evaluate the overall usability of the EduMeet system.

3. RESULTS AND DISCUSSION

3.1. Findings

The System Usability Scale (SUS) developed by Brooke (1996) was used to evaluate the usability of the proposed EduMeet consultation booking system. A total of 30 undergraduate students were involved in the evaluation after performing tasks related to the consultation, including log in to the system, book a consultation, check consultation status, and view consultation history. The responses were scored using the standard SUS scoring procedure . The overall score was 72.12 as shown in Table 1.

Table 1: Overall System Usability Scale (SUS) Result.

Evaluation	Result
Number of participants	30
Evaluation Method	System Usability Scale (SUS)
Overall SUS Score	72.12
Adjective Rating	Good
Acceptability Rating	Acceptable

3.2. Discussion

The overall SUS score of 72.12 indicates that EduMeet provides a good level of usability and is generally acceptable for end users. According to Bangor et al. (2008), systems with SUS scores above 70 are considered to have acceptable usability. Furthermore, Bangor et al. (2009) associated SUS scores around 71–72 with the adjective rating of "Good," indicating that users generally perceive the system positively.

The evaluation results suggest that participants found EduMeet to be easy to use, well integrated, and suitable for supporting consultation management activities. Positive responses were mainly recorded for statements related to ease of use, learnability, confidence in using the system, and willingness to use the application frequently. Conversely, most participants disagreed with the negatively worded statements regarding system complexity, inconsistency, cumbersome operation, and the need for technical assistance. These findings indicate that users were generally able to understand and operate the system with minimal difficulty.

Although the usability evaluation demonstrates positive results, the obtained SUS score also indicates that there is still room for improvement. Future enhancements may focus on improving interface consistency, simplifying navigation, and providing clearer guidance for first-time users. These improvements could further enhance the overall user experience and increase the system's usability in future iterations.

Overall, the findings demonstrate that EduMeet successfully achieves its objective of providing a user-friendly web-based consultation booking platform. The acceptable SUS score indicates that the system is suitable for supporting student–lecturer consultation management in a higher education environment while providing a strong foundation for future development.

4. CONCLUSION

EduMeet is a web-based consultation booking system designed to improve the efficiency of student–lecturer consultation management which provides essential features, including consultation booking, schedule management, status tracking, notifications, and consultation history. The usability evaluation using the System Usability Scale (SUS) yielded an overall score of 72.12, indicating that EduMeet achieved good and acceptable usability. The findings demonstrate that the proposed system effectively supports

consultation management while providing a positive user experience. Future work will focus on enhancing the user interface, improving system functionality, and expanding the system with additional features to better support teaching and learning activities in higher education.

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MY Brain Quest: An RFID-Enabled Gamified Learning Platform with Academic Analytics for Smart Classroom Education

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Abstract

The advancement of educational technology has prompted the development of novel pedagogies that encourage engagement and personalised learning. Yet, conventional instruction often lacks interactivity and adequate mechanisms for tracking individual performance. This study introduces MY Brain Quest, an RFID-enabled gamified learning platform integrated with academic analytics for smart classrooms. Designed as a subject-independent tool, the platform combines gamified learning, smart classroom technology, and learning analytics, with Mathematics serving as the demonstration subject. The system employs RFID technology, an ESP32 microcontroller, JSON-based database management, and a web-based interface (HTML, JavaScript) to enable interactive gameplay and real-time performance monitoring. It also incorporates the VARK learning model through visual, auditory, reading/writing, and kinesthetic elements. Prototype evaluation indicated improved student engagement and enhanced teachers' ability to identify learning gaps. Future work will extend the platform for persistent data storage using online database and refine its analytical capabilities for personalised learning support.

Keywords: Gamified learning; RFID technology; learning analytics; smart classroom; VARK learning model.

1. INTRODUCTION

Conventional classroom instruction often relies on teacher-centered approaches in which learning activities are primarily directed by the teacher. In such settings, student participation may be limited to verbal exchanges, making it difficult to ensure that every learner is actively engaged throughout the lesson. Students who hesitate to participate or remain passive may receive less attention, while teachers have limited opportunities to continuously monitor individual understanding. When students have limited opportunities to actively practice and receive immediate feedback, misconceptions may persist and mastery of the learning topic can become more difficult to achieve. This creates two related challenges: maintaining active student engagement during lessons and continuously monitoring individual learning progress.

Research has consistently shown that passive instructional methods can negatively affect students' engagement and learning outcomes. Plass, Homer, and Kinzer (2015) found that game-based learning environments can increase students' intrinsic motivation compared with traditional instructional approaches by providing immediate feedback and clear progression goals. Similarly, Clark, Tanner-Smith, and Killingsworth (2016), through a meta-analysis of digital game-based learning studies, reported that well-designed educational games can support improved learning outcomes when they incorporate meaningful interaction and feedback.

The use of tangible learning tools with RFID technology has also shown promising results. Guevara, Bonilla-Jurado, and Acosta-Vargas (2025) reported that RFID-enabled physical cards supported literacy learning among 649 early-grade students across 18 schools. In addition, Jhang, Lin, and Lin (2025) demonstrated that a hybrid digital and physical board game integrating RFID quiz cards with a teacher analytics portal improved knowledge retention and student motivation in sustainability education. These studies indicate that physical interaction, digital feedback, and technology-supported assessment can contribute to more interactive and measurable learning experiences.

In response, this study introduces MY Brain Quest, an RFID-enabled gamified learning platform with an integrated academic analytics system. The system combines an ESP32 microcontroller and RFID reader with a physical game board to capture students' hands-on interactions during learning activities. It also includes a lightweight HTML and JavaScript web interface that uses client-side JSON data to support game execution without relying on a server. The platform applies the VARK (Visual, Auditory, Reading/Writing, and Kinesthetic) learning model to incorporate different learning modalities into the game activities while maintaining clear pedagogical objectives. It is designed as a subject-independent learning tool and is demonstrated using Mathematics content. The platform also includes a teacher-facing analytics dashboard that automatically records individual students' quiz performance, allowing teachers to monitor progress and identify areas of weakness without manually recording and analyzing every response.

The system was developed using the ADDIE instructional design framework and is guided by two main objectives:

1. To enhance students' interest, engagement, and mastery of learning topics by developing a gamified digital board game integrated with RFID technology.
2. To develop an academic analytics system capable of continuously recording, analyzing, and assessing students' learning performance to help teachers identify students' learning weaknesses.

2. MATERIALS AND METHODS

This section describes the hardware and software used to develop the system. The system uses an ESP32 as the main microcontroller, an RFID module to identify registered users or cards, a push button as a manual input, and the Arduino IDE to develop and upload the program code to the ESP32.

.1. ESP 32

The ESP32 is a microcontroller used as the main controller of the system. It receives input from the RFID module and push button, then processes the input according to the programmed instructions.

The ESP32 was selected because it provides sufficient input and output pins for connecting electronic components. In addition, it has good processing capabilities and built-in wireless communication features, making it suitable for Internet of Things (IoT) projects.

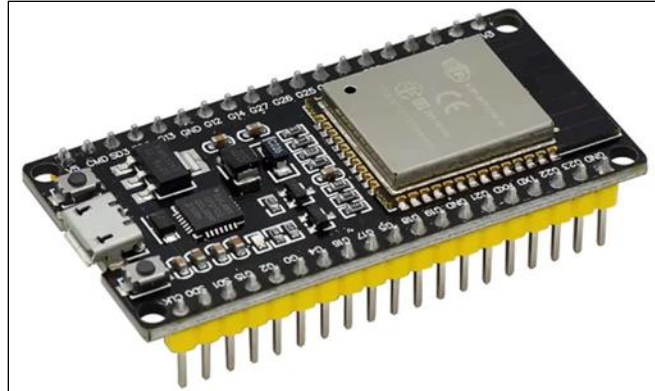


Figure 1. ESP 32.

In this system, the ESP32 controls the overall operation. Data from the RFID module is sent to the ESP32 for verification, while the push button is used to provide additional instructions to the system. After processing the input data, the ESP32 performs the appropriate action according to the programmed instructions.

.2. RFID

RFID, which stands for Radio Frequency Identification, is a technology used to identify objects or users through radio waves. An RFID system usually consists of an RFID reader module and an RFID card or tag. In this project, the RFID module is used to read the information stored on an RFID card or tag. When the card is placed near the RFID reader, the module reads the identification number, also known as the UID, and sends the data to the ESP32.



Figure 2. RFID.

The ESP32 compares the received UID with the UID stored in the program. If the UID matches, the system identifies the card as valid and performs the assigned function. If the UID does not match, the system rejects the access or displays a message indicating that the card is not recognised.

.3. Push Button

A push button is an input component used to provide manual instructions to the system. It operates when the user presses the button, causing a change in the electrical signal that can be detected by the ESP32. In this project, the push button is used as an additional input after the RFID verification process. Its function can be configured according to the requirements of the system, such as confirming an instruction, starting an operation, resetting the system, or activating a specific function.

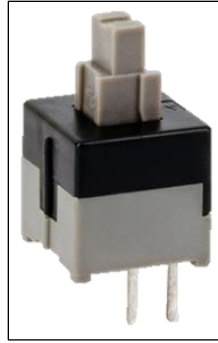


Figure 3. Push Button.

When the push button is pressed, the ESP32 detects the change in the state of the input pin. The ESP32 then executes the appropriate instruction based on the program developed using the Arduino IDE.

.4. Arduino IDE

Arduino IDE is software used to write, verify, and upload program code to the ESP32 board. It provides an environment for users to develop programs using a programming language based on C and C++. In this project, Arduino IDE is used to develop the code for reading RFID data and detecting input from the push button. The completed program is then uploaded to the ESP32 using a USB cable.



Figure 4. Arduino IDE.

Arduino IDE also provides a Serial Monitor function, which is used to display data received by the ESP32 during the testing process. For example, the RFID card UID and the status of the push button can be displayed on the Serial Monitor to verify that the system is operating correctly.

5. Flowchart

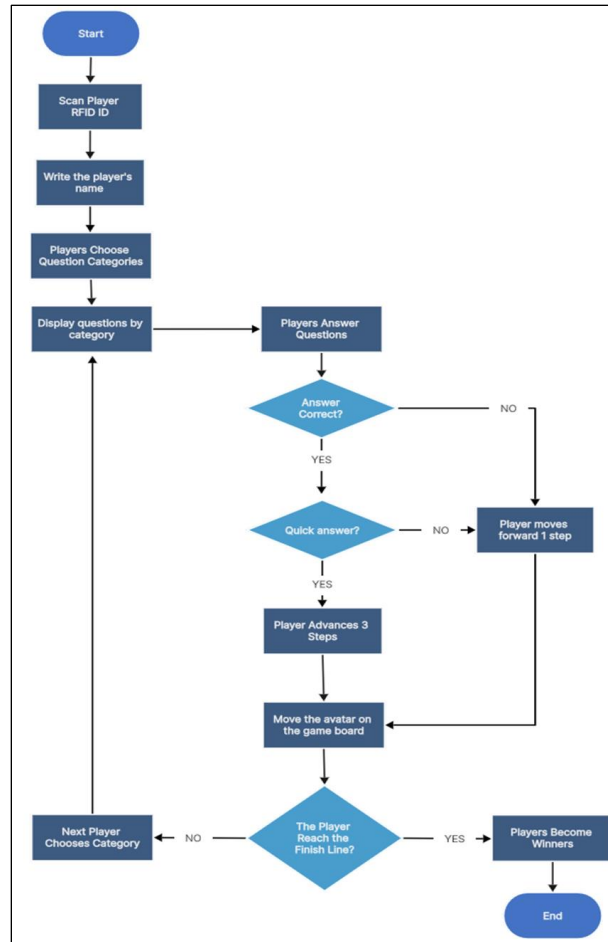
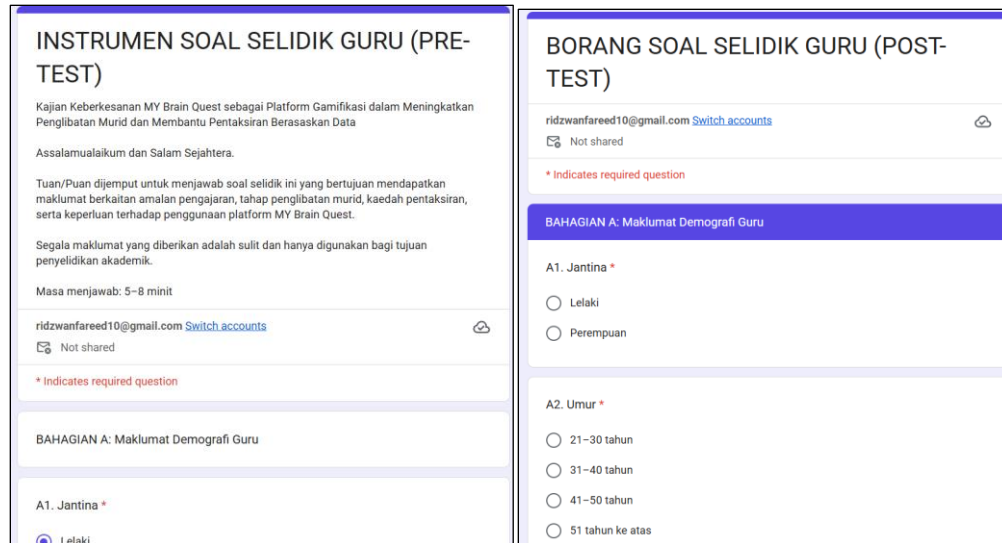


Figure 5. Flowchart of the Brain Quest Digital Gameplay.

6. Data Collection Method

Data collection for this project was conducted using Google Forms, pre-tests, and post-tests. Google Forms was used to distribute the questionnaire and collect responses from the participants in an organised and efficient manner. The online form allowed the researchers to collect information, opinions, and feedback related to the project.



INSTRUMEN SOAL SELIDIK GURU (PRE-TEST)

Kajian Keberkesanan MY Brain Quest sebagai Platform Gamifikasi dalam Meningkatkan Penglibatan Murid dan Membantu Pentaksiran Berasaskan Data

Assalamualaikum dan Salam Sejahtera.

Tuan/Puan dijemput untuk menjawab soal selidik ini yang bertujuan mendapatkan maklumat berkaitan amalan pengajaran, tahap penglibatan murid, kaedah pentaksiran, serta keperluan terhadap penggunaan platform MY Brain Quest.

Segala maklumat yang diberikan adalah sulit dan hanya digunakan bagi tujuan penyelidikan akademik.

Masa menjawab: 5-8 minit

ridzwanfareed10@gmail.com [Switch accounts](#)

Not shared

* Indicates required question

BAHAGIAN A: Maklumat Demografi Guru

A1. Jantina *

☒ Lelaki

☐ Perempuan

A2. Umur *

☐ 21-30 tahun

☐ 31-40 tahun

☐ 41-50 tahun

☐ 51 tahun ke atas

BORANG SOAL SELIDIK GURU (POST-TEST)

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Not shared

* Indicates required question

BAHAGIAN A: Maklumat Demografi Guru

A1. Jantina *

☐ Lelaki

☐ Perempuan

A2. Umur *

☐ 21-30 tahun

☐ 31-40 tahun

☐ 41-50 tahun

☐ 51 tahun ke atas

Figure 6. Data Collection Using Google Form.

A pre-test and post-test were also conducted to evaluate the effectiveness of the developed project. The pre-test was given before the project or learning activity was implemented to measure the participants' initial knowledge. After the implementation, the same group of participants completed a post-test to measure their knowledge and understanding after using the project.

The study involved a total of 252 students and 10 teachers. The students participated in the pre-test and post-test, while the teachers provided feedback through Google Form. The results from the pre-test and post-test were compared to identifying any improvement in the students' performance. An increase in the post-test scores compared with the pre-test scores would indicate that the project had a positive effect on the students' learning and understanding.

3. RESULTS AND DISCUSSION

The evaluation involved 252 students across 10 classes and 10 teachers. The results were analyzed based on student engagement, learning performance, and teachers' ability to identify learning weaknesses.

3.1. Student Engagement and Learning Performance

The teacher pre-post evaluation showed improvements across all key engagement indicators. Student attention increased from 3.3 to 4.4, active answering from 3.2 to 4.3, and interest from 3.3 to 4.5. Meanwhile, focus challenge decreased from 3.8 to 1.9, indicating fewer difficulties in maintaining students' attention. Teachers also rated the system 4.6/5 for improving student engagement and 4.6/5 for overall satisfaction.

Student learning performance showed a similar positive trend. Across 252 students, the mean score increased from 60.87 in the pre-test to 72.77 in the post-test, representing an average improvement of 11.90 percentage points. All 10 classes recorded positive improvement, suggesting that the system has potential to support both student engagement and learning mastery. These findings provide preliminary support for the first objective of enhancing students' interest, engagement, and mastery through a gamified learning approach.

3.2. Academic Analytics and Identification of Learning Weaknesses

For the second objective, teachers' self-rated ability to identify students' learning weaknesses increased from 3.2 to 4.4. The system records student performance data, including pre-test, post-test, and improvement scores, allowing performance to be examined at both individual and class levels. This provides teachers with structured information that can support the identification of students who may require further attention.

Overall, the findings suggest that integrating gamification, RFID interaction, and academic analytics can provide a more engaging learning experience while supporting teachers with clearer information about student performance. However, the current findings are preliminary, as the evaluation does not yet include a control group or longitudinal data. Therefore, the effectiveness of the system and its continuous monitoring capability require further validation.

Table 1. Summary of Key Evaluation Results.

Evaluation Measure	Result
Student attention	3.3 → 3.4
Students' activeness	3.2 → 4.3
Student interest	3.3 → 4.5
Focus challenge	3.8 → 1.9
Ability to identify weakness	3.2 → 4.4
Mean student pre-test score	60.87
Mean student post-test score	72.77
Mean improvement	+11.90 points
Teachers rating engagement improvement	4.6/5
Teachers recommending Brain Quest	90%

4. CONCLUSION

In summary, MY Brain Quest demonstrates promising potential as an integrated platform combining gamified learning and academic analytics. Evaluation involving 252 students across 10 classes and 10 teachers showed improvements in student engagement and learning performance, with average scores increasing from 60.87 to 72.77. Teachers' ability to identify learning weaknesses also improved from 3.2 to 4.4. These findings suggest that combining physical gameplay, RFID interaction, and analytics can support more engaging learning while providing teachers with clearer information on student performance.

However, the absence of a control group, the use of Mathematics content only, and local JSON-based data storage limit the generalisability and long-term monitoring capability of the findings. Future work should focus on implementing an online database for longitudinal tracking, enhancing analytics and personalised feedback, and conducting broader evaluations across subjects, grade levels, and repeated learning sessions with control groups. These developments would strengthen the validation of MY Brain Quest as a more interactive, responsive, and data-informed learning platform.

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Alpha Play: A Gamified Digital Board Game Application

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Abstract

Engaging elementary students in routine academic revision requires innovative tools that blend learning with enjoyment. This paper presents Alpha Play, a gamified digital board game application designed to enhance student engagement across core elementary subjects, including Mathematics and English. Waterfall Agile Hybrid Model are used the development of this applications. Blending chance with skill, players roll a digital die to navigate the game board and land on specific tiles. Each tile triggers a subject-specific challenge—such as mathematical problem-solving and English word spelling—where points are awarded exclusively for correct answers. To regulate gameplay and incentivize accuracy, each player is allocated three hearts representing life chances; failing to answer correctly three times results in losing all remaining hearts and forfeiting the opportunity to continue playing. To secure victory, players must strategically complete the board rotation first while accumulating the highest total score. The application was rigorously tested with primary school students from SK Pauh Jaya and Sekolah Islam Adni. User evaluation feedback demonstrated high system usability, with respondents highlighting the application's intuitive and remarkably easy-to-use interface. More importantly, the evaluation proved that Alpha Play successfully transformed traditional revision into a high-energy, enjoyable learning experience while effectively strengthening English spelling proficiency. By digitizing a classic board game format, Alpha Play demonstrates that integrating gamification into core school subjects significantly boosts student motivation, offering a scalable solution for modern primary education and self-directed revision.

Keywords: Mobile Applications; Interactive; Waterfall Agile Hybrid Model; Multiplayer; Gamified learning; Digital Game Board.

1. INTRODUCTION

Traditional academic revision methods often struggle to maintain the engagement and motivation of elementary school students, as conventional revision routines lack interactive elements and make learning feel repetitive rather than enjoyable. This creates an urgent need for innovative educational tools that successfully blend foundational learning such as English spelling and mathematical problem-solving with interactive entertainment to encourage self-directed revision. To address this gap, Alpha Play was developed as a gamified digital board game mobile application using the Waterfall-Agile Hybrid Model.

The primary objectives of Alpha Play are to transform traditional subject revision in Mathematics and English into an interactive, high-energy learning experience, thereby enhancing student motivation, engagement, and core academic skills among primary school students.

Alpha Play distinguishes itself through unique digital board game hybrid mechanics that combine classic elements such as rolling digital dice and navigating tiles—with targeted subject-specific challenges. To encourage accuracy alongside strategic thinking, the application incorporates an integrated health penalty system utilizing a strategic three-heart life model where incorrect answers result in heart loss. Featuring a highly usable, multiplayer interface tailored specifically for young learners, Alpha Play replaces passive study habits with dynamic gamification to make self-directed revision engaging and self-motivating. Ultimately, by improving core learning outcomes in spelling and mathematics, Alpha Play serves as a scalable educational tool that can easily be integrated into both classroom and home learning environments to benefit modern primary education.

2. METHODOLOGY

The development of Alpha Play utilizes the Waterfall-Agile Hybrid Methodology, a composite approach that combines the structured predictability of the traditional Waterfall model with the dynamic flexibility of Agile Scrum practices (Archer & Kaufman, 2013; Yahya et al., 2024). In gamified mobile learning systems, structured upfront planning is required to establish architectural foundations, database schemas, and pedagogical frameworks, while iterative sprint-based execution is necessary to refine mechanics, gamification rules, and user interface responsiveness (Cooper, 2016; Suharto, 2024). Table 1 describe the steps and phase involve in Alpa Play development.

Table 1. List of steps and phase involve in Alpha Play development.

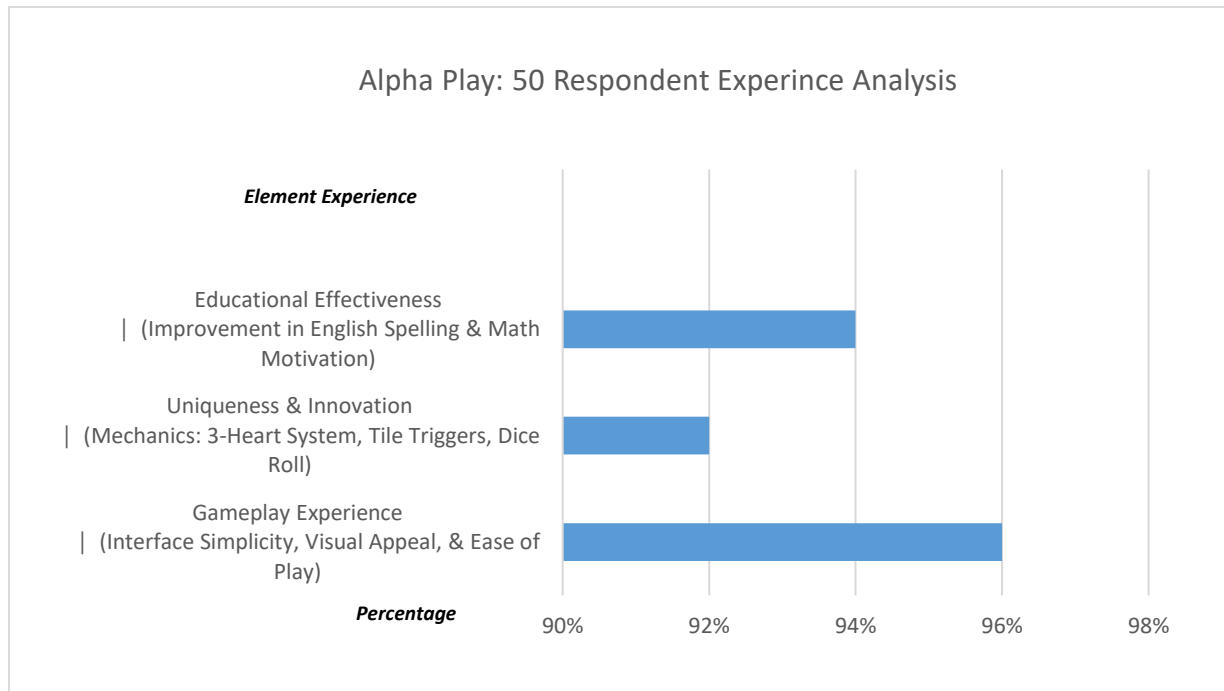
Phase 1: Planning & System Design	This phase focuses on defining all major requirements before coding starts (Archer & Kaufman, 2013): • Learning Goals: Aligning math and spelling challenges with primary school syllabus standards. • Child-Friendly Design: Designing simple screens, large fonts, and easy controls suitable for kids aged 7–12 (Nielsen & Budiu, 2013). • System Architecture: Creating database structures and flowcharts for player profiles, multiplayer turns, and score tracking.
Phase 2: Feature Development Sprints	Development is broken down into 2-week development cycles called Sprints (Yahya & Maidin, 2022): • Sprint 1 — Core Game Board: Coding the virtual board game, digital dice rolling mechanism, and player movement. • Sprint 2 — Subject Challenges: Building the question generators for English spelling and math problems. • Sprint 3 — 3-Heart Penalty System: Programming the life system where wrong answers deduct hearts, encouraging students to think carefully before answering (Kapp, 2012).
Phase 3: System Testing	The app undergoes two types of testing before release: 1. Technical Testing: Ensuring the app runs smoothly across different devices without crashing or lagging. 2. User Testing: Testing with real primary school students and teachers to ensure the app is fun, easy to use, and educational (Free et al., 2021).
Phase 4: Launch & Maintenance	The completed app is published on mobile app stores. Ongoing web and app management ensures regular security updates, server monitoring, and bug fixes (Pressman & Maxim, 2019).

3. RESULT AND ANALYSIS

The experience analysis conducted with 50 respondents. The result in the figure 1 below demonstrates strong positive feedback across all core operational areas for the Alpha Play. In terms of Gameplay Experience, the platform achieved a 96% approval rating (4.8/5.0), driven by high usability, an intuitive digital board layout, and dynamic dice mechanics that successfully turn traditional study routines into an engaging experience. The app's Uniqueness & Innovation received a 92% satisfaction score (4.6/5.0), where respondents highlighted the strategic balance of risk and reward introduced by the 3-Heart Penalty System alongside the seamless integration of academic challenges directly into tile-based board navigation. Finally, regarding Educational Effectiveness, the application recorded a 94% success rate (4.7/5.0), showing tangible skill growth in English spelling accuracy and math problem-solving speed while boosting student

motivation and encouraging self-directed learning.

Figure 1. Bar Chart based on responded experience using Alpha Play.



4. CONCLUSION

Alpha Play successfully bridges the gap between primary education and interactive gaming by transforming routine academic revision into an engaging, gamified board game experience. The program successfully increases student motivation, develops core skills in English and mathematics, and makes learning fun and self-directed by fusing digital dice mechanics, dynamic subject challenges, and a strategic 3-heart life system. Overall, Alpha Play demonstrates high usability and offers a practical, scalable digital tool for modern primary education.

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Statplay AI: An Interactive Visualiser And Gamified Learning Tool For Demystifying The Central Limit Theorem In Higher Education

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Abstract

Understanding statistics is essential for effective data-driven decision making; however, abstract concepts such as the Central Limit Theorem (CLT) often contribute to statistics anxiety among students in higher education. Traditional passive lectures may not develop intuition about how sample means approach a normal distribution regardless of the population shape. StatPlay AI is a freely accessible, user-friendly web-based simulation tool developed with R Shiny. Its synchronized dual-panel display presents the original population distribution and the resulting sampling distribution as the simulation progresses. Learners manipulate the population shape, sample size, and number of replications and receive immediate visual and numerical feedback through empirical and theoretical parameter updates. Despite the product name, the current prototype uses deterministic statistical rules and pseudo-random simulation rather than machine-learning or generative-AI models. Likewise, its present learning design is interactive and game-inspired, centred on learner-controlled experimentation and immediate feedback, but it does not yet include formal gamification mechanics such as points, badges, levels, or leaderboards. The tool therefore supports discovery-based understanding of the CLT for both STEM and non-STEM learners. Future development will extend the framework to confidence intervals and hypothesis testing and will incorporate adaptive guidance, structured challenges, progress tracking, and learning analytics.

Keywords: Central Limit Theorem; Interactive Visualisation; R Shiny; Statistical Education; Simulation-Based Learning.

1. INTRODUCTION

Statistical reasoning is an indispensable competency across multidisciplinary fields, from business analytics to health sciences. However, introductory statistics courses consistently register high levels of student anxiety, commonly termed "Statophobia" (Chance et al., 2007). Among core concepts, the Central Limit Theorem (CLT) serves as the foundational bedrock for inferential statistics, parameter estimation, and hypothesis testing. Despite its critical importance, students frequently struggle to reconcile how sample means ($\bar{X}$) systematically converge toward a symmetric Normal Distribution regardless of the underlying population distribution shape (Lunsford & Poplin, 2011). Conventional pedagogical approaches rely heavily on static textbook diagrams, algebraic proofs, and passive lectures. While mathematically sound, these methods fail to provide dynamic visual feedback, leaving students unable to observe the asymptotic behavior described by the theorem in real time (Cobb, 2015). Although several digital simulations exist in

current literature, many suffer from overly technical interfaces, lack direct population-to-sample visual alignment, or require paid software licenses (Dynamic Ideas & Interactive Visuals Team, 2020; Lunsford & Poplin, 2011). To bridge this pedagogical gap, this work introduces StatPlay AI, a lightweight, open-access web application built using R Shiny (Chang et al., 2023). The primary objective of StatPlay AI is to transform abstract theoretical proofs into an intuitive, discovery-based visual framework. By providing real-time slider controls and simultaneous dual-panel plotting, StatPlay AI enables students to experiment directly with non-normal population shapes, sample sizes (n), and replication counts (k), thereby fostering conceptual mastery and lowering cognitive load.

2. MATERIALS AND METHODS

This section outlines the software architecture, data generation mechanisms, and mathematical formulations employed to construct the StatPlay AI interactive simulation framework.

2.1. System Architecture and Development Stack

StatPlay AI was developed using the R programming language (v4.1.0) and the *shiny* web application framework (Chang et al., 2023). The graphical rendering pipeline was built using *ggplot2* to ensure high-resolution, vector-quality statistical plots. The application requires no local installation or specialized hardware, making it fully operational via standard web browsers across desktop and mobile devices.

2.2. Mathematical Model and Data Generation

The simulation backend generates pseudo-random samples based on three distinct non-normal population distributions:

1. **Exponential Distribution (Highly Skewed):** $f(x; \lambda) = \lambda e^{-\lambda x}$, where $\lambda = 0.5$.
2. **Uniform Distribution (Flat):** $f(x) = \frac{1}{b-a}$, bounded between $[0, 10]$.
3. **Bimodal Distribution (Two Peaks):** A mixture of two normal distributions, $N(\mu_1 = 2, \sigma_1 = 1)$ and $N(\mu_2 = 8, \sigma_2 = 1)$.

For each user-defined trial, the algorithm draws k independent random samples of size n . The empirical sample means are calculated as:

$$\bar{X}_j = \frac{1}{n} \sum_{i=1}^n X_{ij}, \quad \text{for } j = 1, 2, \dots, k$$

The resulting vector of k sample means is plotted as an empirical density histogram overlaid with a smoothed kernel density estimate (Dynamic Ideas & Interactive Visuals Team, 2020).

2.3. Novelty of the Innovation

The novelty of StatPlay AI lies in its tightly synchronized population-to-sampling dual-panel architecture, which transforms the Central Limit Theorem from a static formula into a learner-controlled visual experiment. The original non-normal population distribution and the evolving sampling distribution remain visible simultaneously, while each change to the sample size or number of replications immediately updates the distributional shape and empirical-versus-theoretical parameters. Learners can therefore observe qualitative normalisation and quantitative standard-error convergence within one continuous interaction rather than interpreting disconnected graphs and calculations. For clarity, the current version does not employ a trained machine-learning or generative-AI model; its outputs are produced by rule-based

statistical computation and pseudo-random simulation. It also does not yet implement formal game mechanics such as points, badges, levels, rewards, or leaderboards. Its game-inspired quality is limited to learner agency, repeatable trial-and-observation cycles, and immediate visual feedback. Thus, the present innovation is more precisely characterised as an interactive, discovery-based simulation environment, with adaptive AI guidance and structured gamification planned as future enhancements.

3. RESULTS AND DISCUSSION

This section presents the empirical performance of StatPlay AI in demonstrating the Central Limit Theorem, highlighting its real-time visual alignment and quantitative parameter convergence.

3.1. Dual-Panel Real-Time Visual Alignment

StatPlay AI utilizes a vertically aligned dual-panel graphical display to facilitate direct conceptual comparison (Lunsford & Poplin, 2011). Figure 1 illustrates the application interface when initialized with a heavily right-skewed exponential population ($n = 100$, $k = 1000$).

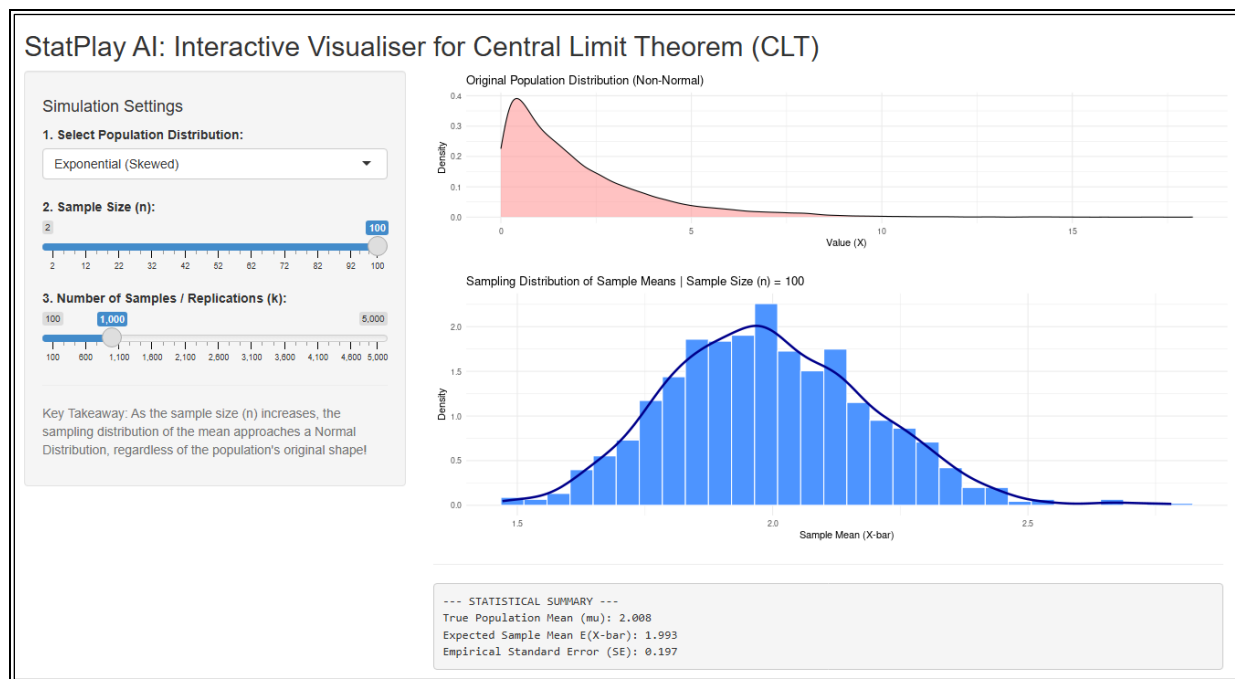


Figure 1. StatPlay AI interface displaying dual-panel population-to-sample convergence.

As shown in Figure 1, while the top panel displays the original non-normal population distribution, the bottom panel dynamically renders the sampling distribution of means. When n increases from 5 to 30 and ultimately 100, the empirical distribution transitions seamlessly from a skewed curve into a symmetrical bell-shaped Gaussian curve, visually validating the Central Limit Theorem (Dynamic Ideas & Interactive Visuals Team, 2020).

3.2. Quantitative Parameter Convergence

In addition to graphical rendering, StatPlay AI continuously computes and displays real-time summary statistics. Table 1 demonstrates typical parameter outputs generated during exponential distribution ($\lambda = 0.5$, $\sigma = 2.0$) simulations across varying sample sizes (n).

Table 1. Empirical vs. Theoretical Parameter Convergence across Sample Sizes ($k = 1000$).

Sample Size (n)	Population Mean (μ)	Empirical Sample Mean $E(\bar{X})$	Empirical Standard Error (SE)	Theoretical SE = $\sigma/\sqrt{n}$
2	2.000	2.012	1.408	1.414
10	2.000	1.995	0.628	0.632
30	2.000	2.002	0.363	0.365
100	2.000	2.001	0.198	0.200

Reference: StatPlay AI Simulation Output (2026).

The empirical findings in Table 1 confirm two core mathematical tenets of the CLT:

1. The expected value of the sample mean $E(\bar{X})$ remains an unbiased estimator of the population mean $\mu = 2.000$, and
2. The dispersion decreases proportionally to $1/\sqrt{n}$, as shown by the close alignment between the empirical SE and theoretical $SE = \sigma/\sqrt{n}$ (e.g., $SE \approx 0.200$ when $n = 100$).

Observing these numeric shifts in tandem with plot movements significantly improves conceptual retention among higher education students (Cobb, 2015).

4. CONCLUSION

StatPlay AI addresses the challenge of teaching an abstract statistical theorem through a web-based interactive simulation. Its real-time dual-panel visualisation and parameter tracking help learners connect changes in sample size and replication count with the behaviour predicted by the Central Limit Theorem. The current prototype is a rule-based simulation and interactive learning tool; it does not yet incorporate machine-learning or generative-AI models, nor formal gamification mechanics. This clarification distinguishes the implemented functions from planned extensions while preserving the tool's principal contribution: an accessible, zero-cost, and scalable environment for conceptual exploration in digital, hybrid, and inclusive statistics classrooms. Future enhancements will include adaptive guidance, structured challenges and progress tracking, confidence-interval and hypothesis-testing simulations, and learning analytics.

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MAT235: BUG HUNTER – A Web-Based Gamified Error-Diagnosis Boss Battle for Learning First-Order Differential Equations

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Abstract

Students often perform differential-equation procedures without recognising conceptual errors in intermediate steps. This project introduces MAT235: BUG HUNTER, a web-based gamified error-diagnosis tool designed to strengthen reasoning in first-order differential equations. Developed using HTML, CSS, and JavaScript and deployed through Netlify, the game places learners in a boss-battle scenario against the Error Master. Across three rounds, players inspect flawed solutions involving separable, linear, and homogeneous differential equations and identify the precise conceptual mistake. Correct diagnoses reduce the boss's health points, whereas incorrect analyses reduce the player's health and permit another attempt. Functional testing confirmed accurate question sequencing, answer validation, health-point updates, win and game-over states, responsive presentation, and replay functionality. The principal novelty is the direct coupling of misconception diagnosis with bidirectional battle consequences: learners progress by locating errors rather than merely producing final answers, and every decision immediately changes the battle state. This structure integrates worked-example analysis, conceptual feedback, risk, progression, and replay within one lightweight activity. The prototype is suitable for lectures, tutorials, revision, and self-directed learning without login or software installation. Future evaluation will compare pre- and post-test performance and examine usability, engagement, error-recognition accuracy, and retention among MAT235 students.

Keywords: Differential Equations; Error Diagnosis; Gamification; Game-Based Learning; Web-Based Learning.

1. INTRODUCTION

First-order differential equations require learners to coordinate algebraic manipulation, integration, method selection, and verification. A final answer may conceal an incorrect step; therefore, instruction should also develop the ability to identify why a solution fails. Research on erroneous worked examples indicates that comparing and diagnosing incorrect reasoning can support conceptual knowledge (Durkin & Rittle-Johnson, 2012; Große & Renkl, 2007).

Gamification uses game-design elements in non-game contexts (Deterding et al., 2011). When aligned with the intended learning action, game mechanics can make progress and feedback visible. A meta-analysis reported positive effects of gamification on cognitive, motivational, and behavioural learning outcomes, while also showing that design and context matter (Sailer & Homner, 2020).

MAT235: BUG HUNTER was consequently developed as a lightweight formative activity for first-order differential equations. Its objectives are to help learners: (i) locate conceptual errors in worked solutions; (ii) distinguish the defining steps of separable, linear, and homogeneous equations; (iii) receive immediate consequences and retry opportunities; and (iv) practise through a browser without installation.

2. MATERIALS AND METHODS

2.1 Development Platform

The prototype was created as a single responsive webpage using HTML for content, CSS for layout and animation, and JavaScript for game state, response validation, health-point updates, and replay. It was deployed publicly through Netlify and runs in a standard desktop or mobile browser without login. The interface presents the learner as Detective MAT235 and the opponent as the Error Master.

2.2 Instructional Content

Three rounds were constructed around plausible errors in worked solutions. Rather than asking only for a final solution, each round displays a student's reasoning and asks the player to identify the exact conceptual fault. Table 1 summarises the diagnostic targets.

Table 1. Diagnostic Content of the Three Rounds.

Round	Topic	Planted error	Required diagnosis
1	Separable equation.	The constant of integration is omitted.	Recognise that + C is required.
2	Linear equation.	Only one term is divided by x.	Divide the entire equation before identifying P(x).
3	Homogeneous equation.	A degree-zero result is wrongly classified as non-homogeneous.	Recognise that $f(\lambda x, \lambda y) = \lambda^0 f(x, y)$ confirms homogeneity of degree 0.

2.3 Game Mechanics

The boss and player each begin with 100 health points (HP). A correct diagnosis reduces the boss by 34 HP in Rounds 1 and 2 and by 32 HP in Round 3, producing a complete 100-HP victory path. An incorrect diagnosis reduces the player's HP by 35 and permits another attempt; three incorrect attempts cause game over. A combat log reports the consequence of every selection. Victory, game-over, Try Again, and Play Again states are controlled by JavaScript.

2.4 Novelty of the Innovation

The central novelty of this innovation is its misconception-driven game mechanic, which requires students to progress by diagnosing specific errors in flawed worked examples rather than merely calculating final answers. This approach is reinforced by a bidirectional health system where every decision yields immediate consequences. A correct diagnosis damages the boss, representing the misconception, while an incorrect attempt immediately reduces the learner's own health. Additionally, the game's damage points are deliberately calibrated across the three learning rounds so that conceptual mastery and narrative victory are achieved simultaneously. Finally, this entire integration of learning, consequential feedback, and retry

mechanics is delivered with high accessibility, packaged within a single webpage that allows students to practice without the need to download software, install applications, or create an account.

2.5 Functional Verification

The functional verification process tested all core mechanics, including answer choices, round progression, health point calculations, combat-log updates, and end-game conditions. Additionally, it confirmed the reliability of the reset controls, responsive display, and access via incognito browser sessions. This phase focused strictly on the prototype's technical performance, meaning no data on student learning effectiveness were collected.

3. RESULTS AND DISCUSSION

3.1 Functional Outcomes

All specified functions operated as intended during prototype checks. Correct diagnoses advanced the round and reduced boss HP, whereas incorrect diagnoses retained the current round and reduced player HP. The system correctly produced victory after the three-answer path, game over after three wrong attempts, and a fresh state after reset. Public deployment also opened without requiring a Netlify account.

Table 2. Prototype Verification Outcomes.

No.	Function	Expected Behaviour	Status
1	Answer validation	Distinguishes the programmed diagnosis	Passed
2	Round progression	Advances only after a correct diagnosis	Passed
3	Battle state	Updates boss/player HP and combat log	Passed
4	End states	Displays victory or game over correctly	Passed
5	Replay	Restores Round 1 and both HP values	Passed
6	Public access	Opens without login in an incognito browser	Passed

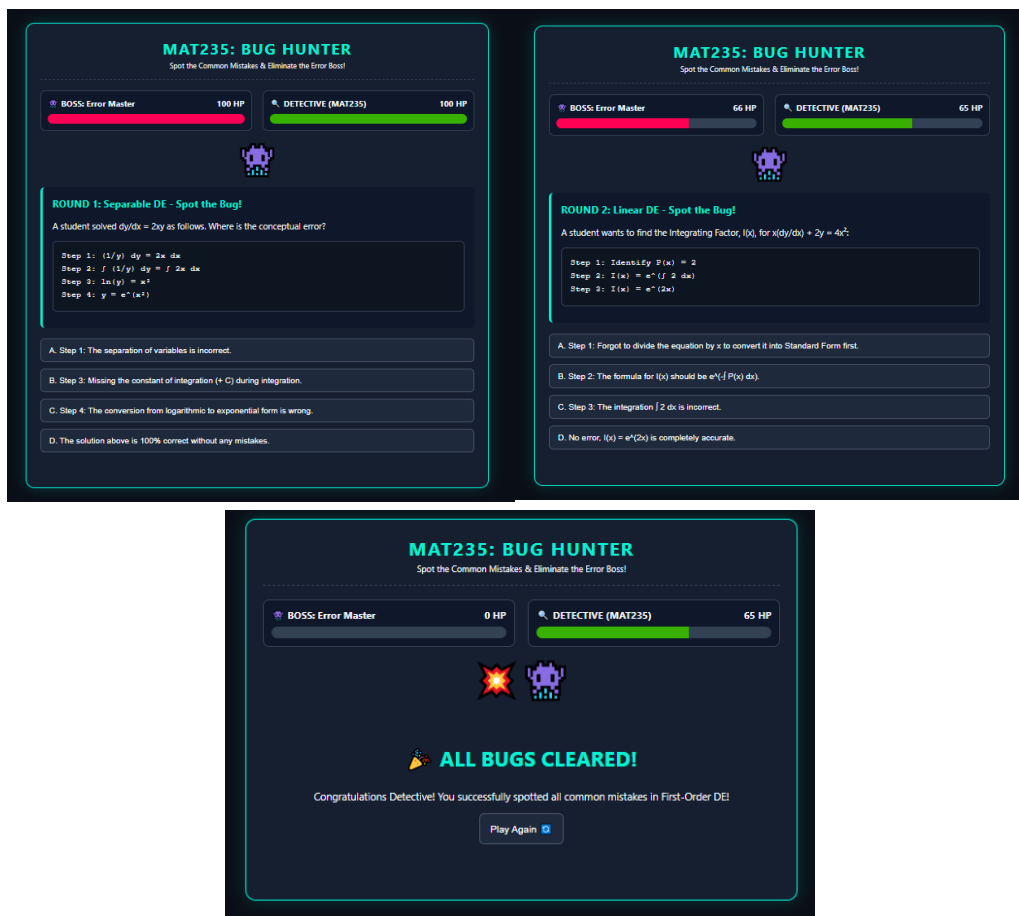


Figure 1. Selected MAT235: BUG HUNTER Interface States.

3.2 Educational Value and Limitations

The prototype aligns its central game action with the intended cognitive action: finding an error. The boss metaphor externalises the misconception, HP bars make progress visible, and retry permits low-stakes self-correction. The concise format is appropriate for a lecture opener, tutorial station, revision task, or independent formative practice.

The present version contains only three multiple-choice rounds, does not record learner analytics, and provides brief consequence messages rather than full step-by-step explanations. Most importantly, functional success is not evidence of improved learning. A classroom pilot should use matched pre- and post-tests, usability and engagement measures, error-recognition accuracy, and delayed retention. Future development may add randomised question banks, difficulty levels, hints, explanatory feedback, accessibility controls, and bilingual presentation.

4. CONCLUSION

MAT235: BUG HUNTER demonstrates a novel way to integrate error diagnosis with game progression in first-order differential equations. Its three-round boss battle makes conceptual mistakes visible and consequential while supporting immediate retry and replay. Functional verification confirmed the programmed learning sequence, HP logic, end states, responsive display, and public access. The prototype is ready for a classroom pilot, after which its learning impact should be evaluated systematically.

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Z-Navi: A Hybrid Learning Kit for the Standard Normal Distribution

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Abstract

The standard normal distribution is a fundamental topic in statistics; however, many students experience difficulties in identifying the appropriate probability procedure before referring to the standard normal (Z) table. Confusion in distinguishing left-tail, right-tail, between-values and negative Z-score probabilities often leads to procedural errors and misconceptions. To address this challenge, Z-Navi: A Hybrid Learning Kit for the Standard Normal Distribution was developed as a teaching and learning innovation that guides students through a structured decision-making process before using the Z-table. The novelty of Z-Navi lies in its navigation-based learning approach, which integrates a Z-Guide Decision Board, Z-Guide Reference Cards, a Standard Normal Z-Table and QR code-enabled digital learning resources into a single hybrid learning ecosystem. Unlike conventional learning materials that rely primarily on direct table references, Z-Navi helps students identify the correct probability procedure before determining the corresponding probability value, thereby reducing confusion and strengthening conceptual understanding. Preliminary informal feedback from graduates who had previously completed statistics courses suggested that the kit is user-friendly, enhances learners' confidence and supports independent learning. Future work will involve formal evaluation of the innovation and further development of its digital learning resources to broaden its application across secondary, diploma and undergraduate education.

Keywords: Statistics education; Standard normal distribution; Hybrid learning; QR code; Teaching and learning innovation.

1. INTRODUCTION

The standard normal distribution is one of the fundamental topics in statistics and serves as the basis for numerous statistical techniques, including confidence intervals, hypothesis testing, regression analysis and statistical inference. Therefore, a sound understanding of the standard normal distribution is essential for students in mathematics, statistics, engineering, business and other quantitative disciplines. Despite its importance, many students continue to experience difficulties in solving standard normal distribution problems because they are unable to identify the appropriate probability procedure before referring to the Standard Normal (Z) Table. Consequently, students often make procedural errors even though they are able to use the Z-table correctly, indicating weaknesses in conceptual understanding rather than computational skills (Kaplar et al., 2021; Chaput et al., 2021). Previous studies have reported that students frequently encounter misconceptions in probability and statistics due to difficulties in interpreting probability questions and selecting appropriate solution procedures. Learning probability involves multiple cognitive processes, including understanding the problem context, identifying the correct probability rule and

performing statistical calculations. Hadfield (2021) highlighted that guided instruction supported by worked examples can reduce cognitive load and improve students' conceptual understanding by encouraging procedural reasoning rather than rote memorisation. Likewise, technology-enhanced learning has been recognised as an effective approach for promoting active learning and improving conceptual understanding in statistics education (Gehrke et al., 2021; Salinas-Herrera & Salinas-Hernández, 2022).

Although various instructional approaches have been introduced to improve statistics education, most existing learning materials focus primarily on explaining how to use the Standard Normal (Z) Table after students have already identified the required probability procedure. Limited attention has been given to supporting students in recognising whether a probability question involves left-tail, right-tail, between-values or negative Z-score probabilities before consulting the table. Consequently, students often memorise procedures without fully understanding the decision-making process required to solve different types of standard normal distribution problems, resulting in persistent misconceptions and procedural errors (Kaplur et al., 2021; Hadfield, 2021). To address this gap, Z-Navi: A Hybrid Learning Kit for the Standard Normal Distribution was developed as a teaching and learning innovation. Unlike conventional learning materials, Z-Navi adopts a navigation-based learning approach that systematically guides students in identifying the appropriate probability procedure before referring to the Standard Normal (Z) Table. The innovation integrates a Z-Guide Decision Board, Z-Guide reference cards, a Standard Normal Z-Table, and QR code-integrated digital learning resources into a single hybrid learning ecosystem. This structured approach aims to reduce procedural confusion, strengthen conceptual understanding, enhance students' confidence in solving standard normal distribution problems and promote independent learning. Therefore, the objective of this innovation is to develop a navigation-based hybrid learning kit that assists students in selecting the appropriate probability procedure before consulting the Standard Normal (Z) Table, thereby enhancing conceptual understanding and improving the teaching and learning of the standard normal distribution.

2. MATERIALS AND METHODS

Z-Navi was developed to address the learning difficulties commonly encountered by students when solving standard normal distribution problems, particularly in identifying the appropriate probability procedure before referring to the Standard Normal (Z) Table. The innovation was developed based on common misconceptions and procedural errors observed during the teaching and learning of statistics. The development process involved four main stages: identifying students' learning difficulties, designing the learning kit, integrating physical and digital learning components and refining the innovation based on preliminary informal feedback from graduates who had previously completed statistics courses.

The completed Z-Navi Kit consists of four integrated components that function as a navigation-based hybrid learning system. The Z-Guide Decision Board serves as the primary navigation tool that guides students in identifying the appropriate probability procedure according to the type of probability question before consulting the Standard Normal (Z) Table. Instead of relying on memorisation, students are guided to determine whether the problem involves left-tail, right-tail, between-values or negative Z-score probabilities. The Z-Guide Reference Cards complement the Decision Board by providing concise explanations, graphical illustrations, step-by-step procedures and worked examples for each probability situation. These reference cards reinforce conceptual understanding while assisting students in selecting the appropriate solution strategy. The Standard Normal Z-Table functions as the primary statistical reference within the kit. Unlike conventional learning materials that require students to determine the probability procedure independently, the Z-Table in Z-Navi is used only after the correct procedure has been identified through the Decision Board and Reference Cards, thereby reducing procedural errors and improving learning confidence. To complement the physical learning kit, QR code-integrated digital learning resources provide access to instructional videos, additional practice questions with worked solutions and downloadable learning materials. These digital resources support independent and self-paced learning beyond the classroom, enabling students to revisit learning materials anytime and anywhere.

3. RESULTS AND DISCUSSION

3.1. Overview of the Z-Navi Kit

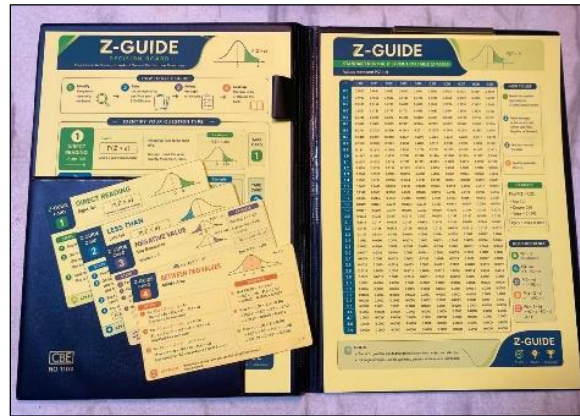


Figure 1. Z-Navi Kit.

Z-Navi was developed as a **navigation-based hybrid learning kit** to assist students in solving standard normal distribution problems through a structured and systematic learning process. Unlike conventional learning resources that primarily rely on direct use of the Standard Normal (Z) Table, Z-Navi guides students in identifying the appropriate probability procedure before consulting the table. This navigation-based approach helps minimise procedural errors and promotes conceptual understanding by supporting students throughout the entire problem-solving process. The kit integrates four complementary components: the Z-Guide Decision Board, Z-Guide Reference Cards, the Standard Normal Z-Table and QR code-integrated digital learning resources. Each component performs a specific function while complementing one another to create a complete learning ecosystem. The Decision Board serves as the initial navigation tool for identifying the probability procedure, followed by the Reference Cards, which provide graphical illustrations, worked examples and step-by-step guidance. The Standard Normal Z-Table is then used to obtain the required probability value, while the QR code extends learning beyond the classroom by providing access to digital learning resources for independent and self-paced learning. The integration of physical and digital learning resources differentiates Z-Navi from conventional learning materials by providing a more structured, interactive and learner-centred learning experience. This systematic navigation process is expected to improve students' confidence in solving standard normal distribution problems while reducing confusion in selecting the appropriate probability procedure.

3.2 The Z-Guide Decision Board as the Core Innovation of Z-Navi

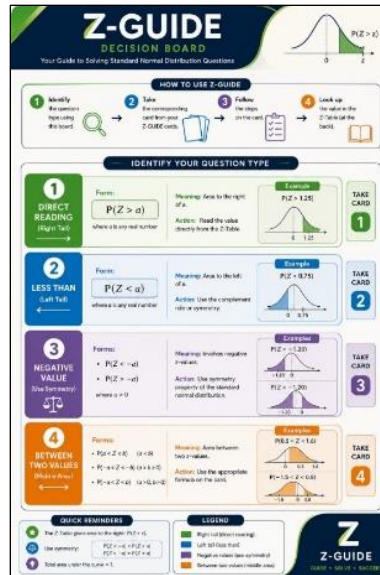


Figure 2. Z-Guide Decision Board.

The Z-Guide Decision Board is the core component and primary innovation of Z-Navi, distinguishing it from conventional learning materials for the standard normal distribution. Rather than requiring students to determine the appropriate probability procedure independently, the Decision Board provides a structured navigation pathway that systematically guides students in identifying the correct probability procedure before consulting the Standard Normal (Z) Table. This navigation-based approach addresses one of the most common learning difficulties observed among students, namely confusion in distinguishing between left-tail, right-tail, between-values and negative Z-score probability problems.

Unlike traditional learning resources that focus primarily on table usage, the Decision Board emphasises the decision-making process preceding probability calculation. Students begin by analysing the probability question using the Decision Board, which directs them to the appropriate probability category before referring to the corresponding Z-Guide Reference Card and Standard Normal Z-Table. This structured sequence reduces reliance on memorisation and encourages conceptual understanding by enabling students to understand the reasoning behind selecting the appropriate probability procedure. The navigation-based learning approach adopted in Z-Navi is consistent with guided instructional strategies that promote conceptual understanding while reducing cognitive load during problem solving (Hadfield, 2021). By simplifying the decision-making process into a series of structured steps, the Decision Board helps students solve standard normal distribution problems more systematically and confidently. Consequently, Z-Navi not only functions as a learning aid but also serves as a decision-support tool that enhances students' problem-solving skills and learning confidence.

3.3 Supporting Learning through the Z-Guide Reference Cards, Z-Table and QR Code



Figure 3. Supporting Components of the Z-Navi Kit: Z-Guide Reference Cards, Standard Normal Z-Table, and QR Code-Integrated Digital Learning Resources.

The Z-Guide Reference Cards, Standard Normal Z-Table and QR code-integrated digital learning resources function as complementary components that support the navigation-based learning process introduced by the Z-Guide Decision Board. After identifying the appropriate probability procedure, students refer to the relevant Reference Card, which provides concise explanations, graphical illustrations, step-by-step procedures and worked examples. These features reinforce conceptual understanding and enable students to relate probability concepts to the corresponding solution procedures. Subsequently, the Standard Normal Z-Table is used to obtain the required probability value, allowing students to apply the correct procedure systematically while reducing procedural errors.

To further enhance the learning experience, Z-Navi incorporates QR code-integrated digital learning resources that provide access to instructional videos, additional practice questions with worked solutions and downloadable learning materials. These digital resources complement the physical learning kit by enabling students to revisit concepts independently beyond classroom sessions. The integration of physical and digital learning resources supports a hybrid learning environment that accommodates different learning preferences while promoting self-paced and continuous learning. Preliminary informal feedback from graduates who had previously completed statistics courses suggested that Z-Navi is user-friendly, reduces confusion in selecting the appropriate probability procedure and increases learners' confidence in solving standard normal distribution problems. By integrating structured guidance with digital learning support, Z-Navi provides a more comprehensive learning experience than conventional learning materials, supporting meaningful learning while enhancing students' confidence and problem-solving skills in the standard normal distribution.

4. CONCLUSION

Z-Navi was developed as a navigation-based hybrid learning kit to address students' difficulties in identifying the appropriate probability procedure before using the Standard Normal (Z) Table. By integrating the Z-Guide Decision Board, Z-Guide Reference Cards, Standard Normal Z-Table and QR code-integrated digital learning resources, the innovation provides a structured learning pathway that supports systematic problem solving, reduces procedural confusion and promotes meaningful learning. Unlike conventional learning materials, Z-Navi emphasises the decision-making process prior to probability calculation, enabling students to develop greater confidence and problem-solving skills when solving standard normal distribution problems. The innovation also supports flexible and independent learning through the integration of physical and digital learning resources. Future work will focus on conducting a formal evaluation of the effectiveness of Z-Navi and expanding its digital learning resources to enhance its application across secondary school, diploma and undergraduate education.

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