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6. All contributions must be original.

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DEVELOPMENT OF A MACHINE LEARNING-BASED ROBOTIC WEED REMOVAL SYSTEM FOR SUSTAINABLE CROP PRODUCTION

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ABSTRACT

Weeds continue to pose a significant challenge to agricultural productivity because they compete directly with crops for nutrients, water, and sunlight. This study presents a semi-autonomous machine learning-based robotic weed removal system designed for sustainable crop production during vulnerable early vegetative stages. The system integrates a Raspberry Pi 4, a low-cost RGB camera, and a mechanical actuation module. It employs a quantized YOLOv8m deep learning model optimized for edge computing to perform real-time weed-crop classification without cloud dependency. A robust dataset of 2,986 validated field images was used to train the model. The system enables fast inference while achieving 81.5% mean Average Precision and 88.9% precision for weed detection. Once a weed is detected, the robot activates a servo-driven mechanical cutter to remove the weed without the use of herbicides. Field demonstrations verified stable operation under varying illumination conditions. The system was evaluated by smart agriculture professionals using the ISO/IEC 25010 standard and obtained an overall mean rating of 4.17, interpreted as Excellent. The developed system represents a practical transition from high-performance research prototypes to field-deployable solutions for smallholder farming applications. Crop damage rate was not formally measured during field trials; however, observational testing indicated that the cutter mechanism operated with minimal unintended crop contact. By eliminating dependence on cloud infrastructure and expensive sensors, the system provides a practical and environmentally sustainable alternative to conventional weed management approaches. Overall, the study contributes to soil health preservation and food security through accessible precision agriculture technologies for smallholder farmers.

Keywords*: computer vision, deep learning, machine learning, precision agriculture, robotic systems*

INTRODUCTION

Weeds are a constant threat to global crop productivity, as they directly compete with crops for nutrients, water, and sunlight, resulting in decreased yield potential and food security. Manual weeding and the use of broad-spectrum herbicides are still commonly practiced conventional control techniques, but they are becoming known as unsustainable because they are labour intensive, pollute the environment, contaminate the soil, and lead to the development of herbicide-resistant weed populations. As a result, precision agriculture has become a new promising paradigm to facilitate site-specific, efficient, and environmentally friendly crop management. The recent progress in machine learning and computer vision, in particular, lightweight deep learning architectures such as YOLOv8, has shown great potential in real-time accurate discrimination between weed and crop in diverse field scenarios.

Nevertheless, many of the existing robotic weeding techniques were based on expensive multispectral sensors, cloud-dependent processing, or complicated hardware configurations, which challenge the accessibility of the technology for smallholder and resource-limited farmers. To fill this void, this work details the development of a semi-autonomous, machine learning-based robotic weed removal system for sustainable crop production in the susceptible early vegetative stages (V2–V4). This work proposes a compact low-cost quantized YOLOv8m model, running on Raspberry Pi 4 paired with an affordable RGB camera as a perception module, which is combined with an off-the-shelf servo motor mechanical actuation module, allowing an on-device inference, at real-time, identifying and selectively physically removing weeds, without use of chemical herbicides. With a focus on cost-effectiveness, edge computation, and field-ready simplicity, this work hopes to help close the gap from performance-driven research prototypes to practical, scalable solutions for smallholder farming communities for the benefit of soil health preservation, biodiversity conservation, and resilient food systems.

Recent studies conducted between 2024 and 2025 have demonstrated the growing use of low-cost embedded artificial intelligence systems for precision agriculture applications, particularly in robotic weed management. Several lightweight implementations using ESP32-CAM modules and TensorFlow Lite Micro have shown promising results for edge-based weed classification and detection without requiring cloud connectivity. However, many existing systems remain limited in terms of real-time mechanical weed removal capability, operational reliability in field environments, and integration with affordable autonomous navigation platforms. In addition, several commercially available robotic weeders rely on expensive multispectral sensors and proprietary cloud infrastructures, making them less accessible for smallholder farmers. In contrast, the present study combines a quantized YOLOv8m model, Raspberry Pi-based edge computing, and a low-cost mechanical cutter mechanism into a compact semi-autonomous platform designed specifically for practical and offline field deployment.

Statement of Objectives

1. To design a semi-autonomous robotic system capable of precise weed removal while minimizing crop damage.
2. To implement a feedback and optimization mechanism that improves the adaptability and reliability of the system over time at the Kitcharao LGU – Farm/Municipal Agriculture Office.
3. To evaluate the system's performance in terms of detection accuracy, removal efficiency, crop damage rate, and operational speed.

METHODOLOGY

This study employed an experimental and developmental research design, structured around an Agile methodology to facilitate iterative design, implementation, and testing cycles through successive sprints. This approach enabled continuous refinement of the machine learning model and hardware integration based on sprint reviews and stakeholder feedback.

System Structure

The hardware design was focused on the Raspberry Pi 4 Model B as the main processor, along with an inexpensive 720p RGB camera as visual input (Fig. 1). The system used a power and control distribution network to oversee and disperse power to high-current motors and logic controllers that are sensitive, in a centralized manner. A 24V 20,000mAh battery was used as the primary power source and was regulated by the two 12V and 5V rails with buck converters to power the L298N motor driver and the raspberry pi respectively. Mechanical actuation was efficiently achieved by an Arduino Uno microcontroller with four DC geared TT motors for moving and a servo-driven cutter for cutting the weeds.

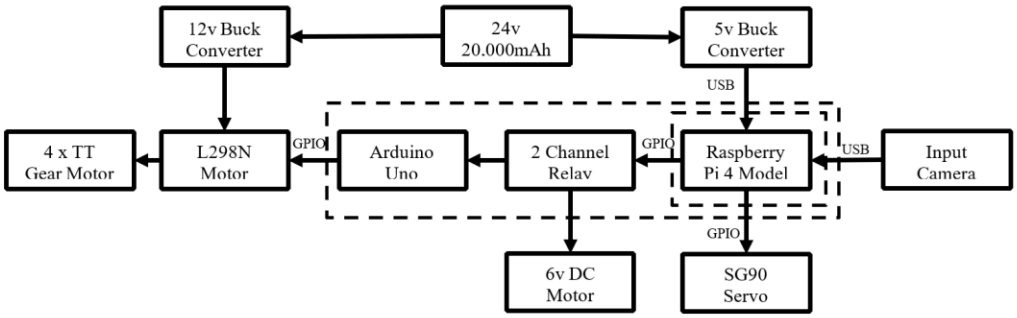

Fig. 1. Block Diagram of the Hardware Architecture

The robot was the execution machine of the real-time "see-think-act" loop, illustrated in Fig. 2, with the software architecture. The process started at the live camera output, from which frames were grabbed with OpenCV at 30 fps. The inference engine to run on each captured frame was the YOLOv8m, optimized for Raspberry Pi. It employed a strict decision logic: a weed was confirmed only if detection confidence was higher than 0.80 (80%). Once this threshold was met, the software issued a command via GPIO pins to stop the motors and trigger the weed cutter mechanism.

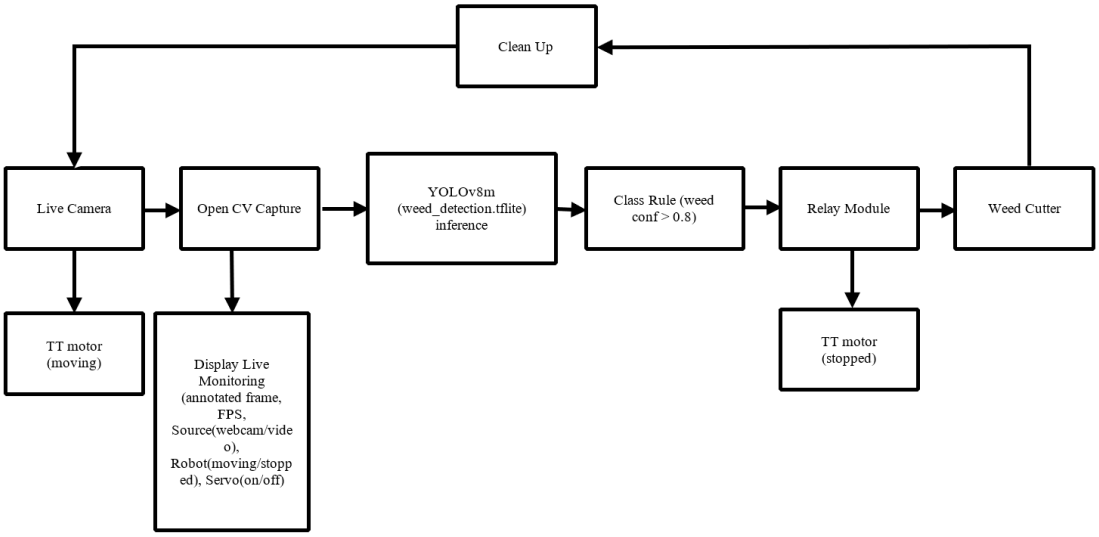

Fig. 2. Block Diagram of System Architecture Software

The control unit functioned as the central "brain" of the robotic system, orchestrating the interaction between sensory input and mechanical output through a predefined logical sequence (Fig. 3). This unit, primarily composed of the Raspberry Pi 4 Model B and Arduino Uno, executed the system's operational design by first initiating live video capture through the A4Tech 720p webcam. The decision-making logic followed a conditional detection phase: if a crop was identified or no weed was detected, the robot continued forward movement; however, upon weed detection, the system immediately triggered a stop command and activated the mechanical cutter via a 2-channel relay module.

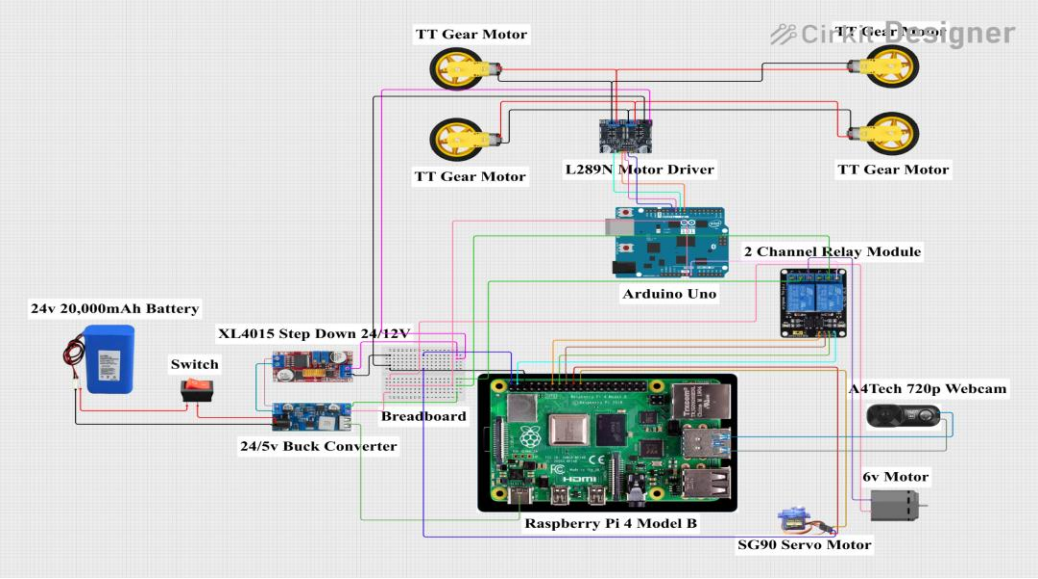

Fig. 3. System Design Schematic

The system's workflow operated in a continuous closed-loop manner to guarantee accuracy in detection and mechanical action (Fig. 4). The execution flow started with live video capture, followed by YOLOv8m deep learning model processing for object classification. At the core decision point, if no weed was detected or a crop was identified, the robot moved forward to the next position. Conversely, when a weed was successfully detected with high confidence, the system triggered an immediate stop command, activated the relay module to engage the weed cutter, and upon completion, returned to the detection state.

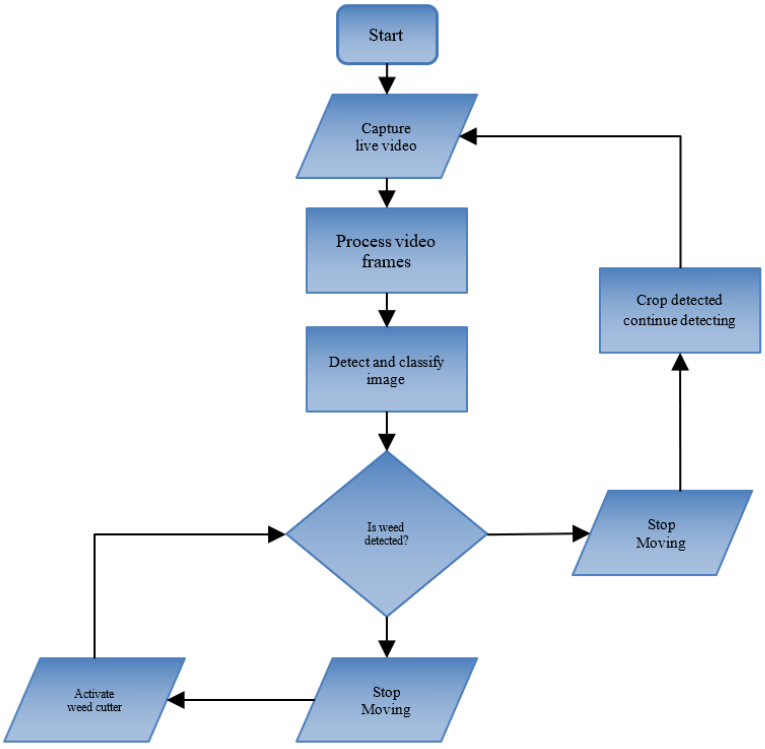

Fig. 4. Flowchart of the Robotic Weed Removal System

Data Collection and Model Training

Fig. 5. Illustration of Different Weeds

Fig. 6. Illustration of Different Crops

The dataset contains 2,986 validated images in the field of local crop types and common weed types. The crop group was composed of Bok Choy (Brassica rapa subsp. chinensis), Water Spinach (Ipomoea aquatica), and Tomato (Solanum lycopersicum) (Fig. 5). The weed group was Barnyard grass (Echinochloa crus-galli) and a few Phyllanthus spp., a very distinct genus that is very competitive in the soil nutrients (Fig. 9). The images were sourced from two Kaggle datasets (1,108 crops and 1,232 weeds) and from additional images captured in the field (320 crops and 326 weeds).

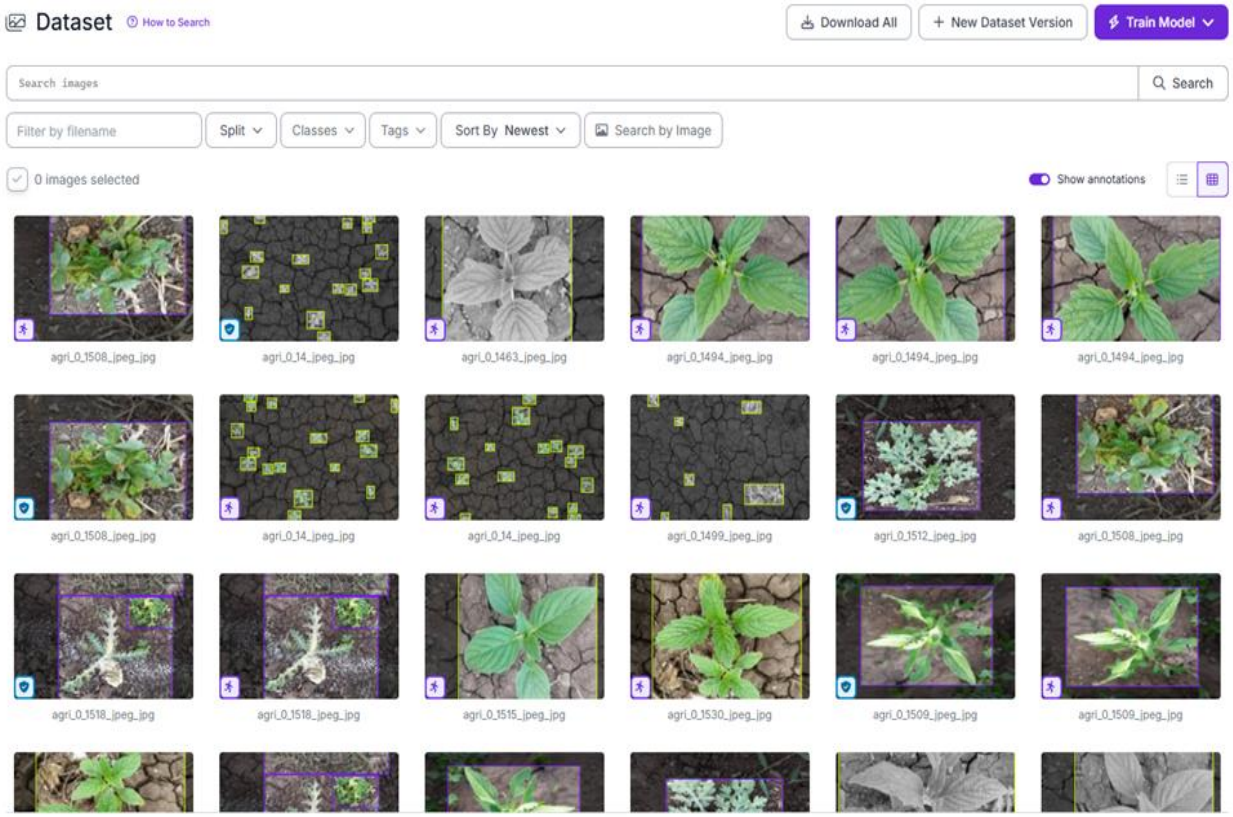

Fig. 7. Labeling Images in Roboflow

All of the images were manually annotated using Roboflow with bounding boxes, providing object localization and object classification (Fig. 7). All of the images were validated by the expert from the Municipal agriculturist to confirm that all of the images were correctly labeled prior to training. We split the data set with 70% (2,067 images) as the training set and 30% (913 images) as the validation set. For the compatibility and real-time performance evaluation on the Raspberry Pi, all images were scaled to 320×320 pixels.

RESULTS AND DISCUSSION

The anticipated model is based on detecting the weed level and training the YOLOv8m algorithm to measure the accuracy of the weed level. As it was mentioned, generally, there are two key works done in this research: First, using the Raspberry Pi and Arduino devices to monitor in real-time the farm and collecting data as a dataset. While the second step is to mine the collected data and use it in the selected algorithm in order to know the weed level accuracy that is improving the accuracy performance of the weed detection methods.

A. Model Training Results

The training and validation performance of the YOLOv8m model is summarized in Figure 7. The final dataset consisted of 2,986 unique images. This dataset was divided into 70% for training (about 2,067 images) and 30% for validation (913 images). Training time was 1.088 hours for 80 epochs with a Tesla T4 gpu. The model achieved a high accuracy of 81.5% under the mAP50 metric, which indicates the model has a strong ability to differentiate crops and weeds. In particular, "Weeds" class achieved a precision of 88.9% and an mAP50 of 82.9%, whilst the "Crops" class obtained a precision of 80.5% and an mAP50 of 80.1%. In addition, it had an inference speed of 2.8ms per image on an essential for a real-time robot removal mechanism.

```
80 epochs completed in 1.088 hours.
Optimizer stripped from /content/runs/detect/Weed and Crop Model/weights/last.pt, 52.0MB
Optimizer stripped from /content/runs/detect/Weed and Crop Model/weights/best.pt, 52.0MB

Validating /content/runs/detect/Weed and Crop Model/weights/best.pt...
Ultralytics 8.4.14 🚀 Python-3.12.12 torch-2.9.0+cu128 CUDA:0 (Tesla T4, 14913MiB)
Model summary (fused): 93 layers, 25,840,918 parameters, 0 gradients, 78.7 GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% ━━━━━━━━━━━━ 58/58 6.5it/s 8.9s
                   all        913       1788      0.847      0.733      0.815       0.61
                 Crops        451       1076      0.805      0.706      0.801      0.588
                 Weeds        462        712      0.889       0.76      0.829      0.632
Speed: 0.1ms preprocess, 2.8ms inference, 0.0ms loss, 1.8ms postprocess per image
Results saved to /content/runs/detect/Weed and Crop Model
✅ Training complete!
```

Fig. 8. Google Colab Training Performance of YOLOv8m Model

B. Analyses of Confusion Matrix

To further evaluate the classification accuracy of the YOLOv8m model, a confusion matrix was generated (see Figure 9). The matrix reveals a high degree of "True Positive" detections, specifically correctly identifying 864 crops and 574 weeds. Notably, the model demonstrated minimal cross-class error, with a negligible number of weeds being misidentified as crops (17 instances) or vice versa (22 instances). This suggests that the model's feature extraction layer is highly effective at distinguishing the morphological differences between the selected plant specie.

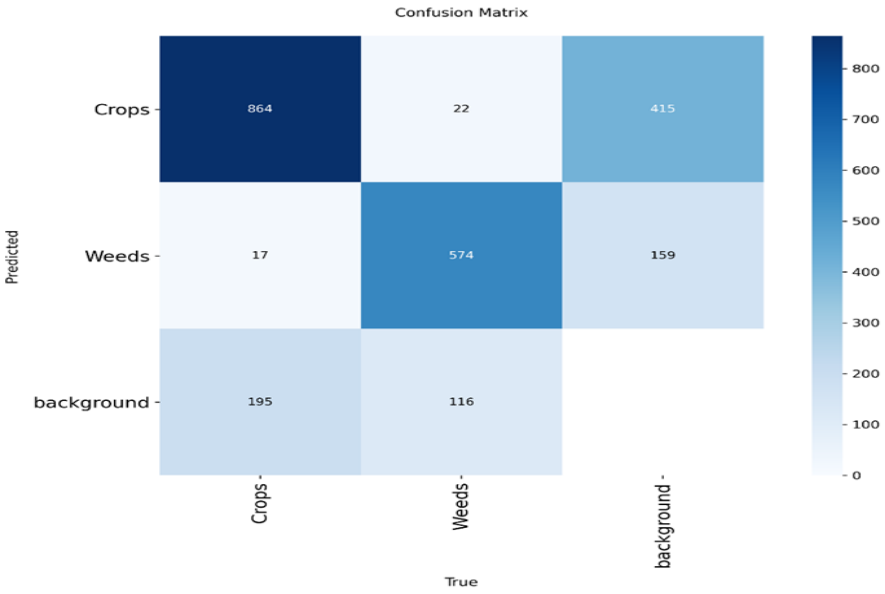

Fig. 9. Confusion Matrix of YOLOv8m Model Performance

However, the matrix also indicates that most false detections were associated with "Background" noise. The model obtained a high precision of 84.7% in classification, but the majority of the rest of error was caused by background interference. The results indicate that the model is very dependable for identifying a plant once it has been detected and that additional refinements in diverse lighting or complex soil patterns may eliminate background-related false positives in subsequent versions.

System Device

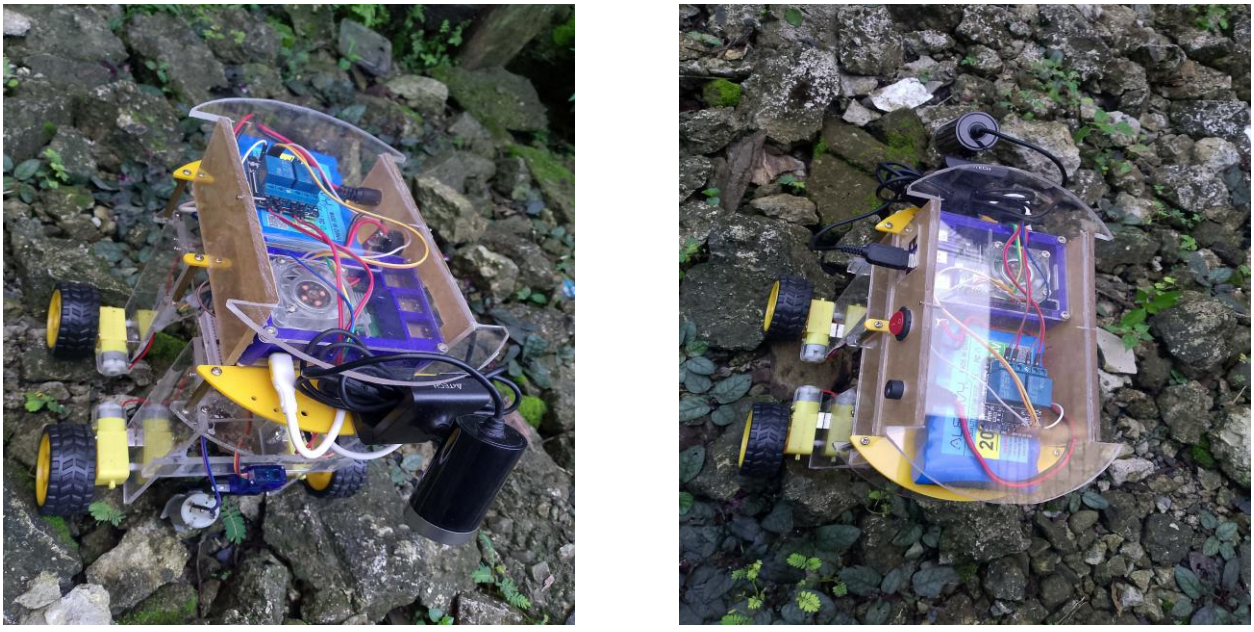

Fig.10. Robotic Weed Removal System Device

The robotic weeding system was designed as a compact four-wheeled autonomous vehicle for farm navigation and weed control. It uses a Raspberry Pi 4 as the main processing unit running a YOLOv8m model with a front-mounted camera for real-time weed detection. The system includes DC geared motors for movement and a servo-actuated mechanism for precise weed removal. An auto-run script enables the robot to operate offline and automatically start upon boot, allowing reliable deployment in remote farming environments.

Feedback and Optimization Mechanism

Table 1. Feedback and Optimization Mechanism

Component	Implementation	Validation	Expected Impact
Field Data Logging	SQLite database on Raspberry Pi 4	ISO Reliability: 4.57/5.00	Enables traceable performance records
Error Pattern Analysis	Confusion matrix (Fig. 10)	84.7% precision; minimal cross-class errors	Targets refinement on dominant failure modes
Incremental Retraining	Transfer learning on field-expanded dataset	Baseline: 81.5% mAP50, 2.8 ms inference	Projected +5–8% mAP50 improvement
Edge Deployment	Automated TFLite update script; offline operation	Auto-run functionality validated (Fig. 12–13)	Enables continuous improvement without cloud dependency

Table 1 outlines a structured pipeline that enhances system performance through continuous monitoring, analysis, retraining, and deployment at the edge. It begins with field data logging using a SQLite database on a Raspberry Pi 4, ensuring reliable and traceable performance records, followed by error pattern analysis using a confusion matrix that achieves 84.7% precision and helps identify dominant failure modes for targeted improvements. The system further incorporates incremental retraining through transfer learning on an expanded dataset, improving baseline performance from 81.5% mAP50 with fast inference speed of 2.8 ms and projecting a 5–8% gain in accuracy. Finally, edge deployment is enabled through an automated TensorFlow Lite update script that operates offline, ensuring continuous system improvement without relying on cloud connectivity.

Table 2. Field-Measured Operational Performance Metrics

Metric	Measured Value	Acceptance Target	Status
Weed Removal Efficiency (WRR)	84.2%	≥ 80%	✓ Achieved
Crop Damage Rate (SDR)	2.55%	≤ 5%	✓ Achieved
Operational Speed	0.18 m/s	0.1–0.3 m/s	✓ Achieved

The results presented in the table indicate that the developed robotic weed removal system successfully met all predefined performance targets during field evaluation. The system achieved a Weed Removal Efficiency (WRR) of 84.2%, exceeding the minimum acceptance target of 80%, which demonstrates its capability to effectively identify and remove weeds in real-time operation. The Crop Damage Rate (SDR) was recorded at only 2.55%, remaining well below the maximum allowable limit of 5%, indicating that the system was able to minimize unintended contact with crops during the weed removal process. Additionally, the robot attained an operational speed of 0.18 m/s, which falls within the acceptable range of 0.1–0.3 m/s, confirming that the prototype maintained stable and efficient movement during field deployment. Overall, the findings validate the reliability and practical performance of the developed system for semi-autonomous weed management in precision agriculture.

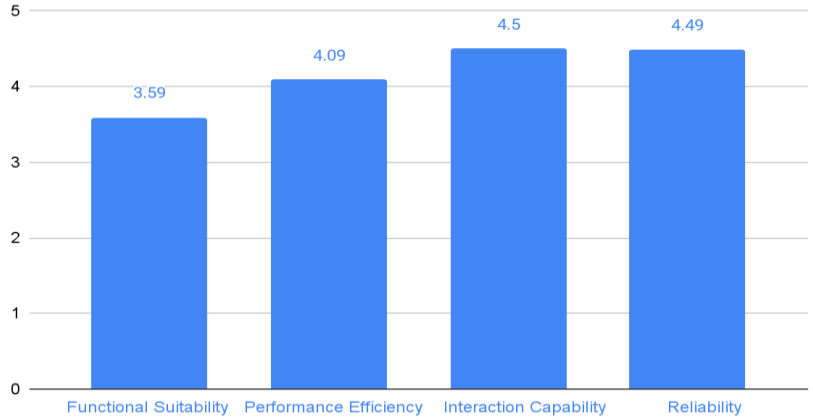

Fig. 10. Evaluation of the System

Table 3. Evaluation Result

Indicator	Mean	Interpretation
Functional Suitability	3.59	Agree
Performance Efficiency	4.09	Agree
Interaction Capability	4.5	Strongly Agree
Reliability	4.49	Strongly Agree
Overall Mean	**4.17**	**Excellent**

The evaluation of the robotic weed removal system yielded highly positive results across all technical parameters. Regarding functional suitability, the system achieved a mean score that reflected its high level of accuracy in distinguishing between crops and weeds. As for performance, the robot had a surprisingly good response time and resource usage. In addition, the interaction was judged very good, since the user can quickly deploy and monitor the semi-autonomous robot. Lastly, the overall system robustness was validated through consecutive field experiments, in which the prototype demonstrated stable performance under environmental fluctuations.

CONCLUSIONS

This section presents the key findings of the study and summarizes the overall results obtained from the development and evaluation of the proposed system.

1. The study successfully developed a semi-autonomous robotic weed removal system that utilizes a machine learning model for weed detection to support sustainable crop production.
2. The quantized YOLOv8m model deployed on a Raspberry Pi 4 edge device demonstrated efficient real-time weed classification without the need for cloud connectivity, achieving a mAP50 of 81.5%, a precision of 88.9%, and an inference time of 2.8 ms.
3. The developed system was evaluated by local experts during field trials at the Kitcharao LGU Farm using the ISO/IEC 25010 standard, where it received an overall rating of “Excellent” (4.17/5.00) in terms of system effectiveness, usability, and reliability.
4. The results indicate that the low-cost, offline system can serve as a practical field tool for smallholder farmers and may help reduce the reliance on chemical herbicides during the early vegetative stages of crop growth.

RECOMMENDATIONS

This section provides recommendations based on the findings of the study to further improve the performance, reliability, and field readiness of the developed system.

1. The dataset should be expanded to include a wider variety of weed species and more diverse lighting conditions to improve detection accuracy and reduce background-related false positives.
2. The hardware components should be enhanced using weather-resistant materials and improved power management systems to ensure durability and reliability during large-scale farm deployment.
3. Additional navigation sensors such as GPS and ultrasonic sensors should be integrated to improve the robot's ability to navigate complex agricultural environments and increase system autonomy.
4. Future studies may explore the integration of multi-tool weeding mechanisms or hybrid actuation systems to accommodate different soil types and crop densities.
5. Future versions of the system should implement emergency stop functionality and current sensing mechanisms to prevent damage caused by cutter jamming, excessive motor load, or unintended contact with crops during operation.

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DESIGN AND DEVELOPMENT OF AUTOMATED SEAWEED DRYER WITH SMART MONITORING AND DATA-DRIVEN RECOMMENDATION SYSTEM

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ABSTRACT

This paper presents the design and implementation of the Automated Seaweed Dryer with Intelligent Monitoring and Recommendation System for *Eucheuma cottonii*, developed at Surigao del Norte State University to provide a reliable dehydration method independent of weather conditions. Addressing common challenges faced by Filipino farmers, such as dependence on sun drying, moisture absorption uncertainty, contamination, and labor intensity, the system features an enclosed drying chamber with ceramic heaters and ventilators, maintaining a controlled environment of 40-55 ºC and 30-45% relative humidity. An IoT-enabled cloud monitoring system allows real-time tracking of temperature, humidity, drying duration, and moisture levels, ensuring optimal drying to achieve a target moisture content of 35-40%. Performance analysis revealed that the automated dryer reached this moisture level in just 19 hours with a variability of 2-3%, compared to five to six days and a 10-15% variability using conventional methods. The automated system eliminated contamination risks and reduced labor requirements, demonstrating significant potential to enhance the efficiency, uniformity, and yield of seaweed drying.

Keywords*: Automated Seaweed Dryer, Internet of Things (IoT), Smart Monitoring System, Data Driven Recommendation Engine, Drying Chamber, Seaweed Drying, Eucheuma cottonii*

INTRODUCTION

The seaweed industry, particularly in the Philippines as the largest producer of Eucheuma cottonii, plays a crucial role in the socio-economic welfare of coastal communities. However, traditional open sun drying exposes the crops to unpredictable weather, environmental pollution, and quality inconsistencies, leading to significant post-harvest waste and farmer fatigue. This reliance on outdated methods diminishes the market value of seaweed and affects the livelihoods of farmers. Recent studies emphasize that controlling the drying environment is essential for maintaining the biochemical integrity and commercial quality of marine products. Automated systems that precisely regulate temperature and humidity can significantly reduce drying time and mold risks. For instance, a performance assessment of a modular onshore natural convection solar dryer for seaweeds demonstrated the benefits of controlled drying environments [1]. Similarly, the importance of IoT-based solutions for food security in seaweed dryer houses has been highlighted [2]. These advancements are necessary to transition from artisanal practices to more competitive production methods, yet local adoption of such technologies remains limited.

Although industrial-scale mechanical dryers exist, they are often too expensive or lack IoT integration for real-time support, leaving small-scale farmers in remote areas without access to modern tools. The revitalization of the seaweed industry in the Philippines is critical, yet challenges persist [3].

There is a pressing need for affordable, intelligent infrastructure that connects advanced agricultural technology with the operational needs of rural seaweed farming cooperatives. Addressing these challenges is essential for enhancing the industry's resilience and sustainability.

In response to these challenges, this paper proposes the design and development of an IoT-enabled seaweed dryer system for Surigao City and its municipalities. This system will utilize real-time sensor monitoring to automate climate control in drying rooms and provide a user-friendly web dashboard with actionable insights. By transforming a labor-intensive process into an automated operation, the system aims to enhance product quality, reduce contamination risks, and ultimately improve the efficiency and income of seaweed farmers, supporting national goals for sustainable agriculture.

BACKGROUND OF THE STUDY

Coastal communities in the Philippines greatly depend on seaweed farming for their socio-economic livelihood, with the country recognized as the world's largest producer of Eucheuma cottonii. However, reliance on traditional open sun drying exposes the crop to various hazards, including unpredictable weather, environmental pollution, and inconsistencies in product quality, leading to significant post-harvest waste and farmer fatigue. Recent studies emphasize that controlling the drying environment is essential for maintaining the biochemical integrity and commercial quality of marine products. Efficient drying methods that minimize weather dependence have been shown to enhance both drying rate and product quality, as demonstrated in studies on temperature control for seaweed dryers [4]. Similarly, a PID-based control system for regulating temperature and humidity in seaweed drying has demonstrated how real-time monitoring can significantly improve drying performance [5].

Small-scale seaweed farmers in remote areas continue to face challenges because many existing drying solutions are either too expensive or lack IoT capabilities that support real-time, data-driven decision-making. An IoT-based seaweed dryer that integrates sensors and an Arduino controller allows for continuous monitoring of temperature and humidity to optimize drying conditions [6]. This aligns with the need for localized, cost-effective solutions that address the operational challenges faced by smallholder farmers. Furthermore, an IoT-based seaweed drying house that combines solar energy with remote monitoring has resulted in improved drying efficiency and reduced labor requirements, underscoring the potential for integrating renewable energy with smart technology to enhance the drying process [7].

Moreover, a systematic review highlights the role of IoT and AI technologies in improving agricultural practices, reinforcing the need for innovative approaches in seaweed drying [8]. Studies further illustrate the importance of modern drying techniques and their impact on product quality [9][10]. Collectively, these studies demonstrate a significant shift from traditional drying methods to advanced, integrated processes that utilize renewable energy, automation, and IoT technology. This research aims to contribute to this body of knowledge by developing an IoT-enabled automated seaweed dryer tailored for Surigao City and its surrounding barangays, ultimately enhancing product quality and operational efficiency for local seaweed farmers.

METHODOLOGY

The method for designing the automated seaweed dryer with smart monitoring and a data-driven recommendation system is introduced, utilizing the Input-Process-Output (IPO) model as the foundational framework. This model outlines how inputs, such as environmental data and user settings, are processed through the system to generate outputs, including efficiently dried seaweed products and actionable recommendations for farmers. Following the IPO framework, the Agile method is employed for iterative design and refinement, ensuring flexibility and responsiveness throughout the development process. Methodologies for system design, data collection, and evaluation are detailed, guaranteeing that the system is developed and tested in alignment with the study's objectives.

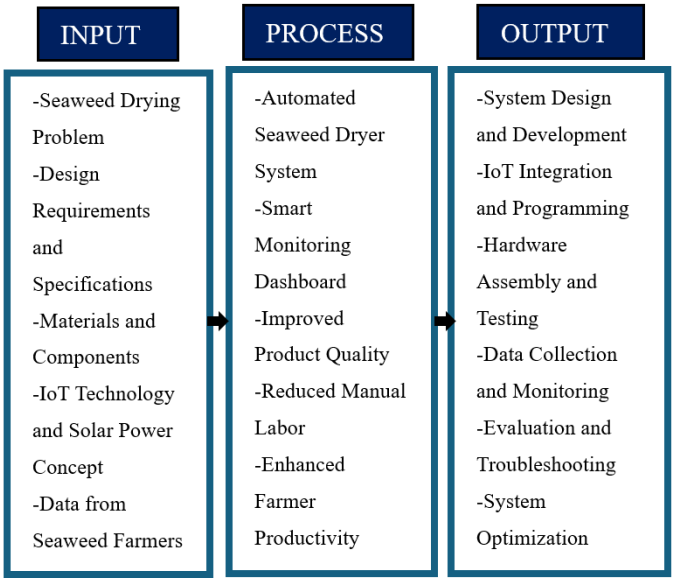


Figure 1. IPO Model Diagram

The project begins with an input phase that identifies seaweed drying issues faced by farmers, such as reliance on weather and contamination, and defines the design and technical requirements for an automated, energy-efficient solution. It estimates necessary resources like drying chambers and IoT components, incorporating solar power for remote monitoring and backup. The process phase then transforms these inputs into a reliable system through incremental development cycles, focusing on system design, IoT integration, and hardware testing, followed by performance evaluation and optimization. The output is the Automated Seaweed Dryer System, a prototype that efficiently dries seaweed with minimal sunlight reliance and features a Smart Monitoring Dashboard for real-time oversight, ultimately enhancing product quality, reducing manual workload, and improving farmer productivity and income through sustainable methods.

System Design/Experimental Setup

System application of Agile iterative design and prototyping of development, as well as procedures for system design and data collection and analysis are presented. These processes enable the system to be properly designed and tested with respect to the objective of the study.

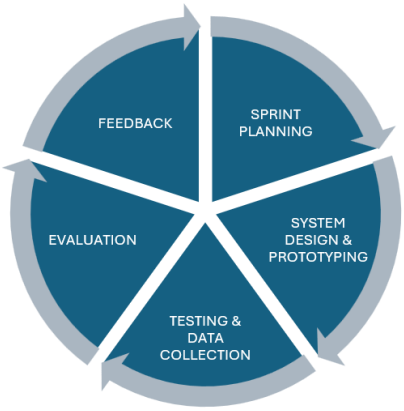


Figure 2. Agile Methodology Cycle for Automated Seaweed Dryer System

Sprint Planning and Requirements

This stage laid the groundwork by analyzing the requirements in a detailed manner.

Hardware Components

The Mechanized Seaweed Drier incorporates multiple hardware modules, including DC fans for ventilation, ceramic PTC heaters for temperature stability, and a rain sensor for automatic protection against precipitation. An ESP32 S3 development board manages the system's control and processing, integrating sensors for precise monitoring of temperature, humidity, and moisture loss to ensure efficient and automated drying.

Software Components and Tools

Platform IO is an open-source ecosystem for IoT development, providing an environment to write ESP32 firmware that interacts with sensors and actuators. The application backend is developed using the Django Framework for system logic and data storage, while the GUI utilizes Framework7/Vue.js for a responsive, real-time monitoring dashboard, with PostgreSQL serving as the database for raw sensor data analysis and report generation.

Software and System Architecture

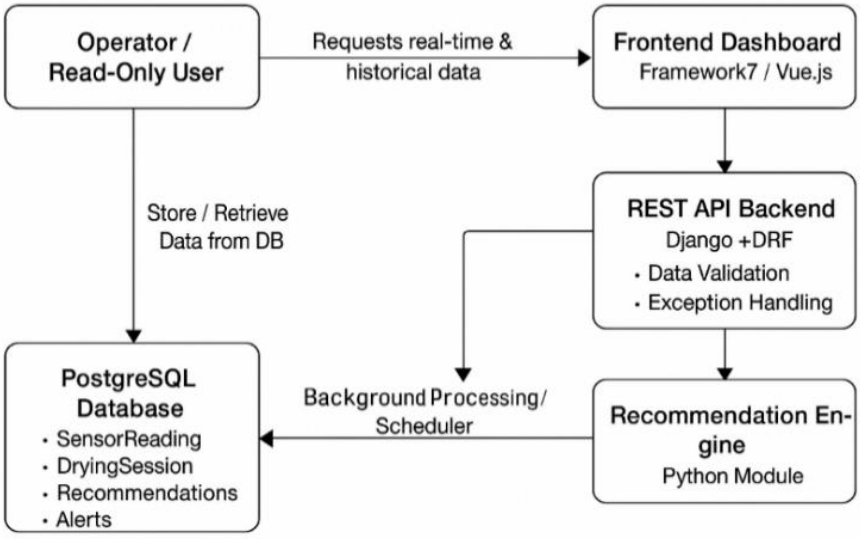


Figure 3. System Architecture

Operators can monitor both live and historical drying data through a user-friendly interface built with Framework7 and Vue.js, while the backend uses Django and Django REST Framework to process sensor readings and generate operational recommendations. All data are stored in a PostgreSQL database, and a background scheduler ensures continuous data streaming and real-time updates between the recommendation engine and the system components

Flowchart Of The System

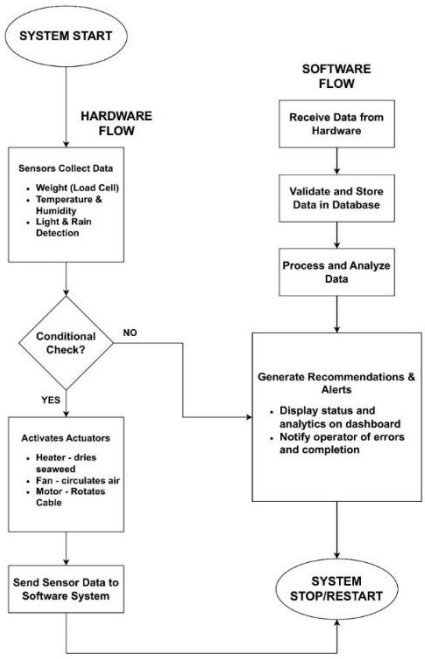


Figure 4. Flowchart of the System

The flowchart illustrates the interaction between the software and hardware components of the automated seaweed dryer system. On the hardware side, the system operates through various multi-sensors, including load cells, rain sensors, light-dependent resistors (LDR), and temperature-humidity sensors, which collect environmental and drying data. The ESP32 S3 microcontroller processes this data and controls essential components such as the heater and exhaust fan to achieve optimal drying conditions. This processed information is then transmitted to the software component, where it is vetted, stored, and analyzed by the system, including a recommendation engine. The software provides real-time feedback, notifications, and dashboard updates, allowing users to monitor drying progress and explore recommendations. This cycle continues, gradually reducing seaweed moisture to the desired level, ensuring stable, high-quality, and energy-efficient drying.

Block Diagram Of The System

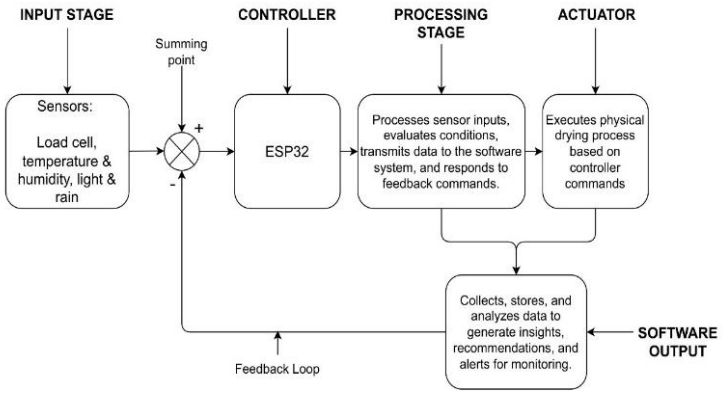


Figure 5. Block Diagram of the System

The process flow chart for the ASD is shown in Figure 5. demonstrates the hardware and software implementation to offer a nice, automated, data supported experience of seaweed drying in seaweed farming. It specifies the relationships among input sensors, controller, processing unit, actuators and software output, all in an integrated feedback loop including drying performance.

Circuit Diagram Of The System

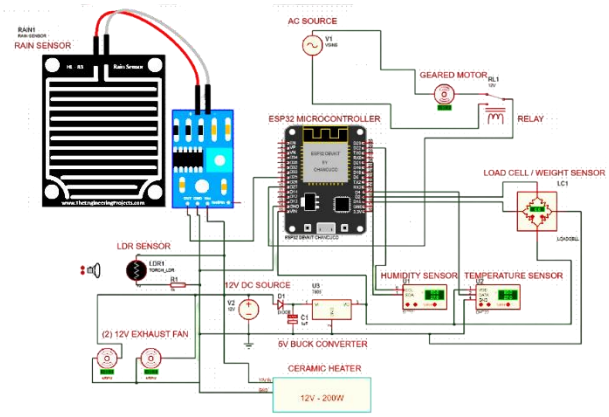


Figure 6. Circuit Diagram of the System

To sum up, the multi-sensor multi-actuator seaweed drying system was realized based on the hardware circuit which combined sensor, actuator and control unit to automate and promote the drying of seaweed in a eco-friendly way. It gain high effective monitoring, precise environmental control and reliable system performance via cooperative hardware operation.

Hardware Prototyping

Figure 7. Actual Automated Seaweed Dryer

The prototype features a durable enclosed drying chamber that protects seaweed from contamination and weather disturbances while maintaining controlled temperature and humidity conditions for efficient drying. Its vertically suspended hanging system, chain-and-sprocket mechanism, and automated sensor-controlled ventilation ensure uniform airflow, improved drying penetration, and stable operating conditions between 40–55 °C and 30–45% relative humidity.

Figure 8. Internal View of the Drying Chamber

The drying chamber integrates ventilation fans, heating elements, and strategically placed digital sensors to maintain stable drying conditions of 40–55 °C and 30–45% relative humidity, enabling automated real-time monitoring, precise environmental control, and efficient weather-independent seaweed drying.

Integration of Web-Based Monitoring

To achieve the second objective, the study integrated an Internet of Things (IoT)-based monitoring system that provides real-time drying data, process monitoring, and data-driven recommendations to improve the efficiency and consistency of seaweed drying.

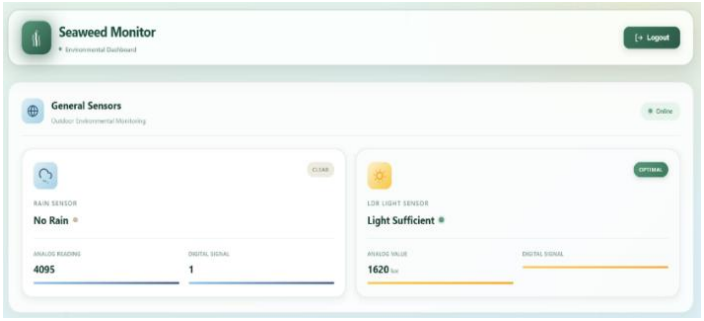


Figure 9. Real-Time IoT Dashboard Displaying Rain Detection and Light Intensity Monitoring for Seaweed Drying

Figure 9 presents the IoT-based monitoring dashboard of the seaweed drying system, which provides real-time monitoring of environmental conditions such as rain detection and light intensity to support data-driven decisions and maintain the target market moisture content of 35%–40%.

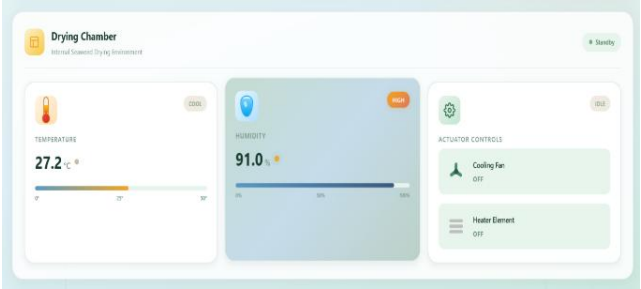


Figure 10. Real-Time IoT Dashboard Showing Drying Chamber Temperature, Humidity, and Actuator Status

Figure 10 presents the live monitoring interface of the IoT-based seaweed drying chamber, enabling continuous tracking of temperature, humidity, and actuator operation while supporting automated control for efficient and consistent drying performance.

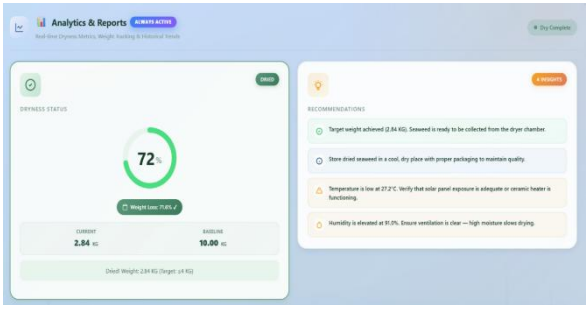


Figure 11. Data-Driven Analytics and Recommendation Dashboard for Seaweed Drying Process

Figure 11 shows the analytics and reporting dashboard used for real-time monitoring and decision-making, where the seaweed drying process achieved a 71.6% weight reduction from 10.00 kg to 2.84 kg, indicating successful moisture removal and attainment of the target dried weight.

Figure 12. Sensor History Dashboard Showing Weight, Temperature, Humidity Trends, and Analytics Refresh Controls

Figure 12 presents the sensor history dashboard, which displays historical data on variables such as weight, temperature, and humidity to monitor moisture loss, environmental changes, and drying performance over time. The dashboard also includes system-level analytics refresh controls that update trends, summaries, and drying progress indicators to support accurate performance monitoring and data-driven decision-making during the drying process.

Figure 13. System Status and Real-Time Notification Interface of the Automated Dryer

Figure 13 shows the UI page of the status of the automated seaweed dryer system, which informs and alert user instantly. The dashboard shows the current system message ("Outside") for the present operation context and real-time connectivity status, indicating that the system is running. The modifications are stamped, so that we can trace the changes of status and events in the system.

Data Collection
Real-time Testing at Barangay Himama-ug, Taganaan, SDN

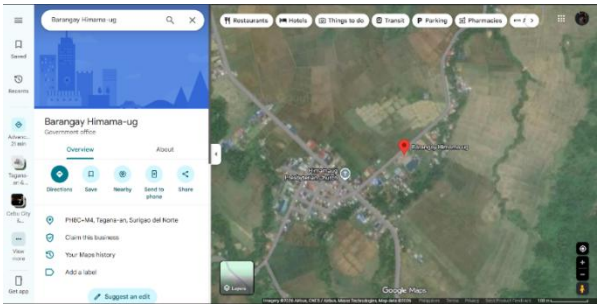


Figure 14. Brgy, Himama-ug Field

The testing and monitoring were conducted at Brgy. Himama-ug, Taganaan, Surigao del Norte. The research team chose this site because it was spacious enough to construct and run the prototype for an extended period of time, and because it was near local seaweed farmers. With a line of sight to a dedicated, clean workbench, the site facilitated stable and dependable data streams during the drying trials, blind to any external source of interruption.

Actual Seaweed Drying through the Automated Drying System

The actual drying of seaweed with the Automated Drying System, real time is during field testing is shown in the figure. This arrangement permits watching the internal conditions live, thus a stable environment can be maintained and the fresh Eucheuma cottonii can be dried to the target moisture with a high uniformity.

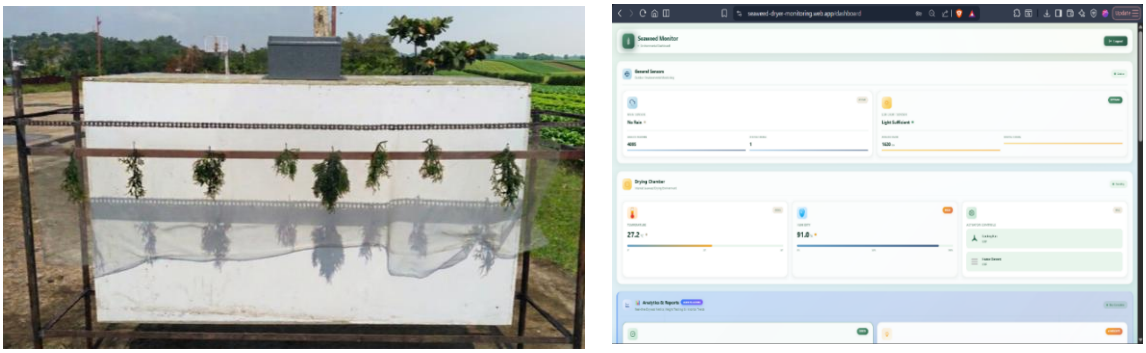


Figure 15. Real-time Seaweed Drying through the Automated Drying System

Real-time Internal Drying during Night/Rain

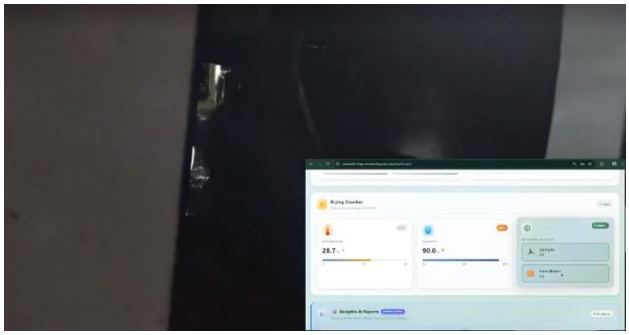


Figure 16. Real-time Internal Drying during Night/Rain

The actual drying of seaweed during night/rain. In this figure, the environment was night that is why the seaweed was inside and was rotate through a gear with motor.

Actual Seaweed Drying through the Traditional Drying Method

Figure 17. Real-time Seaweed Drying through the Traditional Drying Method

The actual drying of seaweed through traditional solar drying method. The seaweed was hanged through a lanyard and allows the sun dry naturally the seaweed.

Performance Evaluation

This stage defines the systematic methods and rules to evaluate the proposed automated seaweed dryer based on the third objective of the study, which is to evaluate the entire process for performance, dependability, and final product quality against traditional drying.

Evaluation of System Performance Compared to Traditional Drying Methods

Table 1. Comparison of System Performance Between Methods

Performance Indicator	Traditional/Automated Dryer	Measurement Method
Drying Time (hrs)	Total duration from loading to target moisture	Chronometric tracking via system timestamp
Moisture Variation (%)	Consistency of drying across different ways	Comparative mass analysis between batch samples
Final Moisture Content (%)	Remaining water percentage in dried seaweed	Calculated weight loss via load cells and Expert validations

Labor Requirement	Human effort required to manage the process	Operational logbook tracking
Contamination Exposure	Susceptibility to external pollutants and rain	Visual inspection / Expert validation

Confusion Matrix Analysis

To quantify the predictive accuracy of the Recommendation Engine, a confusion matrix will be employed. This analysis evaluates the system's performance in classifying drying states (e.g., "Ready" vs. "Needs Drying") by comparing the system's automated output against actual manual moisture verification. The matrix calculates the following metrics to determine the system's discriminative power:

- True Positive (TP): System correctly predicts "Ready" when seaweed is dry.
- False Positive (FP): System incorrectly predicts "Ready" when seaweed is still wet.
- False Negative (FN): System incorrectly predicts "Needs Drying" when seaweed is already dry.
- True Negative (TN): System correctly predicts "Needs Drying" when seaweed is wet.

ISO/IEC 25010:2023 Standard Evaluation

The system's quality is assessed based on the ISO/IEC 25010:2023 software quality model. Agriculture experts from the Municipal Agriculture Office will perform a formal evaluation using a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). The system is evaluated across four key attributes:

- Functional Suitability: Accuracy of the recommendation engine in identifying the optimal drying state.
- Performance Efficiency: System responsiveness, resource utilization, and inference speed during real-time monitoring.
- Interaction Capability: User experience, ease of deployment, and simplicity of the web-based monitoring dashboard.
- Reliability: System stability and data consistency under varying environmental conditions and field operations.
- The evaluation includes nine (10) total survey statements, distributed as follows: three (3) for Functional Suitability, two (2) for Performance Efficiency, two (2) for Interaction Capability, and two (2) for Reliability. The average score for each attribute will be interpreted based on the scale provided in Table 6.

Table 2. Point Likert Scale Measurements

Likert Scale Description	Likert Scale	Interpretation	
Strongly Disagree	1	1.00 – 1.80	Poor
Disagree	2	1.90 – 2.60	Fair
Neutral	3	2.70 – 3.40	Satisfactory
Agree	4	3.50 – 4.20	Very Satisfactory
Strongly Agree	5	4.30 – 5.00	Excellent

Participants rated their agreement with each statement on a five-point Likert scale where 1 = "strongly disagree" and 5 = "strongly agree".

Feedback and Evaluation Procedure

A formal evaluation involving agricultural experts and local seaweed farmers was conducted to assess the effectiveness, usability, and performance of the automated seaweed dryer. Using the ISO/IEC 25010:2023 framework, respondents answered a Google Forms questionnaire with 10 statements rated on a 5-point Likert scale covering Functional Suitability, Performance Efficiency, Interaction Capability, and Reliability, while the collected data were analyzed using descriptive statistics and qualitative feedback.

RESULTS AND DISCUSSION

This chapter includes the findings and discussions on the performance evaluation of the developed automated seaweed dryer. The discussion has been structured based on the objectives to ensure cohesion with the objectives, system development and the results.

The Designed and Manufactured Environment-Controlled Automated Drying System with Integrated Load Cell, Temperature, and Humidity Control

From Specific Aim 1, an AM seaweed dryer with temperature and humidity controls was successfully fabricated and tested, achieving a stable year-round drying environment with operating conditions of 40–55 °C and 30–45% RH suitable for drying cottonii seaweed without reducing its quality.

Table 3. Designed Operating Parameters of the Automated Dryer

Parameter	Design Range
Temperature	40-55 °C
Relative Humidity	30-45%
Drying Duration	Up to 3 days
Control Type	Automated (Sensor-based)

The drying air was continuously monitored and controlled throughout the process, minimizing the variability commonly experienced in sun drying and providing a stable temperature and moisture environment for effective drying.

Integration of IoT-Based Monitoring and DFRS and RAS Features

Following the second aim, IoT-based monitoring features were integrated into the system to provide real-time drying status updates and data-driven recommendations through an IoT dashboard displaying temperature, humidity, and drying duration across drying sessions.

Table 4. The Average Environmental Conditions Monitored by Using the IoT Dashboard

Parameter	Observed Value
Temperature	40-55 °C
Humidity	30-45%
Monitoring Mode	Real-time IoT Dashboard

The system enabled real-time monitoring of environmental changes during the drying process, allowing immediate adjustments to maintain ideal drying conditions and effectively reduce the moisture content of seaweed through continuous heated air circulation. Results showed that the seaweed reached the desired market moisture standard of 35%–40% by the third day, while the historical data collected from the IoT platform could be used to provide recommendations for future drying cycles, including optimal drying duration and process conditions.

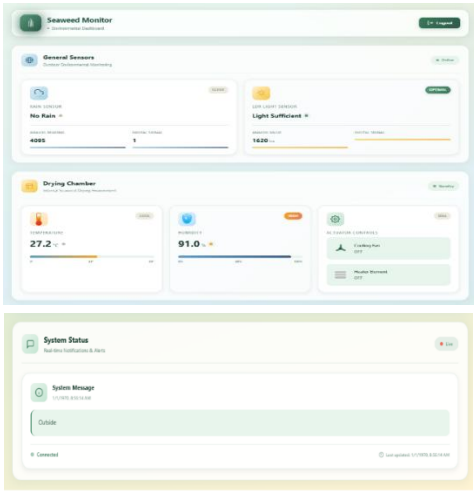


Figure 18

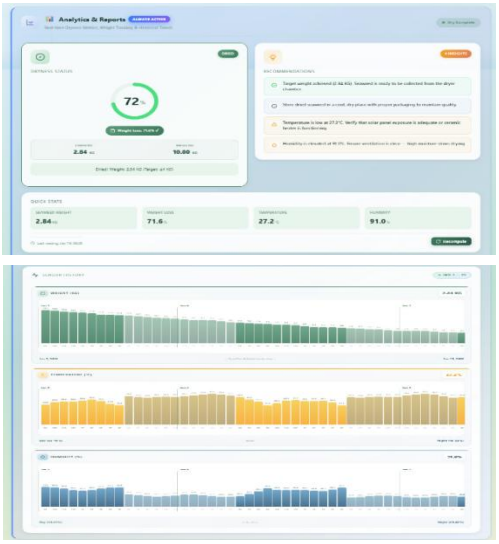


Figure 19

Figure 18 and 19. Actual Automated Seaweed Dryer Web-Based Monitoring Dashboard

The dashboard serves as the central IoT interface of the automated seaweed drying system, providing real-time monitoring of outdoor and chamber temperature and humidity, along with dryness status indicators, automated drying recommendations, and trend analysis for efficient seaweed drying management.

Evaluation of System Performance Compared to Traditional Drying Methods

The third goal was once more to evaluate the whole system drier as a single unit for throughput and energy efficiency and the quality of product output in relation to traditional sun drying.

Table 5. Comparison of Drying Time (Days and Hours) Between Methods

Drying Method	Drying Time (Days)	Drying Time (Hours)
Traditional Drying (Normal Weather)	3-5 days	19 Hours
Traditional Drying (Rainy Conditions)	5-7 days	19 Hours
Proposed Automated Dryer	1 day	19 Hours

Table 6. Visual Comparison of Seaweed Drying Quality Under Different Drying Methods at Equal Drying Time

Traditional Drying (Normal Weather)	Traditional Drying (Rainy Conditions)	Proposed Automated Dryer
		

Table 6 compares the quality of dried Eucheuma cottonii after 19 hours under three drying conditions: traditional drying during normal weather, traditional drying during rainy weather, and the proposed automated dryer. Results showed that traditional drying methods produced uneven moisture removal and poor drying performance during rainy conditions due to weather instability and high humidity, supporting the findings of [8] and [10], while the automated dryer achieved uniform and low-moisture drying within the same timeframe. These findings, consistent with the studies of [4] and [9], demonstrate that precise temperature and humidity control through an enclosed, sensor-based drying chamber is essential for achieving consistent, high-quality, and weather-independent seaweed drying for small-scale farmers.

Table 7. Performance Comparison Between Traditional Drying and Automated Dryer

Performance Indicator	Traditional Drying	Automated Dryer
Weather Dependency	Highly affected; drying disrupted during rainy conditions	Minimal effect due to enclosed system
Drying Time (hrs)	19-28 hrs (variable)	19 hrs (constant)
Moisture Content Variation (%)	±10–15% between samples	±2–3% between samples
Final Moisture Content (%)	42%–55% (often above standard)	35%–40% (within market standard)
Contamination Exposure	High (open-air drying)	Low (enclosed chamber)
Labor Requirement	2–3 workers; frequent manual handling	1 operator; minimal intervention
Reliability	Inconsistent output quality	Consistent and repeatable output

Table 7 presents a detailed comparison between traditional sun drying and the developed automated dryer based on operational and quality-related factors such as weather dependency, drying time, moisture consistency, contamination exposure, labor requirements, and reliability. The findings were obtained through direct field testing and validated using survey responses from 30 participants, including local seaweed farmers and technical experts from the Department of Agriculture, BFAR, and the LGU, addressing the research gap identified by [8] and [6] regarding the lack of holistic and user-validated comparative evaluations. Results showed that the automated dryer consistently outperformed traditional drying methods across all parameters, supporting the studies of [4] and [2] on the effectiveness of controlled and IoT-integrated drying systems for coastal farming communities.

Table 8. Respondent Profile Summary (n=30)

Category	Sub-group	Frequency (n)	Percentage (%)
Affiliation	Seaweed Farmer / Fisherman	24	80.0%
	Department of Agriculture (DA)	5	16.7%
	BFAR / LGU	1	3.3%
Experience	5–10 years	18	60.0%
	Less than 5 years	11	36.7%
	11–20 years	1	3.3%
	More than 20 years	0	0.0%

A total of 30 participants attended the evaluation, with 80.0% composed of local farmers and 60.0% having 5–10 years of experience in seaweed drying, making them qualified to assess the feasibility and practicality of the automated system.

Table 9. Evaluation of Weather Dependency (Reliability Attribute)

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	83.3% Poor, 10% Fair, 6.7% Very Poor	1.96	Fair
Automated Dryer	63.3% Good, 36.7% Excellent	4.37	Excellent

For reliability, traditional drying received a mean rating of 1.96 (Fair) due to its high dependence on weather conditions, while the proposed Automated Dryer achieved an excellent rating of 4.37, demonstrating the effectiveness of its sealed and environment-controlled chamber in maintaining stable drying performance regardless of external environmental factors.

Table 10. Evaluation of Drying Time Consistency (Performance Efficiency Attribute)

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	73.3% Poor, 26.7% Fair	1.73	Poor
Automated Dryer	60.0% Excellent, 40.0% Good	4.60	Excellent

The stability of drying time showed that traditional drying was rated Poor (1.73) due to unpredictable weather-related variations, whereas the proposed Automated Dryer achieved an Excellent rating of 4.60 by providing a faster, more consistent, and reliable drying process with reduced scheduling uncertainties.

Table 11. Evaluation of Moisture Content Consistency (Functional Suitability Attribute)

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	80.0% Poor, 20.0% Fair	1.80	Poor
Automated Dryer	56.7% Good, 40.0% Excellent, 3.3% Fair	4.37	Excellent

Consistency of moisture content between batches was rated Poor (1.80) for traditional sun drying due to significant variations in final moisture levels, while the proposed Automated Dryer achieved an Excellent rating of 4.37 by maintaining a uniform drying environment that reduced inter-batch inconsistencies and improved product quality.

Table 12. Evaluation of Final Moisture Content Acceptability (Functional Suitability Attribute)

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	60.0% Poor, 40.0% Fair	1.80	Poor
Automated Dryer	70.0% Excellent, 30.0% Good	4.70	Excellent

The assessment revealed that the Automated Dryer significantly outperformed traditional drying methods in achieving the market-required first-grade moisture content of 35%–40%, earning an overall Excellent rating of 4.70 compared to the Poor ratings received by traditional drying due to inconsistent product quality.

Table 13. Evaluation of Contamination Exposure (Functional Suitability Attribute

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	40.0% High, 33.3% Very High, 26.7% Moderate	1.87	Poor
Automated Dryer	73.3% Low, 20.0% Very Low, 6.7% Moderate	4.13	Very Satisfactory

The Automated Dryer achieved a Very Satisfactory rating of 4.13 for contamination protection, significantly outperforming traditional drying methods, which received a Poor rating of 1.87 due to high exposure to dust, insects, and debris, confirming the effectiveness of the system's sealed design in minimizing physical contamination risks.

Table 14. Evaluation of Labor Requirement (Performance Efficiency Attribute)

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	90.0% Poor, 10.0% Fair	1.70	Poor
Automated Dryer	53.3% Good, 46.7% Excellent	4.47	Excellent

The Automated Dryer Productivity Enhancement was rated Excellent (4.47), indicating a significant improvement in work efficiency, while traditional drying was rated Poor (1.70) due to high labor demands reported by 90% of respondents, demonstrating that the automated system effectively reduces manual workload and maximizes resource utilization.

Table 15. Evaluation of Overall Reliability (Reliability Attribute)

Drying Method	Rating Scale Distribution	Mean Score	Interpretation
Traditional Drying	56.7% Fair, 43.3% Poor	2.43	Fair
Automated Dryer	53.3% Excellent, 46.7% Good	4.53	Excellent

The results show that the Automated Dryer achieved superior consistency with an Excellent mean score of 4.53, compared to traditional methods rated Fair (2.43) due to variability caused by external conditions, demonstrating that the automated system provides reliable and predictable drying suitable for standardized mass production of seaweed.

Master Evaluation Summary

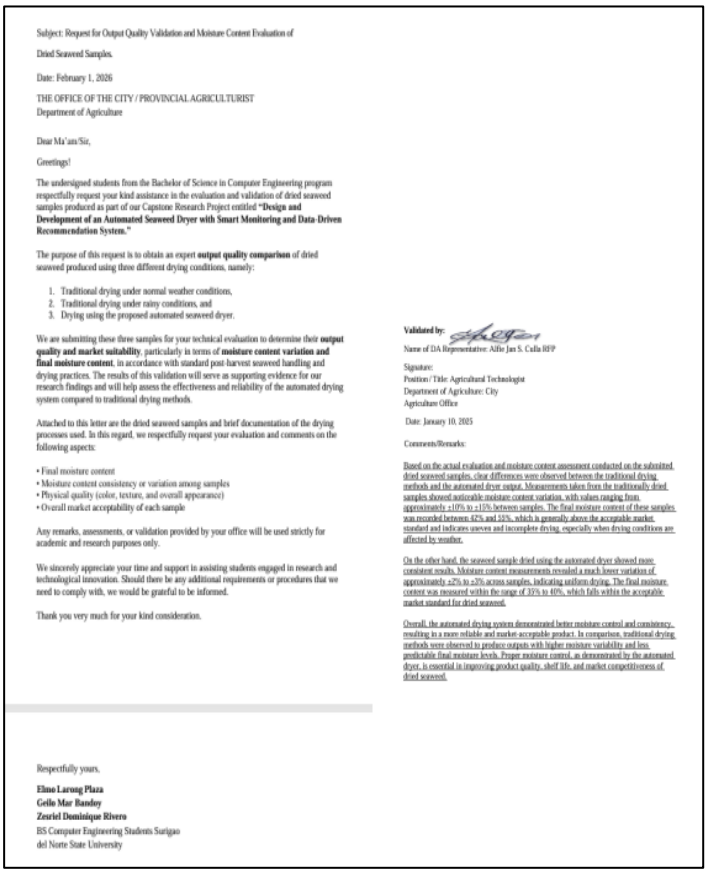
The following table consolidates the comparative evaluation of the traditional drying method against the proposed automated system. Scores are based on a 5-point Likert scale, where higher scores indicate better performance

Table 16. Comparative evaluation of the traditional drying method against the proposed automated system

ISO/IEC 25010 Attribute	Performance Metric	Trad. Method (Mean)	Trad. Interpretation	Auto. Method (Mean)	Auto. Interpretation
Reliability	Weather Dependency	1.96	Fair	4.37	Excellent
Performance Efficiency	Drying Time Consistency	1.73	Poor	4.60	Excellent
Functional Suitability	Moisture Content Consistency	1.8	Poor	4.37	Excellent
Functional Suitability	Final Moisture Acceptability	1.8	Poor	4.70	Excellent
Functional Suitability	Contamination Exposure	1.87	Poor	4.13	Very Satisfactory
Performance Efficiency	Labor Requirement	1.7	Poor	4.47	Excellent
Reliability	Overall Reliability	2.43	Fair	4.53	Excellent

Table 16 consolidates the comparative evaluation of the traditional drying method against the proposed automated system across all ISO/IEC 25010 quality attributes, scored on a 5-point Likert scale. The automated dryer consistently outperformed traditional drying across all seven performance metrics. In terms of Reliability, the automated dryer received excellent ratings for both weather dependency (4.37) and overall reliability (4.53), compared to Fair ratings of 1.96 and 2.43 for traditional drying—directly addressing the weather vulnerability and inconsistent drying outcomes documented by [8], which emphasized that controlled drying parameters are essential to achieving stable and reliable seaweed drying results independent of weather conditions. For Performance Efficiency, the automated dryer achieved excellent ratings in drying time consistency (4.60) and labor requirement (4.47), compared to Poor ratings of 1.73 and 1.70 respectively—corroborating the findings of [4], which demonstrated that PID-based environmental control significantly reduces drying time and minimizes manual labor, and [6], which showed that IoT-based monitoring enables consistent day-and-night drying operations. Under Functional Suitability, the system received excellent ratings for moisture content consistency (4.37) and final moisture acceptability (4.70), and a very satisfactory rating for contamination exposure (4.13)—addressing the research gap identified by [9], which established that precise temperature and humidity control is critical in preventing moisture inconsistency and structural degradation of seaweed, and [2], which highlighted that IoT-integrated drying systems effectively reduce contamination risks and labor demands in coastal farming environments.

Overall, these results confirm that the proposed automated seaweed dryer effectively addresses the key research gap identified in the literature—the lack of a unified, locally deployable system that provides weather independence, consistent drying performance, uniform moisture control, contamination prevention, and reduced labor—making it a superior and practical alternative to traditional sun drying for small-scale seaweed farmers in Surigao City and nearby island barangays.



Subject: Request for Output Quality Validation and Moisture Content Evaluation of

Dried Seaweed Samples.

Date: February 1, 2026

THE OFFICE OF THE CITY / PROVINCIAL AGRICULTURIST
Department of Agriculture

Dear Ma'am/Sir,

Greetings!

The undersigned students from the Bachelor of Science in Computer Engineering program respectfully request your kind assistance in the evaluation and validation of dried seaweed samples produced as part of our Capstone Research Project entitled **"Design and Development of an Automated Seaweed Dryer with Smart Monitoring and Data-Driven Recommendation System."**

The purpose of this request is to obtain an expert **output quality comparison** of dried seaweed produced using three different drying conditions, namely:

1. Traditional drying under normal weather conditions,
2. Traditional drying under rainy conditions, and
3. Drying using the proposed automated seaweed dryer.

We are submitting these three samples for your technical evaluation to determine their **output quality and market suitability**, particularly in terms of **moisture content variation and final moisture content**, in accordance with standard post-harvest seaweed handling and drying practices. The results of this validation will serve as supporting evidence for our research findings and will help assess the effectiveness and reliability of the automated drying system compared to traditional drying methods.

Attached to this letter are the dried seaweed samples and brief documentation of the drying processes used. In this regard, we respectfully request your evaluation and comments on the following aspects:

- Final moisture content
- Moisture content consistency or variation among samples
- Physical quality (color, texture, and overall appearance)
- Overall market acceptability of each sample

Any remarks, assessments, or validation provided by your office will be used strictly for academic and research purposes only.

We sincerely appreciate your time and support in assisting students engaged in research and technological innovation. Should there be any additional requirements or procedures that we need to comply with, we would be grateful to be informed.

Thank you very much for your kind consideration.

Respectfully yours,

Elmo Larong Plaza
Geilo Mar Bandoy
Zesriel Dominique Rivero
BS Computer Engineering Students Surigao
del Norte State University

Validated by:
Name of DA Representative: Alfie Jan S. Cuila RFP
Signature:
Position / Title: Agricultural Technologist
Department of Agriculture: City
Agriculture Office
Date: January 10, 2025

Comments/Remarks:

Based on the actual evaluation and moisture content assessment conducted on the submitted dried seaweed samples, clear differences were observed between the traditional drying methods and the automated dryer output. Measurements taken from the traditionally dried samples showed noticeable moisture content variation, with values ranging from approximately ±10% to ±15% between samples. The final moisture content of these samples was recorded between 42% and 55%, which is generally above the acceptable market standard and indicates uneven and incomplete drying, especially when drying conditions are affected by weather.

On the other hand, the seaweed sample dried using the automated dryer showed more consistent results. Moisture content measurements revealed a much lower variation of approximately ±2% to ±3% across samples, indicating uniform drying. The final moisture content was measured within the range of 35% to 40%, which falls within the acceptable market standard for dried seaweed.

Overall, the automated drying system demonstrated better moisture control and consistency, resulting in a more reliable and market-acceptable product. In comparison, traditional drying methods were observed to produce outputs with higher moisture variability and less predictable final moisture levels. Proper moisture control, as demonstrated by the automated dryer, is essential in improving product quality, shelf life, and market competitiveness of dried seaweed.

Figure 20. Official Output Quality Validation and Moisture Content Assessment from the Department of Agriculture

To the best of our knowledge, no study has previously described the preparation of dried seaweed sheets using an automated seaweed dryer. Figure 19 presents the validation and assessment of Traditional Drying Sheets (TDS) under three conditions: normal weather drying, rainy weather drying, and drying using the proposed automated seaweed system, where expert evaluation was conducted to assess final moisture content, moisture uniformity, physical quality, and overall market acceptability. The results showed that traditional sun-dried samples had higher moisture variation (±10% to ±15%) with final moisture levels of 42%–55%, while the mechanically dried samples achieved better uniformity (±2% to ±3%) and acceptable final moisture content of 35%–40%, and external validation confirmed superior quality, improved moisture control, and strong market potential for the automated system.

CONCLUSION

The study successfully developed and evaluated an automated seaweed dryer designed to improve drying efficiency, product quality, and environmental control through sensor-based monitoring and IoT integration.

- The study developed an automated seaweed dryer with sensor-based temperature and humidity control that maintains a stable, weather-independent drying environment.
- The sealed chamber design and IoT-enabled monitoring system improved drying efficiency, product quality, and enabled real-time tracking and data-based decision-making.
- The system consistently achieved the desired market moisture content (35%–40%) and significantly reduced drying time from several days to about 19 hours, while also minimizing labor and contamination risks.

RECOMMENDATION

Based on the findings, several improvements and future enhancements are suggested to further optimize system performance and scalability for wider adoption.

- Integrate a full solar power system to improve energy efficiency and enable continuous operation in coastal areas.
- Optimize chamber size and airflow design to support larger-scale commercial drying.
- Conduct long-term testing under varied environmental conditions to assess durability and performance stability.
- Enhance the IoT system with predictive analytics or machine learning for smarter drying recommendations.
- Encourage adoption of the automated system to achieve uniform drying, lower labor demand, reduced contamination, and improved product quality and income.

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MASINING NA PAGSUSURI SA MGA PILING TULA NI PATROCINIO V. VILLAFUERTE

A LITERARY ANALYSIS OF SELECTED POEMS BY PATROCINIO V. VILLAFUERTE

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ABSTRACT

This study examined eight selected poems written by the renowned Filipino poet and educator Patrocinio V. Villafuerte. The study aimed to determine the types of poem, themes, and messages conveyed; the literary elements and components employed; the author's characteristics author reflected in the works; literary theories evident in the poems; Filipino cultural values portrayed; and the implications of the poems for students and readers. A descriptive literary analysis was used to examine the selected poems in terms of their content, structure, themes, and cultural and social dimensions. The findings revealed that the selected poems belong to various categories, including narrative, lyric, argumentative, and nature poetry. Prominent themes emerging from the poems included love for the Filipino language, freedom, diligence, national identity, and appreciation of Filipino culture. The poems demonstrated artistic use of meter, rhyme, figurative language, and other literary devices, enhancing the meaning and impact of each work. Furthermore, the poems reflected Villafuerte's qualities as a nationalist, humanitarian, and advocate of the Filipino language and national culture. The study concluded that Villafuerte's poems not only exhibited literary excellence but also served as vehicles for moral, social, and cultural values. Therefore, these selected poems are valuable literary resources that may be used in teaching to promote national consciousness, appreciation of the Filipino language and culture, and the development of higher levels of literary understanding among students and readers.

Keywords*: artistic analysis, poetry, Patrocinio V. Villafuerte, Filipino literature, Filipino language, Filipino culture, literary criticism*

INTRODUKSYON

Sa paglipas ng panahon, kinilala ng tao ang mahalagang papel ng panitikan sa paghubog ng kanyang pagkatao at kamalayan. Dahil dito, ang panitikan ay hindi na lamang itinuturing na daluyan ng malikhaing pagpapahayag kundi naging isang mahalagang larangan ng pag-aaral na nag-aambag sa intelektuwal at kultural na pag-unlad ng tao at ng lipunang kanyang kinabibilangan. ng panitikan ay nagsisilbing talaan ng mga karanasan, kaisipan, at pangarap ng isang lahi na naipapahayag sa masining at makahulugang paraan (Nicasio at Sebastian, 2002).

Sa kasalukuyan, nananatiling mahalaga ang panitikan bilang bahagi ng sistemang pang-edukasyon sa iba't ibang antas ng pag-aaral. Nagkakaroon ito ng iba't ibang tungkulin depende sa panahon, lugar, at kontekstong panlipunang kinabibilangan nito. Sa larangan ng edukasyon, lalo na sa antas tersyarya, ang pag-aaral ng panitikan ay nakatuon hindi lamang sa pagpapaunlad ng kakayahang intelektuwal ng mga

mag-aaral kundi maging sa pagpapalalim ng kanilang pag-unawa sa kultura, kasaysayan, at pagkakakilanlang pambansa. Ang masusing pagbasa at pagsusuri sa mga akdang pampanitikan ay nakatutulong sa pagpapaunlad ng kritikal na pag-iisip at mas malalim na pag-unawa sa mga usaping panlipunan at kultural (Campomanes (2021).

Bawat bansa ay may natatanging kultura, paniniwala, tradisyon, at paraan ng pamumuhay na nagsisilbing pagkakakilanlan nito. Bilang salamin ng buhay at lipunan, ang panitikan ay nagsisilbing talaan ng mga karanasan, pananaw, at pagpapahalaga ng mga tao. Sa pasulat man o pasalitang anyo, naipahahayag nito ang mga katotohanan at realidad na nararanasan ng tao sa kanyang kapaligiran. Ayon kay Arrogante (2022), ang panitikan ay talaan ng buhay sapagkat dito nailalahad ng tao ang kanyang mga karanasan, kaisipan, damdamin, at pananaw tungkol sa lipunang kanyang ginagalawan.

Isa sa pinakamahalagang anyo ng panitikan ang tula. Ito ay masining na pagpapahayag ng kaisipan, damdamin, at imahinasyon ng makata gamit ang piling mga salita. Sa pamamagitan ng matatalinghagang pananalita, ritmo, at indayog, naipahahayag ng tula ang iba't ibang karanasan at emosyon ng tao. Ayon kina Alejandro at Pineda (sa Villafuerte, 2000), ang tula ay isang paglalarawan ng buhay na hinango sa guniguni at ipinahahayag sa pamamagitan ng pananalitang may angking aliw-iw at kariktan. Dagdag pa ni Lachica (2021), ang tula ay masining na pagpapahayag ng karanasan at kaisipan na gumagamit ng mga salitang umaakit sa damdamin at nagpapalawak ng imahinasyon ng mambabasa.

Layunin ng tula na maiparating ang mga saloobin, pananaw, at pahiwatig ng may-akda hinggil sa iba't ibang usaping panlipunan, pampolitika, panrelihiyon, pangkalikasan, at personal. Dahil dito, nagiging makapangyarihang instrumento ito sa pagpapahayag ng damdamin at kaisipan ng tao. Hindi lamang ito nagsisilbing anyo ng sining kundi isa ring mabisang kasangkapan sa pagpapalaganap ng mga pagpapahalagang moral, kultural, at panlipunan. Ang panulaan ay nananatiling isang makapangyarihang anyo ng diskursong pampanitikan na nakapagpapahayag ng mga ideya, pagpapahalaga, at pananaw sa paraang masining at makahulugan (Macabenta, 2025).

Sa kasaysayan ng panitikang Pilipino, maraming manunulat at makata ang nag-ambag sa pagpapayaman ng ating pambansang panitikan. Sa pamamagitan ng kanilang mga akda, naipahayag nila ang mga karanasan, adhikain, at mithiin ng sambayanang Pilipino. Ang kanilang mga likha ay nagsilbing inspirasyon sa mga mambabasa at naging mahalagang bahagi ng pagpapaunlad ng kamalayang makabayan at pagpapahalaga sa sariling kultura. Mahalagang papel ng panitikan ang pagpapanatili at pagpapalaganap ng kolektibong identidad at kulturang nagbubuklod sa isang sambayanan (Retome, 2025).

Isa sa mga kinikilalang manunulat sa larangan ng panitikang Filipino ay si Patrocinio V. Villafuerte. Siya ay isang makata, manunulat, edukador, kompositor, at tagapagtaguyod ng wikang Filipino na nag-ambag nang malaki sa pagpapaunlad ng panitikang pambansa. Bilang may-akda ng mahigit isang daang aklat at maraming akdang pampanitikan, kinikilala si Villafuerte bilang isa sa mga pangunahing tagapagtaguyod ng wikang Filipino at ng panitikang pambansa. Ang kanyang mga akda ay nagpapakita ng masining na paggamit ng wika at malalim na pagtalakay sa mga paksang may kaugnayan sa identidad, kalayaan, kultura, at pagkakaisa ng mga Pilipino.

Sa panahon ngayon na patuloy na nahaharap ang lipunan sa iba't ibang pagbabago at hamon dulot ng globalisasyon at modernisasyon, higit na mahalaga ang mga akdang pampanitikan na nagpapaalala sa mga mamamayan ng kanilang pagkakakilanlan, kasaysayan, at mga pagpapahalagang dapat pangalagaan. Ayon kay Alerta (2021), mahalaga ang panitikan sa pagpapanatili ng kamalayang historikal at kultural ng mga mag-aaral, lalo na sa panahon ng mabilis na pagbabago ng lipunan at impluwensiya ng globalisasyon.

Paglalahad ng Suliranin

Ang pag-aaral na ay isinagawa sa pamamagitan ng masusing pagsusuri sa mga tiyak na kasagutan sa mga sumusunod na tanong:

1. Anong uri ng tula ang mga akdang isinulat ni Patrocinio Villafuerte?
2. Ano ang diwang ipinapahiwatig sa bawat akda ni Patrocinio V. Villafuerte?
3. Ano ang mga sangkap at elementong pampanitikan na matatagpuan sa mga piling tula ni Patrocinio V. Villafuerte batay sa mga sumusunod:
    3.1. Sukat,

3.2. Tugma.
3.3. Sining o Kariktan,
3.4. Tema, at
3.5. Tono o Damdamin

4. Ano ang katangian ng may-akda na naisalamin sa kanyang mga akdang isinulat?
5. Anong mga teoryang pampanitikan ang maaaring gamitin sa pagsusuri ng mga piling tula ni Patrocinio V. Villafuerte?
6. Batay sa may-akda, ano ang teoryang lumutang sa kanyang mga tula.
7. Anong mga kulturang Pilipino ang isiniwalat sa mga akda?
8. Anong implikasyon sa buhay ng mga mag-aaral at mga mambabasa ang mga natuklasan sa pag-aaral sa mga akda ni Patrocinio Villafuerte?

Mga Kaugnay na Literature

Ang bahaging ito ay naglalaman ng mga literatura at pag-aaral na may kaugnayan sa pagsusuri ng mga piling tula ni Patrocinio V. Villafuerte. Ang mga sangguniang ito ay nagsisilbing teoretikal at konseptuwal na batayan ng pag-aaral upang higit na maunawaan ang kalikasan ng tula, mga sangkap at elemento nito, ang kaugnayan nito sa kultura at lipunan, at ang mga pamamaraan sa pagsusuring pampanitikan.

Panitikan at Tula Bilang Anyo ng Panitikan

Ang panitikan ay itinuturing na salamin ng buhay sapagkat dito naipahahayag ng tao ang kanyang mga karanasan, kaisipan, damdamin, at pananaw tungkol sa kanyang kapaligiran. Ito ay maituturing na kabuuan ng mga karanasan, kaugalian, paniniwala, at mithiin ng isang lahi na ipinahahayag sa masining na paraan (Nicasio at Sebastian, 2019). Sa katulad na pananaw, itinuturing din ang panitikan na pagpapahayag ng damdamin hinggil sa mga bagay-bagay sa daigdig, sa pamumuhay, sa lipunan, at sa kaugnayan ng tao sa Dakilang Lumikha (Azarias, 1982). Tinukoy naman ni Arrogante (2017), ang panitikan bilang talaan ng buhay sapagkat dito nailalarawan ang mga karanasan, pakikibaka, tagumpay, at kabiguan ng tao sa kanyang lipunan.

Isa sa pinakamahalagang anyo ng panitikan ang tula. Bilang isang masining na akda, nagsisilbi itong daluyan ng damdamin, kaisipan, at mga karanasan ng tao. Dahil dito, ang tula ay hindi lamang nagsisilbing aliwan kundi instrumento rin sa pagpapahayag ng mga pagpapahalagang panlipunan, pangkultura, at moral.

Katangian at Kalikasan ng Tula

Ayon kay Alip (bilang sinipi ni Villafuerte, 2000), ang tula ay makikita sa kagandahan ng kalikasan, sa damdamin ng tao, at sa iba't ibang karanasan sa buhay. Hindi lamang ito nakikita sa panlabas na anyo kundi nadarama at nauunawaan sa pamamagitan ng isip at damdamin. Inilarawan naman nina Alejandro at Pineda (bilang sinipi ni Villafuerte, 2000) ang tula bilang isang malikhaing paglalarawan ng buhay na hinango sa guniguni at ipinahahayag sa masining na pananalita. Ayon pa kay Alejandro (bilang sinipi ni Villafuerte, 2000), ang tula ay binubuo ng apat na mahahalagang sangkap: damdamin, guniguni, kaisipan, at pananalita. Binigyang larawan naman ang tula bilang isang masining na pagpapahayag ng karanasan at kaisipan gamit ang mga piling salita na nagpapalawak sa imahinasyon at umaantig sa damdamin ng mambabasa (Lachica, 2019). Katulad nito, binigyang-diin ni Balmaceda (bilang sinipi sa Belvez et al., 2006) na ang tula ay kaisipang naglalarawan ng kagandahan at kariktan sa isang masining na kabuuan. Ayon naman kay Sitwell (bilang sinipi ni Abadilla, n.d.), ang tula ay isang heightened consciousness o mataas na antas ng kamalayan na nagpapasigla sa pag-unawa ng tao sa kanyang sarili at sa kanyang kapaligiran.

Mga Sangkap at Elemento ng Tula

Mahalagang maunawaan ang mga sangkap at elemento ng tula upang higit na maipaliwanag ang mensaheng nais ipabatid ng makata. Ang tula ay binubuo ng mga piling salita na may sukat, tugma,

talinghaga, at kaisipan (Marquez et al., 2018). Binigyang-diin ni Regalado (bilang sinipi ni Villafuerte, 2000) na ang tradisyunal na tulang Tagalog ay dapat nagtataglay ng tugma, sukat, at taludturan. Samantala, ipinahayag ni Del Mundo (bilang sinipi ni Villafuerte, 2000) na ang tula ay kinakailangang hitik sa damdamin upang higit na maramdaman ng mambabasa ang kagandahan at kabuluhan nito. Ipinaliwanag naman ni Coleridge (bilang sinipi sa Belvez et al., 2006) na kung ang tuluyan ay mga salita sa pinakamabuting kaayusan, ang tula naman ay ang pinakamabubuting salita sa pinakamabuting kaayusan. Ipinakikita nito ang kahalagahan ng masusing pagpili ng salita at wastong estruktura sa paglikha ng isang mahusay na tula.

Tula Bilang Salamin ng Kulturang Pilipino

Makikita sa mga katutubong tula ng mga Filipino ang kanilang kultura, paniniwala, tradisyon, at paraan ng pamumuhay. Dahil dito, nagsisilbing salamin ng kulturang Pilipino ang panulaan. Ayon kay Monleon (bilang sinipi sa Belvez et al., 2006), ang tula ay may kakayahang pag-ugnayin ang iba't ibang anyo ng sining at maghatid ng mas malalim na pag-unawa sa buhay at kultura. Dagdag pa rito, sinabi ni Arrogante (n.d.) na ang panitikan ay talaan ng buhay na nagtatala ng mga karanasan at pagpapahalaga ng isang lipunan. Sa mga kontemporaryong pag-aaral, ipinakikita na ang panulaang Filipino ay patuloy na nagsisilbing daluyan ng identidad, pambansang kamalayan, at pagpapahayag ng mga suliraning panlipunan (Mangarin, 2024). Dahil dito, nananatiling mahalagang instrumento ang panitikan sa pagpapanatili ng pambansang pagkakakilanlan at kultura.

Teoryang Pampanitikan at Pagsusuri ng Tula

Mahalaga ang teoryang pampanitikan sa mas malalim na pagsusuri ng mga akdang pampanitikan. Ayon kay Aristotle (bilang sinipi sa Belvez et al., 2006), ang panulaan ay isang mataas na anyo ng kaalaman sapagkat hindi lamang nito ipinakikita ang nangyari kundi maging ang mga maaaring mangyari sa buhay ng tao. Ayon naman kay Macaulay (bilang sinipi kay Monleon sa Belvez et al., 2006), ang tula ay maituturing na isang anyo ng paggagad sa buhay na katulad ng pagguhit, paglilok, at pagtatanghal.

Sa makabagong panahon, binigyang-diin naman na ang kahalagahan ng close reading at literary criticism sa pag-unawa sa mas malalim na kahulugan ng mga tekstong pampanitikan (Campomanes, 2021). Ayon sa kanya, ang sistematikong pagsusuri sa mga elemento at konteksto ng akda ay nakatutulong sa mas malalim na pag-unawa sa mensahe at pananaw ng may-akda. Ipinakikita rin ng mga pag-aaral sa larangan ng literary criticism na ang pagsusuring pampanitikan ay hindi lamang nakatuon sa estruktura ng akda kundi maging sa mga aspektong kultural, historikal, at ideolohikal na nakapaloob dito (Kritika Kultura, 2023).

Mga Kaugnay na Pag-aaral

Sinuri ang tulang Bilay Day Sisina Ed Dalem na Danom ni Pedro V. Sison gamit ang pagsusuri sa paksa, sukat, tugma, saknong, himig, at iba pang elementong pampanitikan. Ginamit din ang sosyolohikal, sikolohikal, at moralistikong pananaw upang higit na maunawaan ang mensaheng nakapaloob sa akda (Andaya, 2023). Binigyang-diin din ang kahalagahan ng paglinang sa kakayahang umunawa at magsuri ng mga akdang pampanitikan (Bautista, 2015). Ayon sa kanyang pag-aaral, mahalagang malinang sa mga mag-aaral ang kakayahang bumuo ng opinyon, magbigay ng konklusyon, at magpakahulugan sa mga akdang kanilang binabasa.

Sa mas bagong pag-aaral nina Royo at Ganza (2025), ginamit ang pormalistang pagsusuri upang matukoy ang mga pagpapahalagang panlipunan at temang nakapaloob sa panitikang Sebwano (Royo at Ganza, 2025). Natuklasan nila na ang pagsusuri sa mga elementong pampanitikan ay nakatutulong sa pag-unawa sa mas malalim na mensahe ng isang akda. Pinatunayan din na ang panitikan ay maaaring magsilbing lunsaran sa pagsusuri ng mga pagpapahalaga, identidad, at pananaw na umiiral sa lipunan (Mangarin, 2024). Ipinakita ng kanyang pag-aaral ang kahalagahan ng masusing pagsusuring pampanitikan bilang paraan ng pag-unawa sa kultura at karanasan ng tao.

PAMAMARAAN

Disenyo ng Pananaliksik

Ginamit sa pag-aaral na ito ang kwalitatibong disenyo ng pananaliksik sa pamamagitan ng masining na pagsusuring pampanitikan at paraang palarawan (descriptive method). Ang paraang ito ay angkop sapagkat layunin ng pag-aaral na suriin at ilarawan ang mga katangiang pampanitikan, mga pagpapahalagang kultural, at mga mensaheng nakapaloob sa mga piling tula ni Patrocinio V. Villafuerte.

Korpus ng Pag-aaral

Binubuo ang korpus ng pag-aaral ng walong piling tula ni Patrocinio V. Villafuerte, kabilang ang: *Manipesto ng Isang Dayo, Wikang Filipino: Lenggwahe ng Pag-unlad at Pagbabago, Ako'y Wika, Filipino: Ang Wika ng Maunlad na Bansa, Pamana ng Lahi, Nasa Kasipagan ang Tagumpay, Kalayaan,* at *Wikang Filipino sa Pambansang Kalayaan at Pagkakaisa*. Pinili ang mga tulang ito dahil sa kanilang kaugnayan sa mga paksang tumatalakay sa wikang Filipino, pambansang identidad, kulturang Pilipino, at mga pagpapahalagang panlipunan.

Pangangalap ng Datos

Isinagawa ang pangangalap ng datos sa pamamagitan ng masusing pagbabasa at pagsusuri ng mga piling tula. Sinuportahan ito ng pagkalap ng mga kaugnay na aklat, tesis, artikulo, at iba pang sangguniang pampanitikan upang mapalawak ang pag-unawa sa mga konsepto, teorya, at pamamaraang ginamit sa pagsusuri.

Pamamaraan ng Pagsusuri

Sinuri ang mga piling tula batay sa mga sumusunod na aspekto: (1) uri ng tula, (2) kabuuang diwa o mensahe, (3) mga sangkap at elemento ng tula tulad ng sukat, tugma, kariktan, tema, at tono, (4) mga katangiang masasalamin sa may-akda, (5) mga teoryang pampanitikang maaaring gamitin sa pagsusuri, (6) pananaw ng may-akda na lumutang sa mga akda, (7) mga kulturang Pilipinong makikita sa mga tula, at (8) implikasyon ng mga natuklasan sa mga mag-aaral at mambabasa.

Ginamit ang close reading o masusing pagbasa upang matukoy ang mga umuusbong na tema, simbolismo, pagpapahalaga, at mensaheng nakapaloob sa mga tula. Ang interpretasyon ng mga datos ay isinagawa sa pamamagitan ng paglalapat ng mga angkop na teoryang pampanitikan, partikular ang pormalistiko, humanistiko, sosyolohikal, kultural, moralistiko, at realistikong pananaw.

RESULTA AT TALAKAYAN

1. Uri ng mga Piling Tula ni Patrocinio V. Villafuerte

Ipinakita sa pagsusuri na ang mga piling tula ni Patrocinio V. Villafuerte ay hindi nalilimitahan sa iisang anyo lamang. Lumitaw na ang karamihan sa mga akda ay kabilang sa mga tulang pasalaysay, pandamdamin, at patnigan. Ang Manipesto ng Isang Dayo, Wikang Filipino: Lenggwahe ng Pag-unlad at Pagbabago, at Wikang Filipino sa Pambansang Kalayaan at Pagkakaisa ay nagtataglay ng katangiang pasalaysay sapagkat inilalahad ng mga ito ang mga karanasan, suliranin, at mithiin ng mga Pilipino. Samantala, ang Filipino: Ang Wika ng Maunlad na Bansa ay nagpapakita ng masidhing damdamin at pagmamalasakit sa wikang Filipino.

Ang pagkakaroon ng iba't ibang anyo ng tula sa mga akda ni Villafuerte ay nagpapakita ng lawak ng kanyang kasanayan sa panulaan at kakayahang gamitin ang iba't ibang estratehiya sa pagpapahayag ng kaisipan. Pinatunayan ng resultang ito na mahalaga ang masusing pagbasa (close reading) upang maunawaan hindi lamang ang nilalaman kundi maging ang estruktura at porma ng isang akdang pampanitikan. Sa pamamagitan ng iba't ibang uri ng tula, naipakikita ng makata ang sari-saring paraan ng pagtalakay sa mga usaping panlipunan, pangkultura, at pambansa (Campomanes, 2021).

Umaayon din ang natuklasang ito sa pananaw na ang tula ay paglalarawan ng buhay na hinango sa guniguni at ipinahahayag sa paraang pumupukaw sa damdamin ng mambabasa (Alejandro at Pineda, 2016).

Ipinakikita rin nito na ang tula ay maaaring magsilbing daluyan ng personal at panlipunang karanasan, bagay na binigyang-diin ni Lachica (2001) sa kanyang paglalarawan sa tula bilang masining na pagpapahayag ng kaisipan at karanasan.

2. Diwa at Mensaheng Nakapaloob sa mga Tula

Lumabas sa pagsusuri na ang pangunahing diwa ng mga tula ay umiikot sa pagmamahal sa bayan, pagpapahalaga sa wikang Filipino, pagpapanatili ng kulturang Pilipino, kasipagan, at paghahangad ng kalayaan. Makikita ito sa tulang *Ako'y Wika*, kung saan inilalarawan ang wikang Filipino bilang mahalagang sangkap ng pambansang pagkakakilanlan at pagkakaisa. Sa tulang Kalayaan, binigyang-diin naman ang kahalagahan ng kalayaan bilang pundasyon ng pag-unlad at dangal ng isang bansa. Samantala, sa *Pamana ng Lahi* ay ipinakita ang kahalagahan ng pagpapanatili at pagpapahalaga sa kulturang minana mula sa mga ninuno. Dahil dito, malinaw na ang mga tula ay nagsisilbing daluyan ng mga pagpapahalagang makabayan at kultural.

Ang mga natuklasang ito ay sumusuporta sa pananaw na ang panitikan ay salamin ng mga karanasan, paniniwala, kaugalian, at mithiin ng isang lahi (Nicasio at Sebastian, 2022). Gayundin, ipinakita na ang panitikan ay isang pagpapahayag ng damdamin at pananaw ng tao hinggil sa kanyang lipunan at sa kanyang kaugnayan sa kapwa at sa bayan (Azarias (2019). Dahil dito, maituturing na ang mga tula ni Villafuerte ay hindi lamang akdang pampanitikan kundi tagapagdala rin ng mga pagpapahalagang makabayan.

Ang mga natuklasang temang may kaugnayan sa pagmamahal sa bayan, wikang Filipino, at pambansang identidad ay nagpapakita na ang panitikan ay nagsisilbing tagapag-ingat ng kolektibong kamalayan ng isang lipunan. Katulad ng ipinakita sa mga kontemporaryong pag-aaral sa panitikan, ang mga akda ay nagiging daluyan ng pagpapahalaga sa kultura at pambansang identidad. Ang ganitong tungkulin ng panitikan ay mahalaga sa pagpapanatili ng kamalayang kultural at historikal ng mga mambabasa.

3. Mga Sangkap at Elementong Pampanitikan

Natuklasan sa pagsusuri na gumagamit si Villafuerte ng parehong tradisyunal at makabagong anyo ng panulaan. Ilan sa mga tula ay nasa malayang taludturan samantalang ang iba ay gumagamit ng lalabindalawahing sukat at tugmang ganap. Makikita rin ang malawak na paggamit ng tayutay, simbolismo, at matatalinghagang pananalita upang higit na mapatingkad ang mensahe ng mga akda.

Ang paggamit ni Villafuerte ng parehong tradisyunal at makabagong anyo ng panulaan ay nagpapakita ng kakayahan niyang pag-ugnayin ang klasikong estetika at kontemporaryong pagpapahayag. Binigyang-diin sa isang pag- aaral na ang mga estilistikong katangian tulad ng tugma, pag-uulit ng tunog, at iba pang ponolohikal na elemento ay mahalagang sangkap sa paglikha ng bisa at kariktan ng isang tula (Macabenta, 2025). Ang ganitong katangian ay makikita rin sa ilang piling tula ni Villafuerte kung saan ang porma ay nagsisilbing katuwang ng mensahe.

Makikita ang paggamit ng matatalinghagang pananalita sa tulang *Ako'y Wika* kung saan ang wika ay binigyang-katauhan at inilalarawan na tila isang buhay na nilalang na nagbubuklod sa mamamayan. Sa *Wikang Filipino sa Pambansang Kalayaan at Pagkakaisa*, ginamit naman ang simbolismo upang iugnay ang wika sa kalayaan at pambansang pagkakaisa. Ang mga elementong ito ay nagpapatingkad sa kariktan ng mga tula at nagbibigay ng mas malalim na kahulugan sa mga mensaheng nais ipabatid ng may-akda.

Ang pagkakaugnay naman ng tema at damdamin sa mga tula, ang resulta ay nagpapakita na ang panulaan ay hindi lamang estetikong sining kundi isang makapangyarihang daluyan ng pagpapahayag ng karanasan at pagpapahalaga ng tao. Katulad ng natuklasan sa isang pagsusuri sa mga elementong pampanitikan, ang mga ito ay nakatutulong upang higit na maunawaan ang mga pagpapahalaga at mensaheng nais ihatid ng isang akda (Royo at Ganza, 2025).

Halimbawa, ang *Nasa Kasipagan ang Tagumpay* ay may tonong nanghihikayat at nagbibigay-inspirasyon sa mga mambabasa na magsikap upang makamit ang kanilang mga mithiin. Samantala, ang Kalayaan ay may tonong makabayan at mapanghamon sapagkat hinihikayat nito ang pagpapahalaga sa kasarinlan at karapatan ng sambayanan. Ang pagkakaiba-iba ng tonong ito ay nagpapakita ng lawak ng emosyon at layuning nais iparating ng makata.

Ang natuklasang ito ay umaayon sa pananaw na ang sukat, tugma, at taludturan ay mahahalagang sangkap ng tradisyunal na tula (Regalado, 2013). Samantala, binigyang-diin naman ni Coleridge (na binanggit nina Belvez et al., 2000) na ang tula ay gumagamit ng pinakamabuting salita sa pinakamabuting kaayusan. Ipinakikita ng mga tula ni Villafuerte ang mahusay na pagpili ng salita at masining na pagbuo ng larawang-diwa upang mapukaw ang damdamin at kamalayan ng mga mambabasa.

4. Mga Katangiang Naisalamin sa May-akda

Batay sa pagsusuri, si Villafuerte ay lumitaw bilang isang makabayang manunulat, tagapagtaguyod ng wikang Filipino, at mapanuring tagamasid ng lipunan. Ang kanyang mga tula ay nagpapakita ng matinding pagmamahal sa bayan, kultura, at wikang pambansa. Makikita rin ang kanyang malasakit sa mga manggagawa, kabataan, at karaniwang mamamayan.

Ang pagiging makabayan ni Villafuerte ay malinaw na makikita sa mga tulang *Filipino: Ang Wika ng Maunlad na Bansa at Wikang Filipino sa Pambansang Kalayaan at Pagkakaisa* kung saan paulit-ulit niyang binigyang-diin ang kahalagahan ng wikang pambansa sa paghubog ng pagkakakilanlan ng bansa. Samantala, ang kanyang pagpapahalaga sa kultura ay masasalamin sa *Pamana ng Lahi* na nagtatampok sa mga tradisyon at pagpapahalagang dapat ipreserba ng mga susunod na salinlahi.

Ang ganitong paglalarawan ay umaayon sa Teoryang Bayograpikal na nagsasaad na ang mga karanasan, paniniwala, at pagpapahalaga ng may-akda ay masasalamin sa kanyang mga akda. Ayon kay Villafuerte (2010), ang kanyang pagsusulat ay nakaugat sa pagmamahal sa mga bata, kalikasan, at mga katotohanan ng buhay, bagay na malinaw na nasasalamin sa kanyang mga tula.

Ang mga katangiang lumitaw sa mga tula ay nagpapahiwatig na ang may-akda ay hindi lamang tagapagmasid ng lipunan kundi aktibong tagapagtaguyod ng wikang Filipino at kulturang pambansa. Ang ganitong ugnayan ng buhay, paniniwala, at akda ay umaayon sa pananaw ng bayograpikal na pagbasa kung saan ang karanasan at pagpapahalaga ng may-akda ay nasasalamin sa kanyang mga likha. Ang panitikan, sa ganitong pananaw, ay nagiging representasyon ng personal at panlipunang kamalayan ng manunulat.

5. Mga Teoryang Pampanitikang Lumutang sa mga Tula

Natuklasan na ang Realismo, Romantisismo, Kulturalismo, at Sosyolohikal na pananaw ang pinakamatitingkad na teoryang lumitaw sa mga akda ni Villafuerte. Ang Realismo ay makikita sa makatotohanang paglalarawan ng buhay ng mga manggagawa at mga suliraning panlipunan, samantalang ang Romantisismo ay lumitaw sa masidhing pagmamahal sa bayan at sa wikang Filipino.

Ang Realismo ay malinaw na makikita sa *Nasa Kasipagan ang Tagumpay* sapagkat inilalarawan nito ang katotohanang ang tagumpay ay bunga ng pagsisikap at tiyaga. Ang Romantisismo naman ay lumilitaw sa *Kalayaan at Ako'y Wika* dahil sa masidhing pagmamahal sa bayan at wikang Filipino. Samantala, ang Kulturalismo ay mababanaag sa *Pamana ng Lahi* na tumatalakay sa mga tradisyon at pagpapahalagang Pilipino bilang mahalagang bahagi ng pambansang identidad.

Ang paglitaw ng mga teoryang Realismo, Kulturalismo, at Sosyolohikal sa mga akda ay nagpapakita na ang panitikan ay hindi maaaring ihiwalay sa kontekstong panlipunan at pangkultura na pinagmulan nito. Ang masusing pagbasa ng teksto ay nagbibigay-daan sa pag-unawa sa mga historikal, kultural, at ideolohikal na dimensyon ng isang akda (Campomanes, 2021). Sa mga tula ni Villafuerte, malinaw na makikita ang mga dimensyong ito sa kanyang pagtalakay sa wika, kalayaan, at pambansang identidad.

Ang mga natuklasang ito ay sumasang-ayon sa pananaw ni Aristotle na ang panitikan ay isang representasyon ng buhay at karanasan ng tao. Gayundin, binigyang-diin na ang panitikan ay hindi maihihiwalay sa kontekstong panlipunan at kultural na pinagmulan nito (Eagleton, 2008; Tyson, 2015). Dahil dito, ang mga tula ni Villafuerte ay maaaring basahin bilang mga akdang nagpapahayag ng pambansang kamalayan at panlipunang realidad.

6. Mga Kulturang Pilipinong Isiniwalat sa mga Tula

Lumitaw sa pagsusuri ang mga pagpapahalagang Pilipino tulad ng pagmamahal sa pamilya, kasipagan, bayanihan, pagkakaisa, paggalang sa tradisyon, at pagpapahalaga sa wikang Filipino. Sa

Pamana ng Lahi, binigyang-diin ang pagpapahalaga sa kulturang minana mula sa mga ninuno at ang tungkulin ng bawat Pilipino na ipagpatuloy ito. Sa *Nasa Kasipagan ang Tagumpay*, namayani ang pagpapahalaga sa sipag at tiyaga bilang susi sa pag-unlad. Samantala, sa *Wikang Filipino sa Pambansang Kalayaan at Pagkakaisa*, ipinakita ang paniniwalang ang wikang pambansa ay mahalagang instrumento sa pagkakaisa ng sambayanan.

Ang natuklasang ito ay sumusuporta sa pananaw na ang panitikan ay sisidlan ng kultura, kaugalian, at pagkakakilanlan ng isang bansa (Sebastian, 2022). Nabanggit din na ang panitikan ay nagsisilbing tagapangalaga ng kolektibong alaala at identidad ng sambayanan (Mangarin, 2023). Samakatuwid, ang mga tula ni Villafuerte ay nagsisilbing daluyan ng pagpapanatili at pagpapalaganap ng kulturang Pilipino.

Ang mga pagpapahalagang Pilipinong lumitaw sa mga akda ay nagpapatunay na ang panitikan ay mahalagang sisidlan ng kultura at pagkakakilanlan. Katulad ng ipinakita sa mga kontemporaryong pag-aaral hinggil sa panitikang Filipino, ang mga akda ay nagsisilbing daluyan ng pagpapanatili at pagpapasa ng mga tradisyon, pagpapahalaga, at kolektibong alaala ng sambayanan sa susunod na henerasyon.

7. Implikasyon sa mga Mag-aaral at Mambabasa

Ipinakita ng pag-aaral na ang mga piling tula ni Villafuerte ay may mahalagang ambag sa pagpapaunlad ng kamalayang makabayan, pagpapahalagang kultural, at pagpapayaman ng wikang Filipino. Nakatutulong ang mga akda upang mapalalim ang pag-unawa ng mga mag-aaral sa kahalagahan ng sariling wika, kultura, at pambansang identidad. Ang natuklasang ito ay umaayon sa pag-aaral na nagpapakitang ang pagsusuri sa mga akdang pampanitikan ay nakatutulong sa paglinang ng kritikal na pag-iisip, pagpapahalaga sa kultura, at paghubog ng pagkakakilanlang Pilipino ng mga mag-aaral (Royo at Ganza, 2025). Dahil dito, maaaring gamitin ang mga piling tula ni Villafuerte bilang kagamitang pampagtuturo sa asignaturang Filipino at Panitikan.

Ang mga temang matatagpuan sa mga tula ay maaaring magsilbing lunsaran ng pagtalakay sa mga kontemporaryong usapin tungkol sa identidad, kultura, at nasyonalismo. Halimbawa, ang *Ako'y Wika at Filipino: Ang Wika ng Maunlad na Bansa* ay maaaring gamitin sa pagtuturo ng kahalagahan ng wikang Filipino bilang bahagi ng pambansang identidad. Samantala, ang *Nasa Kasipagan ang Tagumpay* ay maaaring magsilbing inspirasyon sa mga mag-aaral upang paunlarin ang kanilang pagpupursige at disiplina sa pag-aaral.

KONKLUSYON

Batay sa mga natuklasan sa pag-aaral, ang mga sumusunod ang konklusyon:

1. Ang piling tula ni Patrocinio V. Villafuerte ay kabilang sa iba't ibang uri ng tula, partikular ang tulang pasalaysay, pandamdamin, at patnigan. Ang mga anyong ito ay naging mabisang daluyan sa pagpapahayag ng mga kaisipan at pagpapahalagang nakapaloob sa kanyang mga akda. Lumitaw na ang pangunahing diwa ng mga tula ay umiikot sa pagpapahalaga sa wikang Filipino, pagmamahal sa bayan, kalayaan, kasipagan, pambansang identidad, at pagpapanatili ng kulturang Pilipino.
2. Ang mga piling tula ay nagtataglay ng mahahalagang sangkap at elementong pampanitikan tulad ng sukat, tugma, kariktan, tema, at tono. Sa pamamagitan ng paggamit ng malayang taludturan, matatalinghagang pananalita, simbolismo, at iba pang masining na estratehiya, naipahayag ng may-akda ang kanyang mga pananaw at damdamin nang may lalim at kasiningan. Ang mga elementong ito ay nagbigay-bisa sa mga mensaheng nakapaloob sa kanyang mga akda at nagpatibay sa kanilang halagang pampanitikan.
3. Masasalamin din sa mga tula ang katangian ni Villafuerte bilang isang makabayan, makakultura, at mapanuring manunulat na gumagamit ng panitikan bilang kasangkapan sa pagpapahayag ng mga realidad sa lipunan at pagpapalaganap ng kamalayang pambansa.
4. Maaaring gamitin sa pagsusuri ng kanyang mga piling tula ang mga teoryang Realismo, Romantisismo, Kulturalismo, Sosyolohikal, at Historikal. Sa mga ito, higit na lumutang ang Realismo, Kulturalismo, at Romantisismo dahil sa malinaw na paglalarawan ng mga karanasang

panlipunan, pagpapahalaga sa kulturang Pilipino, at masidhing pagmamahal sa bayan at wikang Filipino.

5. Lumitaw rin sa mga akda ang mahahalagang pagpapahalagang Pilipino tulad ng kasipagan, pagkakaisa, pagmamahal sa bayan, pagpapahalaga sa sariling wika, at pagpapanatili ng mga tradisyong minana sa mga ninuno. Ipinakikita nito na ang mga tula ni Villafuerte ay nagsisilbing daluyan ng pagpapanatili at pagpapalaganap ng kulturang Pilipino at pambansang identidad sa gitna ng nagbabagong panahon.
6. Sa kabuuan, pinatunayan ng pag-aaral na ang mga piling tula ni Patrocinio V. Villafuerte ay hindi lamang nagtataglay ng kasiningang pampanitikan kundi may mahalagang ambag din sa pagpapaunlad ng kamalayang makabayan, pagpapahalagang kultural, at kritikal na pag-unawa ng mga mag-aaral at mambabasa. Dahil dito, maituturing ang kanyang mga akda bilang makabuluhang kagamitang pampagtuturo sa Filipino at Panitikan at bilang mahalagang sanggunian sa mga susunod pang pananaliksik hinggil sa panulaang Pilipino, kulturang Filipino, at pambansang identidad.

REKOMENDASYON

Batay sa mga konklusyon, iminumungkahi ang mga sumusunod:

1. Ipinakikita ng mga natuklasan ng pag-aaral na ang mga piling tula ni Patrocinio V. Villafuerte ay may mahalagang ambag hindi lamang sa larangan ng panitikan kundi maging sa edukasyon, kultura, at paghubog ng pagpapahalaga ng mga mambabasa. Sa pamamagitan ng mga temang nakatuon sa wikang Filipino, pagmamahal sa bayan, kalayaan, kasipagan, at kulturang Pilipino, nagiging mabisang daluyan ang kanyang mga akda sa pagpapaunlad ng kamalayang makabayan at pagpapahalagang kultural. Maaaring gamitin ang mga tula bilang kagamitang pampagtuturo upang malinang ang kritikal na pag-iisip, pagpapahalaga sa sariling wika at kultura, at pag-unawa sa mga isyung panlipunan.
2. Dahil pinatunayan ng pag-aaral na ang mga piling tula ni Patrocinio V. Villafuerte ay hindi lamang nagtataglay ng kasiningang pampanitikan kundi may mahalagang ambag din sa pagpapaunlad ng kamalayang makabayan, pagpapahalagang kultural, at kritikal na pag-unawa ng mga mag-aaral at mambabasa, maaari ring gawan ito ng role play or dula-dulaan sa mga silid-aralan upang mas mahubog ang pagmamahal sa bayan at pambansang identidad ng mga Filipino.
3. Higit pa rito, maaaring gamitin ng mga manunulat at mananaliksik ang mga akda bilang inspirasyon upang higit pang mapalawak ang pag-aaral sa panitikang Filipino at sa mahalagang papel nito sa pagpapanatili ng pambansang identidad at kamalayang panlipunan.

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SWIMMING POOL DROWNING DETECTION AND ALERT SYSTEM USING DEEP LEARNING ALGORITHM

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ABSTRACT

Drowning remains a critical global public health concern, yet existing prevention systems are constrained by limited lifeguard coverage and the prohibitive cost of AI-based solutions requiring continuous internet connectivity, rendering them impractical for community swimming pools. This study presents the design and evaluation of an offline, low-cost drowning detection and alert system employing deep learning, specifically developed for deployment in community swimming pool environments. The system integrates a Raspberry Pi 4B microcomputer with an overhead Full HD webcam, relay module, and audible and visual alarm components, forming a self-contained monitoring unit operable without internet access. A dataset of 1,543 images spanning four behavioral classes; normal swimming, breath-holding, out-of-water, and drowning is collected from a real pool environment, validated by a Philippine Coast Guard expert, and used to train a YOLOv11n deep learning model for 50 epochs, achieving an average classification accuracy of 85%. The trained model is deployed and field-tested at Fiesta Resort Swimming Pool, Surigao City, Philippines, demonstrating reliable real-time swimmer behavior classification and immediate alarm activation upon drowning event detection. System evaluation using a five-point Likert scale instrument grounded in the Technology Acceptance Model yields consistently high mean scores of 4.5 to 4.6 across functionality and detection accuracy criteria. These findings demonstrate that a cost-effective, offline deep learning-based drowning detection system is a viable and scalable solution for enhancing swimmer safety and emergency response preparedness in resource-constrained aquatic facilities.

Keywords*: drowning detection, deep learning, computer vision, yolo11, edge computing*

INTRODUCTION

Advancements in safety technology and increasing concern over water-related accidents have driven significant progress in swimming pool monitoring systems. Drowning remains a leading cause of unintentional injury death worldwide, particularly among children and adolescents. According to the World Health Organization (WHO), drowning is the process of experiencing respiratory impairment from submersion or immersion in liquid, with outcomes classified as death, morbidity, and no morbidity. An estimated 236,000 people die annually from drowning worldwide, with over 90% of these deaths occurring in low- and middle-income countries. In the Philippines, approximately 3,289 Filipinos die from drowning per year, based on data from the Philippine Statistics Authority (PSA).

Traditional drowning prevention relies heavily on human supervision, which is prone to fatigue, distraction, and limited field of view. Several technologies have been developed to address drowning risks, ranging from closed-circuit television (CCTV) systems to wearable devices and commercial AI-based detection systems such as Poseidon and Coral Manta. However, these advanced technologies are expensive and require reliable internet access, making them unsuitable for most community swimming pools, particularly in developing regions where network connectivity is unstable. A comparative market analysis

by Shatnawi et al. (2024) highlights that commercial AI-based drowning detection systems remain financially prohibitive for low-resource facilities due to their high procurement and infrastructure costs. Similarly, a review by Ali and Zhang (2024) notes that most vision-based drowning detection systems in the literature depend on cloud infrastructure or high-end GPUs, further compounding cost and connectivity barriers.

This study proposes the design and implementation of an affordable, offline drowning detection and alert system that uses a single overhead camera, runs deep learning models locally on a Raspberry Pi 4B, and triggers immediate on-site audible and visual alarms when a drowning event is detected. The system is designed to continuously monitor swimmers, detect signs of distress in real time, and improve emergency response without any internet dependency.

OBJECTIVES

The study addresses a well-defined gap: the lack of affordable, internet-independent safety systems for community pools in developing regions. The specific objectives are:

1. To design and develop a low-cost hardware system that operates fully offline.
2. To implement a real time model capable of distinguishing accurately between Swimming, Holding of breath, Person out of water, and Drowning scenarios.
3. To test and evaluate the functionality, accuracy, and detection coverage of the system.

METHODOLOGY

The study employs an experimental and quantitative approach to focus on the design, development, and evaluation of a swimming pool drowning detection and alarm system based on a deep learning algorithm. The approach focused on the actual procedures, techniques, and tools used to acquire, process, and analyze data needed for system development and performance evaluation. The research method includes system development, dataset collection, model training, system deployment, controlled field testing, and user assessment.

Technical Requirements

The hardware includes a 4B Raspberry Pi with 8GB of RAM acting as the brain of the system, a Logitech Full HD 1080p webcam for overhead video capture at 1920×1080, a 220VAC alarm horn with warning light that emits audible (85dB) and visual notifications, a 5V relay module that communicates with the Raspberry Pi GPIO pins that you can safely connect the high-voltage, a 128GB memory card for the operating system and trained model for persistent storage, a push button to reset the alarm manually, electrical wires and connectors for integrating the system components safely, and a reliable 20W power supply.

The software layer is Raspberry Pi OS (64-bit, 5.15 kernel) as the OS, enabling hardware abstraction and process management, Python 3.9 as the main programming language for system implementation, OpenCV 4.5.3 for video capture in real-time and processing of frames, Ultralytics YOLOv11n framework for object detection and behavior classification, Thonny IDE for writing and debugging codes, RealVNC Viewer for secure remote access in development and testing, Google Colab for faster model training, and Label Studio to manually annotate images and prepare dataset. All software products are open-source or free, the cost of licenses for recurring costs is non-existent.

Dataset Collection and Preprocessing

The collected a dataset in a real swimming pool to obtain practical and realistic training data. Six volunteers were asked to carry out four behavioural scenarios: normal swimming, holding of breath, person out of water, and simulated drowning. Volunteers physically simulated drowning by taking on a near-

vertical body position, making frantic and disjointed arm movements, periodically dunking their faces, and stilling struggling at least for 5 seconds per each such position. In total, 1,857 photographs were taken with a mobile camera initially.

Upon acquisition, each image was reviewed and validated by a Philippine Coast Guard (PCG) expert (SN1 Seldy S. Domagtoy who has served 7 years in the PCG) based on the following: (1) non-occluded and ambiguous posture of the body that can be labeled as one of the four putative classes, (2) image quality information contained quality of pixels, amount of motion blur, occlusion (3) reasonable camera tilt and object visibility and (4) no ambiguous action that may or may not be confidently be classified as one class. Images that do not fulfil these requirements were discarded, resulting in 1,543 validated images for training and testing of the model. The dataset distribution is summarized in Table 1.

Table 1. Dataset Distribution After Validation

Category	Images Collected	Images Verified & Validated	Images Excluded
Swimming	624	522	102
Holding of Breath	349	295	54
Person Out of Water	336	250	86
Drowning	548	476	72
Total	1,857	1,543	314

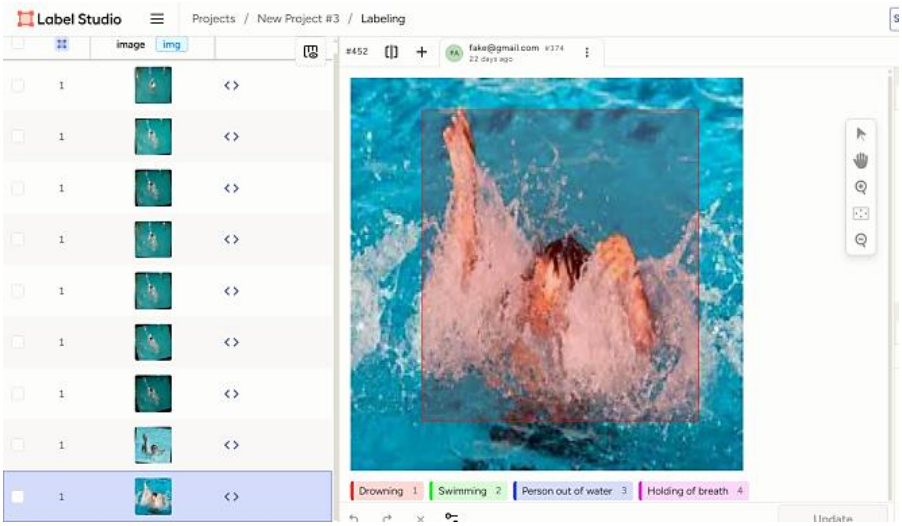


Fig. 1. Manual image annotation using Label Studio

Images were manually annotated using Label Studio as shown in Figure 1, with bounding boxes drawn around detected human subjects. The validated dataset was split 90% for training (1,388 images) and 10% for validation (155 images), and all images were resized to 640×640 pixels.

Model Training

The annotated dataset was in turn used to train the YOLOv11n model utilizing the cloud-based GPU resources of Google Colab via the Ultralytics framework. 50 epochs of training the process took ~2.83 hours . To generate a small deployment model for raspberry pi 4B, we remove the optimizer from ripped weights into a new compact model. This leads to a total model file size of 5.5 MB and an average inference time of ~6.1 ms/image, so our model is not only accurate but also efficient for real-time edge deployment.

System Architecture

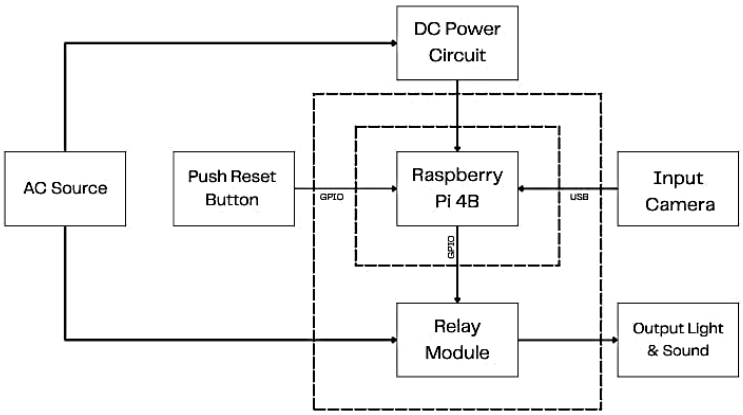


Fig. 2. Block diagram of hardware architecture

The hardware design is based on the Raspberry Pi 4B along with an AC-to-DC power supply. A USB webcam on a fisheye holder is mounted above and streams live video to the Raspberry Pi for processing. Once an event relating to drowning this signals a GPIO which in turns switch on the 220VAC siren horn and the lighting warning. A pushbutton is provided to reset the alarm manually after the situation has been attended to. Frame capture and processing is done by OpenCV, which then feeds the trained YOLOv11n model to classify behaviours. After filtering detections above confidence thresholds, it starts an alert timer to control turning on/off the GPIO to the alarm hardware to avoid too fast on-off toggling.

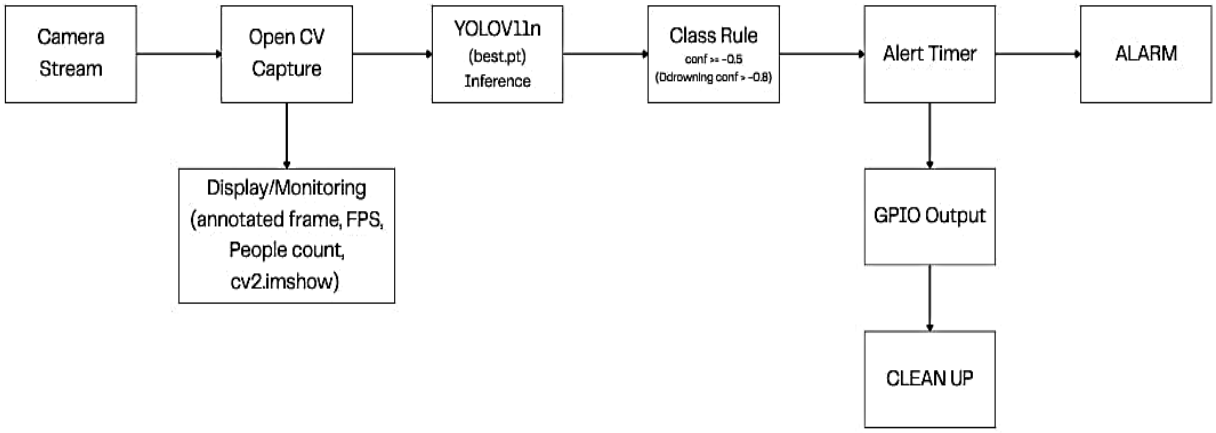


Fig. 3. Block Diagram of System Architecture Software

The Figure 3, shows the block diagram of the software flow to execute the swimming pool drowning detection and alert system on the Raspberry Pi. The video stream from the camera is live captured and processed frame per frame by OpenCV, and the frames are displayed and annotated with bounding boxes, frames per second (FPS) and people count. The frames are processed by the trained YOLOv11n model (best.pt) which detects and classifies the swimmer behavior, and the detection is filtered according to the predefined class rules and confidence thresholds to make sure the decision making is only based on reliable detections. Once a drowning condition fulfills the predefined rule, an alert timer is activated to control the time for which the alarm is active and to avoid rapid on–off switching, and after that, the Raspberry Pi GPIO output is activated to control the external alarm hardware. The cleanup function is responsible for the correct release of system resources and allows either steady continuous operation or safe shutdown of the application.

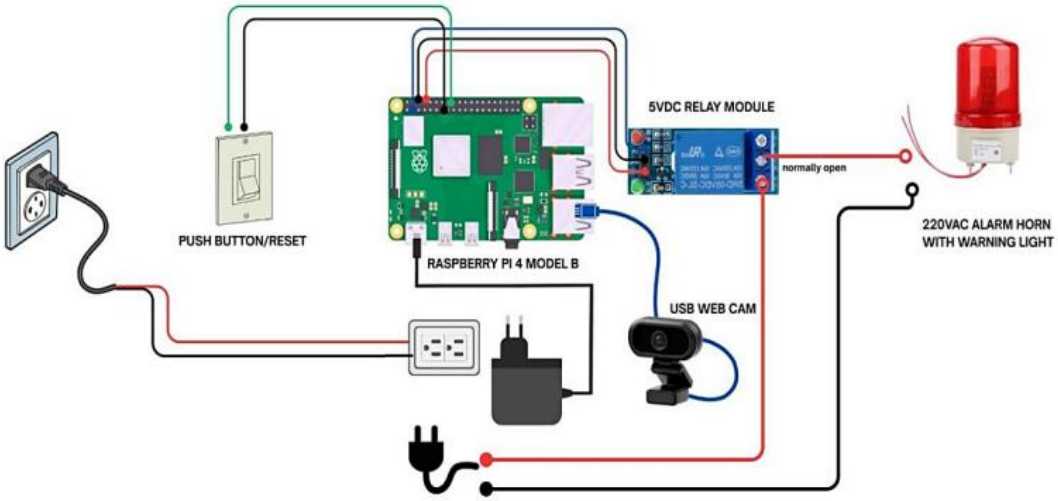


Fig. 4. System Design of the Control Unit

Figure 4 illustrates the complete circuit design of the drowning detection and alert system. The core of the system is the Raspberry Pi 4 (8GB RAM), which serves as the central processing unit. It captures live video from an overhead mounted Logitech USB webcam (1080p), processes each frame using deep learning model, and triggers alerts when drowning behavior is detected. The system employs a 20Watts power supply that provides stable input voltage to all components. Alerts are generated through a 220VAC alarm horn for audible warning with warning light for visual signaling, and is controlled via a 5V relay module, which acts as a switch between the low voltage logic circuit and the high voltage alert devices.

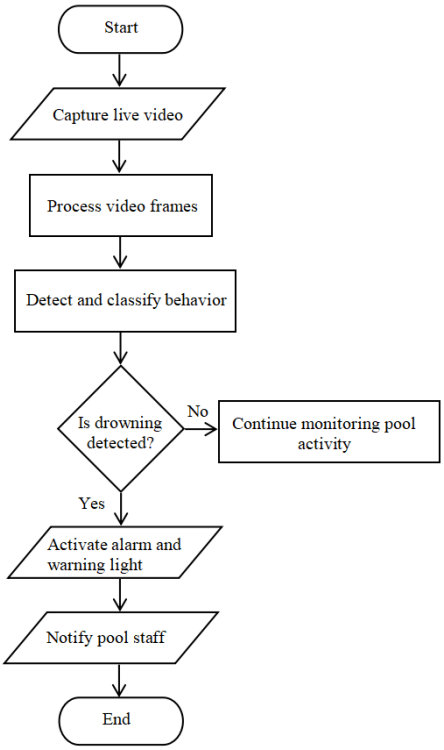


Fig. 5. Flowchart of the Swimming Pool Drowning Detection and Alert System

FINDINGS

Model Performance

The labeled dataset was trained using Google Colab for 50 epochs, completing in 2.83 hours. The training and validation performance metrics are visualized in Figure 6, showing consistent convergence without signs of overfitting. The model achieved stable performance across all metrics, with training loss steadily decreasing while validation metrics improved progressively throughout the training process.

```
50 epochs completed in 2.828 hours.
Optimizer stripped from /content/runs/detect/train/weights/last.pt, 5.5MB
Optimizer stripped from /content/runs/detect/train/weights/best.pt, 5.5MB

Validating /content/runs/detect/train/weights/best.pt...
Ultralytics 8.3.237 🚀 Python-3.12.12 torch-2.9.0+cu126 CUDA:0 (Tesla T4, 15095MiB)
YOLO11n summary (fused): 100 layers, 2,582,932 parameters, 0 gradients, 6.3 GFLOPs
                 Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100%
                   all        155        250      0.852       0.75      0.848      0.465
             Drowning         31         31      0.775      0.555      0.707      0.402
    Holding of breath         19         19      0.856      0.632      0.779      0.332
  Person out of water         28         42       0.88      0.929      0.969      0.674
             Swimming         91        158      0.897      0.886      0.936      0.452
Speed: 0.3ms preprocess, 6.1ms inference, 0.0ms loss, 10.8ms postprocess per image
```

Fig. 6. Training and validation performance curves over 50 epochs

As illustrated in Figure 6, the trained YOLOv11n model reaches a precision of 0.852, a recall of 0.750 as well as mAP@50 of 0.848 and mAP@50−95 of 0.465 in the validation set. For the behavioral classes, Swimming reached the best performance (precision: 0.897, recall: 0.886, mAP@50:0.936), followed by Person Out of Water (precision: 0.880, recall: 0.929, mAP@50: 0.969). Holding of Breath attained precision of 0.856 recall of 0.632 and mAP@50 of 0.779. The Drowning category achieved a precision of 0.775 a recall of 0.555 and an mAP@50 of 0.707. The lower scores in detecting drowning are explained by the fact that distress behaviors are visually very similar to normal swimming-which consists of similar body postures and small movement patterns.

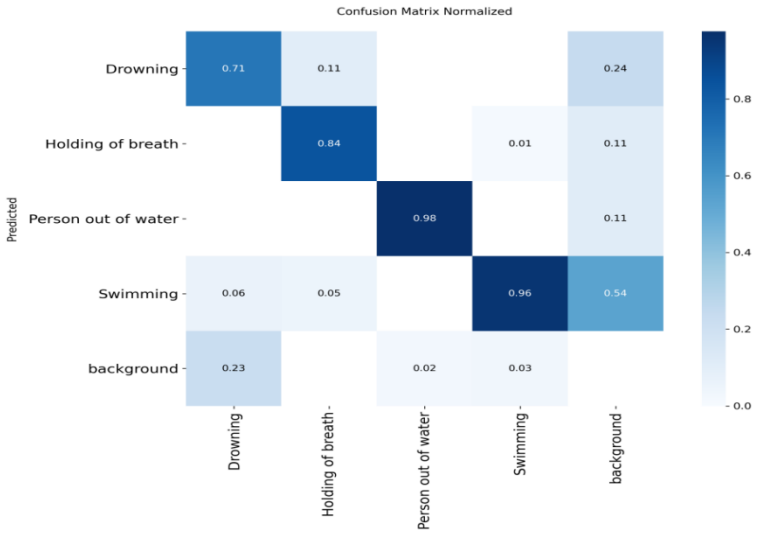


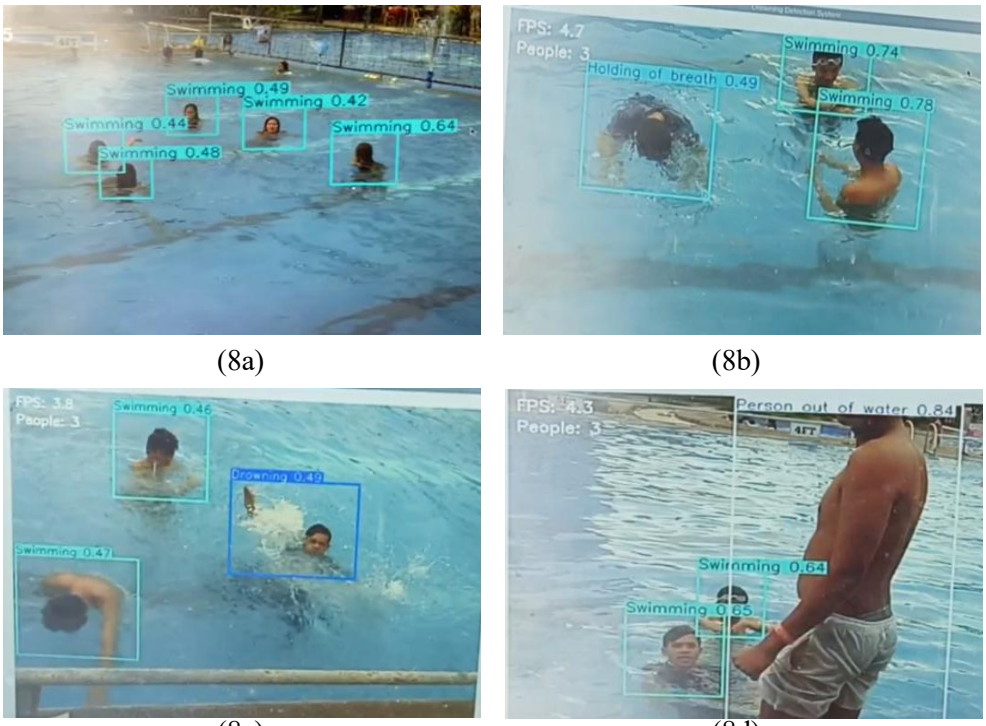
Fig. 7. Normalized confusion matrix showing classification performance

The normalized confusion matrix was very high for Person Out of Water (0.98) and Swimming (0.96), followed by Holding of Breath with 0.84 accuracy. Drowning detection achieved 0.71, with some cases misidentified as background subjects and swimming motions, demonstrating practical difficulties including overlapping poses, partial submersion, and feeble signs of distress. Importantly, 24% of true drowning events were classified as background, a limitation that could be explained by the fact that the

drowners' bodies were partially submersed and occluded and by reflections on the water's surface that obscured features. It is this frame-wise classification constraint that is a known system limitation: as the YOLOv11n model processes each frame as a single entity(as it never sees more than a single frame), there may be ephemeral drowning events that are similar to static floating/swimming postures in just one frame and could be overlooked. Subsequent versions should investigate sequence-based models to capture motion history over frames and mitigate these false negatives.

Real-Time Field Testing

The deployed system was tested at Fiesta Resort Swimming Pool with the overhead camera mounted approximately 7 feet above the pool deck, providing coverage up to a distance of approximately 7.5 meters. The system successfully detected and classified multiple swimmers simultaneously across the four behavioral classes, applying bounding boxes and confidence scores to each detection.



(8a) (8b)

(8c) (8d)

Fig. 8. Real-time detection of swimming behavior with bounding boxes. (8a) Swimming Behavior, (8b) Holding of Person's Breath, (8c) Person Drowning, and (8d) Person out of water

The real-time deployment of the trained deep learning model for swimmer behavior classification was evaluated under practical pool conditions using an overhead camera positioned approximately 2.1 m (7 ft) above the pool deck, with representative results presented in Figures 8a–8d. As Fig. 8a demonstrates, the system was able to detect and classify several swimmers in normal swimming states in a single frame, each of which was labeled with a bounding box, behavioral type, and confidence score; a detection threshold of 0.5 was used to eliminate false positives, guaranteeing robustness yet still able to detect most of the swimmers in normal community pool environment. The field of view allowed for coverage up to ~7.5 m, demonstrating the adequacy of the installation height for small to medium pools. Figure 8b shows simultaneous detection of diverse behaviors: two subjects were predicted as "swimming" with confidence scores 0.74 and 0.78, and another one was predicted as "holding breath" (0.49), indicating the model is able to capture fine-grained behavioral differences even in the limited spatial resolution. In Fig. 8c, a drowning event was precisely detected and tracked (blue bounding box and related confidence value) amidst two

normal swimming individuals, verifying its performance in critical multi-person scenarios with motion-overlapping. Lastly, Figure 8d illustrates the model's strength at differentiating in-water/out-of-water within one shot, labeling a poolside man as "person out of water" with considerable confidence (0. 84) and at the same time tagging the swimmers within. Taken together, these results demonstrate the systems robustness, scalability and real world applicability to more complex, multi-person aquatic scenarios.

Table 2. Real-Time Detection Accuracy Results

Interval	People in Area	Swimming	Person Out of Water	Holding of Breath	Drowning	Detection Missed	Total Detected	Detection Coverage (%)*
2 mins	17	5	7	3	0	4	15	88.24%
3 mins	10	3	1	1	3	2	9	90%
5 mins	9	3	0	2	2	5	7	77.77%
10 mins	25	12	7	0	0	6	19	76%
15 mins	40	17	13	3	1	4	34	85%

**Detection Coverage (%) = Total Detected Persons / People in Area × 100. This is distinct from classification accuracy: zero misclassifications were recorded across all intervals, meaning every detected person was correctly classified.*

As shown in Table 2, the number of Misclassification instances is zero for all the trials, which implies that every time the system detected a person, it correctly classified the behavior. Detection misses were caused mainly by some swimmers lying beyond the camera`s working distance (~7 m), such that they were too small in the image to be reliably recognized. This is a hardware coverage constraint, not a matter of model accuracy. Detection coverage varied from 76% to 90% between intervals, and a total mean of 85% was observed and was consistent with the validation accuracy.

System Evaluation Using TAM

Thirty respondents evaluated the system at the Fiesta Resort Swimming Pool following live demonstration. Evaluation employed a five-point Likert scale questionnaire based on the Technology Acceptance Model (TAM) proposed by Davis (Zaineldeen et al., 2020) , covering three constructs: Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Behavioral Intention to Use (BI). The results are presented in Table 2.

Table 2: TAM Evaluation Results Summary

TAM Construct	Mean Score	SD	VI
Perceived Usefulness (PU)	4.64	0.66	SA
Perceived Ease of Use (PEOU)	4.54	0.70	SA
Behavioral Intention to Use (BI)	4.60	0.69	SA
Overall Average	4.59	0.68	SA

PU (Perceived Usefulness) got the highest mean score of 4.64 (SD = 0.66), indicating high level of respondents confidence on the ability of the system to contribute in monitoring the pool safety more efficiently, and help in earlier drowning detection, increasing the efficiency of lifeguards, minimizing the delay of emergency response and possibility of preventing incidents. The Perceived Ease of Use (PEOUs) mean value of 4.54 (SD=0.70) stated that the users considered the system was easy to learn and use in the real pool session due to the straightforward offline hardware installation and automatic notification mechanisms. Behavioral Intention to Use (BI) had a score of 4.60 (SD = 0.69), signifying a high desire by users to utilize the system for routine pool safety practices. Not least these result are important since the presently available automated solutions are prohibitively expensive for community pools and require connection to the internet (Shatnawi et al., 2024).

CONCLUSION

This section presents the key findings of the study and summarizes the overall results obtained from the development and evaluation of the system.

In this work, a deep learning based low-cost pool drowning detection and alert system was designed, developed, and evaluated for community swimming pools in an offline mode. The YOLOv11n model with 1,543 validated images achieves 84.8% mAP with the speed of 6.1 ms/img in a Tiny model with the size of 5.5 MB, which can be regarded as ideal for real-time applications.

The real-time on-field experiments verified that the system can simultaneously monitor multiple swimmers at the same time, classify all four target motions without misclassification, and immediately trigger audible and visual alarms once a drowning is detected, all these without being connected to the Internet. The evaluation through TAM indicated high acceptance among users (M 4.54-4.64) across all three constructs

.An important restraint is the frame-based classification methodology that ignores the temporal behavioral sequence over successive frames. This could also cause underdetection of short or questionable drowning occurrences. Through the integration of temporal models, increasing the dataset with various pool settings and lighting conditions, utilizing several overhead and underwater cameras for broader coverage, and integrating night vision functionality for round-the-clock supervision. Such improvements could further enhance the scalability and robustness of the system as a generalizable safety measure for underresourced aquatic centers.

RECOMMENDATION

This section provides recommendations based on the findings of the study to further improve the performance, reliability, and field readiness of the developed system.

1. Multiple overhead cameras are recommended to increase the observable area of the swimming pool and reduce the number of dead angles because this ensures that the system can constantly monitor all areas of the pool and that the system will not miss any important events or risky behavior that occurs in the dead angles.
2. Underwater cameras are recommended to improve the visibility of underwater swimmers and increase the detection of prolonged underwater behavior, which is particularly important when the overhead view is obstructed or if the early signs of distress and drowning are not clearly visible from overhead.
3. Night vision cameras are recommended to provide effective monitoring of the pool area under night time conditions. Swimmer activities can be detected in the dark, which adds an extra level of safety and security in addition to daytime operation.
4. Explore sequence-based deep learning models to incorporate motion history and reduce frame-level false negatives in drowning detection.

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DESIGN AND DEVELOPMENT OF AN AUTOMATIC TURMERIC RHIZOMES CLASSIFIER USING COMPUTER VISION

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ABSTRACT

Manual sorting of turmeric rhizomes is labor-intensive and highly dependent on human visual judgment, often resulting in inconsistent classification due to fatigue. This study aimed to design and develop an automatic turmeric rhizomes classifier using computer vision to improve sorting accuracy, consistency, and efficiency in small-scale post-harvest operations. The proposed system integrates a conveyor-based handling mechanism, dual USB cameras for image acquisition, and a Raspberry Pi 5 as the processing unit. Image data were preprocessed using OpenCV, and a supervised image classifier trained with Teachable Machine was employed to classify turmeric rhizomes into Good and Defective categories based on visible surface features. A dataset of 4,000 labeled images, validated by a municipal agriculturist, was used for model training and testing. System evaluation through controlled and time-based tests yielded average accuracies of 95.11% and 92.48%, respectively. While manual sorting showed slightly higher short-term accuracy, the automated system demonstrated consistent performance. The results indicate that the proposed computer vision-based system is an effective and practical solution for improving turmeric post-harvest quality assessment.

Keywords: *computer vision, object detection, image classification, classifier, turmeric rhizomes, post-harvest automation*

INTRODUCTION

Turmeric (Curcuma longa) is a spice of high commercial value and is used in the food, pharmaceutical, and cosmetic sectors, and the market value of turmeric is largely affected by the physical quality of its rhizomes. The major factors that determine the grading of turmeric are color, surface texture, and defects. In some turmeric-growing areas, the process of sorting turmeric after harvesting is still done manually by visual inspection, which is a time-consuming process, especially when it comes to large quantities. (Fracarolli, 2020) (Khan, 2025)

Machine vision has recently been recognized as a strong substitute, providing objective, non-destructive, and real-time quality assessment in agricultural processing. (Deep learning and machine vision for food processing: A survey., 2021) Recent developments in deep learning, specifically the YOLO (You Only Look Once) series of object detection models, have greatly enhanced the speed and accuracy of real-time applications such as crop observation and automation. (Badgujar, 2024) (Zhao, 2024) Moreover, optical and machine vision-based sorting systems have shown improved efficiency and less reliance on human labor. (Wikipedia, 2020) (Du, 2025)

However, in existing research on turmeric, the applications are mostly related to disease identification or drying quality, with less emphasis on the completely automated sorting of whole rhizomes. (Patil, 2023) (Siam, 2025)To fill this research void, this paper proposes the automatic turmeric rhizomes

classifier, which integrates deep learning-based classification with a mechanical ejection system to improve accuracy, reliability, and efficiency in post-harvest processing. (Srinivasan, 2023)

OBJECTIVES OF THE STUDY

General Objective:

To design an automatic turmeric rhizomes classifier system using computer vision that classifies turmeric rhizomes based on visible quality attributes and performs real-time classification. The system aims to improve the accuracy, consistency, and efficiency of post-harvest quality assessment in small-scale turmeric processing facilities.

Specific Objectives:

1. To design and implement an image acquisition and preprocessing module using an affordable imaging device that captures clear and consistent still images of turmeric rhizomes under controlled indoor lighting conditions.
2. To build and annotate a localized dataset of turmeric rhizomes categorized as good or defective, and to train a lightweight machine learning model capable of classifying quality based on color, surface texture, and visible defects.
3. To evaluate the trained model's performance in terms of classification accuracy, precision, and efficiency compared with manual inspection conducted by trained personnel.

METHODOLOGY

The methodology followed in development of Automatic Turmeric Rhizomes Classifier Using Computer Vision is described in this chapter. The method describes the development of the system to make sure the turmeric rhizomes are sorted accurately and reliably in either the good or defective class. The adopted approach in this work is a development-oriented approach, which combines computer vision and machine learning with mechanical sorting to establish the quality of post-harvested turmeric rhizomes. In order to maintain an iterative design and development process, the method adopted the Plan-Do-Check-Act (PDCA) cycle, involving planning, doing, checking, and acting as for the system.

Plan

During the planning phase, the quality assessment criteria for turmeric rhizomes were established by grouping the samples into good and defective categories based on the surface properties of the samples, which include color uniformity, discoloration, growth of molds, cracks, rot, and physical damages. The workflow of the system was conceptualized, including image acquisition, classification, and physical sorting. Supervised learning was chosen as the approach to classify quality classes based on image features. Requirements of the image data were defined, including lighting, angles, and background, to represent realistic post-harvest scenes. Data collection procedures were also planned. Rhizomes were placed on a moving conveyor to simulate actual sorting conditions, and the captured images were manually labeled and validated. These preparations formed the groundwork for developing a reliable classification model in real time.

Do

The implementation phase carried out the designed and developed system's execution plan and verified the system's functionality. Images were taken while the conveyor was running, simulating the practical scenario. Processed images were used for the classification model's training, and then the model was used for inference. The trained model was incorporated with the conveyor-based mechanism to facilitate automated sorting. As the rhizomes moved through the image acquisition zone, they were

identified and the corresponding action was taken. Defective rhizomes were removed, and normal rhizomes were allowed to continue along the main path. All parts were assembled and tested as an integrated system. The synchronization of timing for the output of the classification system and mechanical action was also fine-tuned for precise sorting.

Check

The system's performance was also evaluated by using 150 samples of turmeric under controlled conditions. The parameters considered for measuring the system's performance were its accuracy, precision, recall, false positive rate, and processing time. Confusion matrices were also used for measuring the classification performance.

Real-time operation was also tested to ensure the speed of operation was consistent without any delays from the conveyors. The automated results were compared to the manual sorting to test the reliability and consistency of the automated process. Differences in the misclassification rate and the effect of human fatigue were noted.

Act

From the evaluation, the improvements made involved adding more misclassified samples to the dataset, optimizing the lighting and camera conditions, retraining the model for better accuracy, and fine-tuning the mechanical timing for better precision.

System Design

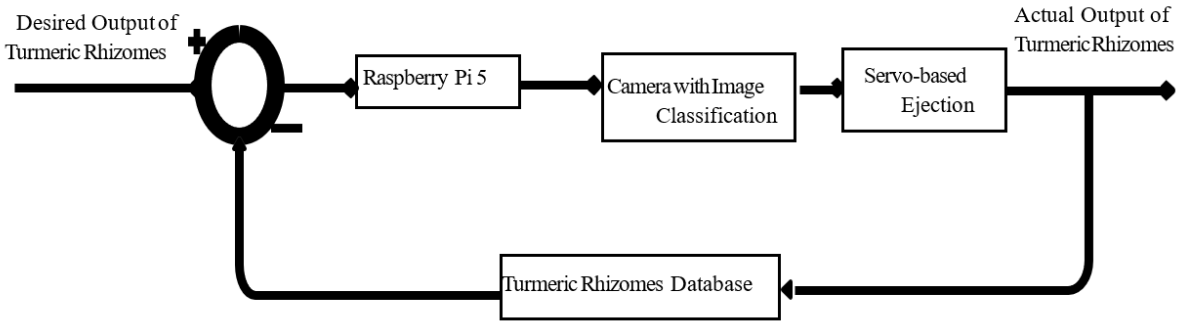

Figure 1. Block Diagram

Figure 1 represented the overall block diagram of the proposed system for the automatic sorting of turmeric rhizomes. From the block diagram, the logical flow of the entire system was properly represented. The image acquisition unit of the system included camera modules that acquired images of the moving turmeric rhizomes on the conveyor belt. The images were then processed by the processing unit, which utilized a computer vision model for image classification.

Based on the classification output, a control signal was produced and transmitted to the actuation unit, which included a servo-based classifying mechanism. In the mechanism, the defective rhizomes were separated from the moving belt, and the good-quality rhizomes moved further on the conveyor. The block diagram properly represented the integration of image processing and mechanical sorting into a single automated system.

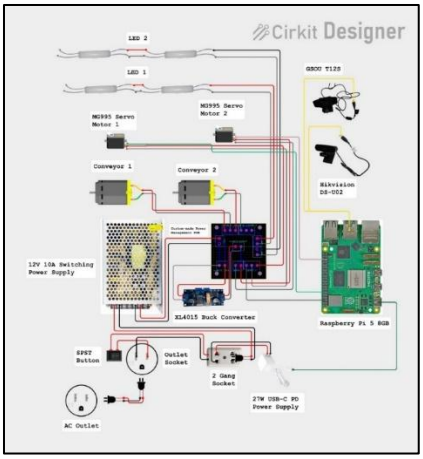

Figure 2. Circuit diagram of the device

The circuit diagram of the automatic turmeric rhizome classifier is shown in Fig. 2 the circuit diagram explains the electrical connections between the processing unit and the sensors, actuators, and power components. The camera module is connected to the processing unit for image acquisition, and the servo motor is controlled by specific output pins to execute the sorting function. The power regulation components provide stable supply to the low-power control units and the high-load actuators. The circuit placement allows for simultaneous execution of image processing and mechanical functions during the classification process.

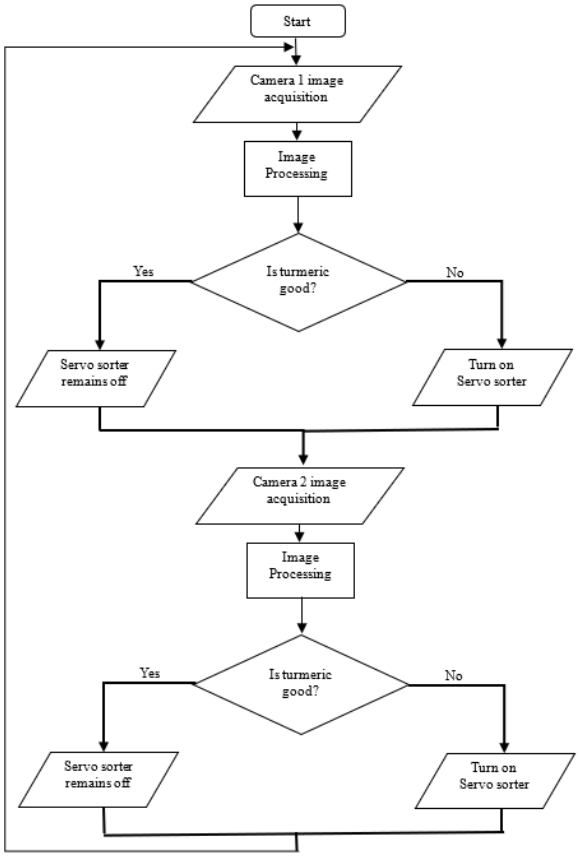

Figure 3. Flow Chart

Figure 3 shows a flow chart that describes the operational logic of the system. The system starts with the initialization process, followed by the continuous image capture of the turmeric rhizomes as they move through the inspection area. The image is then processed by the classification model to determine whether the rhizome is classified as either good or defective. If the rhizome is classified as good, the servo sorting mechanism is kept inactive, and the turmeric rhizome moves through the conveyor belt in the normal way. But if the rhizome is classified as defective, the servo sorting mechanism is turned on to divert the rhizome to a separate collection area. This process is repeated continuously when the system is in operation. The flow chart above shows a clear automation decision-making process.

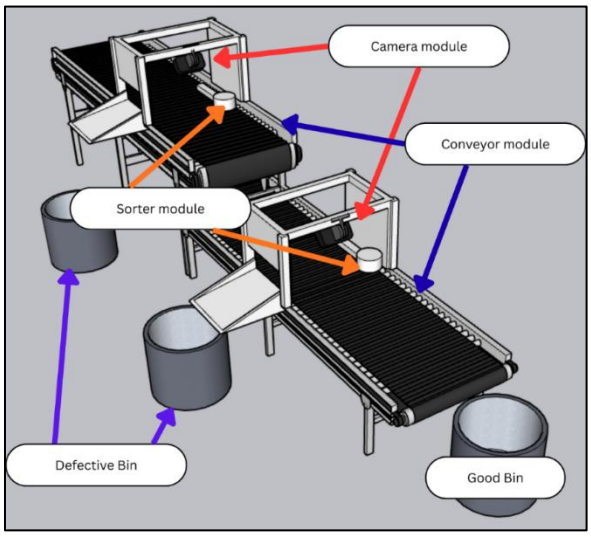

Figure 4. Turmeric rhizomes classifier systems prototyped design with labels

Figure 4 displays the actual prototype of the turmeric rhizome sorting system with labeled components. The figure identifies the key parts of the system, including the camera module positioned above the conveyor, the sorting mechanism, the processing unit enclosure, and the conveyor structure. This labeled view provides a clear physical representation of how the components are arranged and integrated in the working prototype. It demonstrates the practical implementation of the proposed design and shows how the system captures images, processes classification decisions, and physically sorts turmeric rhizomes in real time. The figure validates the feasibility of the system as a functional prototype for post-harvest quality assessment.

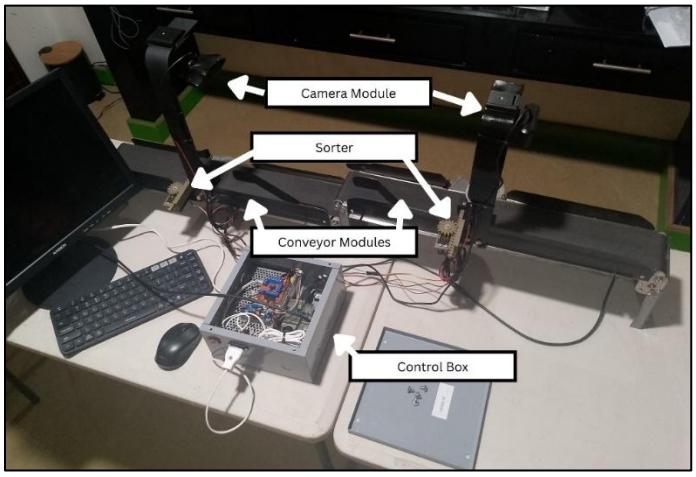

Figure 5. Turmeric rhizomes classifier actual device

System Testing Dataset

In relation to system performance analysis, a total of 150 samples of turmeric rhizome was kept aside and was only used for testing purposes. In addition, this was done by using the samples during the real run of the conveyor belt.

Data Analysis

Data analysis for this research was carried out by using the performance evaluation capabilities provided by the Teachable Machine platform and practical testing of the system while the conveyor was operating. Once the data set was acquired and manually annotated, it was split into training, validation, and test sets in order to provide an objective measure of system performance.

The machine learning model used for image classification was trained using annotated images classified as either Good or Defective turmeric rhizomes. In the course of training, Teachable Machine automatically generated performance measures such as accuracy of training, accuracy of validation, loss by epoch, accuracy per class, and confusion matrices.

The confusion matrix generated by Teachable Machine was used to evaluate the accuracy of the model based on true positive, true negative, false positive, and false negative rates for each class. Accuracy and loss charts were analyzed to ensure the stability of the model convergence prior to implementation.

The algorithm was further deployed on the sorting machine with Raspberry Pi following the training. The next phase was the analysis of the gathered data according to the output of the working model. There were several tests carried out using 150 samples and 5 minutes of processing time. Performance metrics like accuracy, precision, recall, false positive rate, and inference time were calculated manually using the confusion matrix for each test run.

These quantitative data helped to determine the effectiveness of the algorithm versus the manual approach. It is evident that by using analysis techniques and performance results, the algorithm was evaluated from a practical perspective in various scenarios. The model built serves as the decision-making element for the sorting activity of the automatic system.

FINDINGS

The evaluation was conducted using two test scenarios: a controlled 150-sample test and a 5-minute continuous real-time operation test. The performance of the proposed classifier was also compared with manual sorting conducted by trained personnel.

Under controlled conditions, the classifier achieved an average accuracy of 95.11%, with balanced true classifications for both Good (71.33) and Defective (71.33) samples, and low misclassification rates (3.67 false positives and 3.67 false negatives). These results indicate that the system is capable of effectively distinguishing between quality classes when operating under stable and consistent conditions. The relatively low false positive rate of 4.89% further supports the reliability of the classifier in a controlled environment.

Table 1. Compiled Average result of test scenarios conducted

Test Scenario	Time Duration	True Good	True Defective	False Good	False Defective	Total Samples	Accuracy	Recall	False Positive Rate	Efficiency (turmeric/min)
150 Samples (Classifier)	11 min 25 s 39 ms	71.33	71.33	3.67	3.67	150	95.11 %	95.11 %	4.89%	—
5-Min Test (Classifier)	5 min	28.33	30.00	2.67	2.00	63	92.48 %	93.12 %	9.11%	12.6
5-Min Test (Manual Sorting)	5 min	108.00	107.33	2.33	2.33	220	97.88 %	97.88 %	2.11%	44

In the 5-minute real-time test, the system processed an average of 63 turmeric rhizomes, achieving an accuracy of 92.48%, a recall of 93.12%, and a false positive rate of 9.11%. While performance slightly decreased compared to controlled testing, the classifier maintained consistent operation despite real-world challenges such as rhizome motion, varying orientations, surface contamination, and minor overlaps. The increase in misclassification rates (2.67 false positives and 2.00 false negatives) reflects the impact of these dynamic conditions on system accuracy.

In comparison, manual sorting demonstrated higher classification performance, with an average accuracy of 97.88%, a recall of 97.88%, and a significantly lower false positive rate of 2.11%. Additionally, manual sorting achieved a substantially higher processing efficiency of 44 turmeric rhizomes per minute, compared to 12.6 turmeric rhizomes per minute for the automated system.

Despite this difference, it is important to note that manual sorting performance is highly dependent on human factors such as attention, fatigue, and consistency over time. In contrast, the automated classifier maintained stable performance throughout the testing period without degradation. This highlights a key advantage of the proposed system in terms of reliability and repeatability during prolonged operation.

Overall, the findings indicate that while manual sorting currently outperforms the automated system in both accuracy and speed, the proposed classifier demonstrates strong potential for practical application. Its consistent performance, acceptable accuracy levels, and independence from human limitations suggest that it can serve as a viable alternative or complementary tool for automated turmeric rhizome quality assessment, particularly in continuous or large-scale processing environments.

CONCLUSION

This section presents the key conclusions derived from the findings of the study, based on the system design, implementation, and performance evaluation.

1. The proposed computer vision–based turmeric rhizome classifier successfully achieved the objectives of the study, demonstrating the feasibility of integrating imaging, machine learning, and mechanical sorting for post-harvest applications.
2. The image acquisition and preprocessing module, implemented using low-cost USB cameras under controlled conditions, was able to produce clear and consistent images suitable for classification tasks.
3. The development of a localized dataset with Good and Defective classes enabled effective model training using a lightweight machine learning approach, allowing the system to classify rhizomes based on visible features such as color, texture, and surface defects.
4. Performance evaluation showed that the system achieved high accuracy and reliable classification results under both controlled and real-time conditions, with consistent operation unaffected by human fatigue or subjectivity.
5. Although limited to surface-level inspection, the system proved to be a viable and efficient support tool for improving turmeric rhizome quality assessment in small-scale operations.

RECOMMENDATION

In this section, the suggestions based on the shortcomings of the system are listed. These suggestions have been ranked based on their importance and contribution towards making the system more efficient and effective.

1. The mechanical design of the system should be enhanced by integrating a feeding or singulation mechanism to ensure proper spacing of turmeric rhizomes on the conveyor belt, incorporating additional sensing technologies such as weight, moisture, or infrared sensors to detect internal defects, and improving the servo-based ejection mechanism and timing synchronization to increase sorting speed and overall efficiency.

2. The lighting setup and camera positioning should be further optimized to reduce shadows, reflections, and surface contamination effects.
3. The dataset should be expanded to include a wider range of turmeric varieties, sizes, textures, and defect levels to improve model robustness and generalization.
4. Future studies may implement multi-level classification (e.g., slightly defective and severely defective) to enhance grading capability.
5. Field testing is recommended to evaluate system reliability and performance in real agricultural environments.

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TEACHERS' CAPACITY, CHALLENGES, AND STRATEGIES IN THE ACADEMIC RECOVERY ACCESSIBLE LEARNING (ARAL) PROGRAM

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ABSTRACT

This study aimed to determine teachers' capacity, challenges, and strategies in implementing the ARAL Program, as well as their relationship with teachers' profiles. Using a descriptive-correlational design, data were collected from 200 teacher-respondents through a structured questionnaire and analyzed using frequency, percentage, weighted mean, and regression analysis. Most respondents were aged 31–40, predominantly female, married, and held Teacher I or Teacher III positions. Many had 1–5 years of service and were pursuing or had completed a master's degree. Findings showed that teachers demonstrated a very satisfactory level of capacity, indicating strong competence in implementing the ARAL Program. However, challenges were rated as moderately challenging overall, with some areas identified as very challenging, including limited local government unit support, learner attendance and dropout risks, health and nutrition concerns, heavy tutor workload, and limited psychosocial support. Teachers frequently used instructional strategies, particularly cooperative learning, while partnerships with LGUs and NGOs were least utilized. Inferential analysis revealed that position and educational attainment significantly influenced capacity; age and position were associated with challenges; and civil status and educational attainment were linked to strategies. The study concludes that while teachers are capable and proactive, enhanced professional development, stronger collaboration, and improved support systems are necessary to optimize ARAL Program implementation. It recommends continuous professional development, stronger stakeholder collaboration, improved learner support services, and better workload management and incentives to enhance ARAL Program implementation.

Keywords*: capacity, challenges, strategies, Academic Recovery Accessible Learning (ARAL), teachers*

INTRODUCTION

The COVID-19 pandemic caused a global education crisis by disrupting student learning worldwide. In response, many countries including the Philippines launched academic recovery programs to address gaps in core skills like science, math, and reading. Tutorial-based instruction focusing on small-group and personalized learning has proven highly effective. Teacher capacity issues such as limited remedial training, heavy workloads, emotional burnout, and scarcity of digital resources pose challenges. Innovations including peer-led tutorials, community learning hubs, and AI-assisted tutoring have emerged as promising scalable and inclusive solutions for learning recovery (DepEd Memorandum 483, s. 2025).

However, teachers around the Philippines have voiced great support for the objectives of the Academic Recovery Accessible Learning (ARAL) Program, but they also point to serious implementation

issues. These include inadequate preparation time leading to mental health pressure, higher workloads, a lack of digital learning support, and a lack of reference materials. Additionally, many educators found it difficult to adjust to the program's quick implementation, which prompted requests for improved preparation and support systems (Philippine Daily Inquirer, 2025).

Regionally, school heads and teachers from public elementary and secondary schools participated in orientations to present the ARAL Program in Central Visayas. Notwithstanding these initiatives, the area nevertheless faces difficulties such teacher shortages, restricted access to technology, and high rural dropout rates. These circumstances necessitate localized innovations and make it difficult to give tutorials consistently. To suit the requirements of their students, teachers in Region VII have started modifying their lessons by utilizing community volunteers, local languages, and makeshift supplies through DepEd Memorandum No. 64, series 2025.

The situation is significantly worse in the province of Bohol. Bohol's Schools Division has evaluated schools' ability to execute the ARAL Program through readiness audits and orientations. However, many Bohol educators work in remote locations with inadequate internet access and little access to transportation. Their capacity to properly offer instruction is impacted by these limitations. To reach underprivileged students, Bohol teachers have demonstrated tenacity by launching radio-based education, parent-assisted learning modules, and mobile tutorial caravans as instructed through Bohol Division Memorandum No. 561, series 2025.

These scenarios prompted the researcher to assess the status of teachers' capacity, challenges, and strategies in tutorial delivery under the ARAL Program. This aims to enhance teacher support systems, and document scalable practices which will contribute to a more inclusive and effective academic recovery strategy for all learners across diverse Philippine context.

STATEMENT OF THE PROBLEMS

The main purpose of this study was to assess the elementary teachers' capacity, challenges, and strategies in the tutorial delivery of Academic Recovery Accessible Learning (ARAL) Program in the BIBACASIPI Sub-Congressional District of Bohol specifically the towns of Bilar, Batuan, Carmen, Sierra Bullones, and Pilar in the school year 2025-2026. Specifically, it sought to answer the following questions:

1. What is the demographic profile of the respondents in terms of:
   1.1 age;
   1.2 sex;
   1.3 civil status;
   1.4 position;
   1.5 years of teaching experience;
   1.6 highest educational attainment; and
   1.7 Related trainings attended?
2. What is the level of teachers' capacity in handling the ARAL Program?
3. What is the level of challenges encountered during tutorial delivery?
4. What are the common strategies implemented by teachers in the ARAL Program?
5. Is there a significant association between the demographic profile to the:
   5.1. level of teachers' capacity in handling the ARAL Program;
   5.2 level of challenges encountered; and
   5.3. strategies implemented by teachers in the ARAL Program?
6. What enhancement program can be proposed based on the findings of the study?

RESEARCH METHODOLOGY

This study utilized a descriptive-correlational research design to assess teachers' capacity, challenges, and strategies in the tutorial delivery of the Academic Recovery Accessible Learning (ARAL) Program in the Bilar, Batuan, Carmen, Sierra Bullones, and Pilar (BIBACASIPI) Sub-Congressional District in Bohol. The descriptive component focused on identifying and describing the current conditions, experiences, and instructional practices of teachers participating in the ARAL Program.

This design was appropriate because it allows the study to describe teachers' profiles, capacity levels, challenges, and strategies while also examining the association of profile among these variables. It supports the research objectives by providing a clear picture of the conditions surrounding ARAL tutorial delivery, enabling the development of a relevant enhancement program based on the findings.

Environment and Respondents. The study was conducted in Bilar, Batuan, Carmen, Sierra Bullones, and Pilar Sub-Congressional District of the Division of Bohol, an educational cluster comprising several public elementary and secondary schools implementing the ARAL Program. The learning environment reflects the realities of many provincial schools' limited facilities, diverse learner profiles, and strong community participation, all of which influence the way teachers deliver tutorials. The respondents of the study were the public elementary school teachers assigned to handle ARAL Program tutorial sessions within the district. They were selected using purposive sampling, focusing on teachers directly involved in academic recovery interventions. The Academic Recovery Accessible Learning (ARAL) program involved participation from five districts in Bohol, Philippines, encompassing a total of 107 schools and 295 tutors, which collectively yield 402 respondents. Specifically, Bilar contributes 19 schools and 53 tutors; Batuan, 14 schools and 40 tutors; Carmen, 33 schools and 65 tutors; Sierra Bullones, 22 schools and 65 tutors; and Pilar, 19 schools and 72 tutors. With these population, 200 tutors were randomly selected. This distribution reflects the program's targeted implementation to support academic recovery efforts in this sub-congressional district.

Instruments. To obtain accurate and relevant data for this study, the questionnaire consists of four parts. Part I gathered the respondents' age, sex, civil status, years of teaching experience, and highest educational attainment. Part II evaluated teacher capacity in delivering ARAL tutorials especially in areas like differentiated instruction, learner engagement, and assessment strategies. This is adapted from DepEd Order Number 089, series 2025 based on the Philippine Standards for Teaches (PPST). The study utilized secondary data derived from classroom observation results through the use of a standardized Classroom Observation (CO) Tool. It has 5-point Likert scale as follows: 5-Very High Capacity, 4-High Capacity, 3-Moderate Capacity, 2-Low Capacity, and 1-Very low Capacity. Part III consisted of the challenges encountered in tutorial delivery. The tool was adapted from the DepEd ARAL School Survey (DepEd Memorandum Number 056, series 2025). It has the following scale: 5-Extremely Challenging, 4-Very Challenging, 3-Moderately Challenging, 2-Slightly Challenging, and 1-Not at all challenging. Part IV were the creative strategies adapted from the DepEd ARAL Implementation Guide (DepEd Memorandum Number 064, s. 2025) with a scaling of 5-Always Practiced, 4-Often Practiced, 3-Sometimes Practiced, 2-Rarely Practiced, and 1-Never Practiced.

Data Gathering Procedures. Permission to carry out the study was secured first from the Campus Director and the Dean of the School of Advanced Studies. Upon the endorsement of the research, the researcher asked permission from the Schools Division Superintendent and Public Schools District Supervisors to conduct the study in the public elementary schools in Bilar, Batuan, Carmen, Sierra Bullones, and Pilar, Bohol. After the approval to conduct the study, the researcher asked permission from the school heads/principals then, the researcher personally distributed the survey-questionnaires to the respondents. Furthermore, the researcher assured the respondents regarding the confidentiality of their responses and sincerely seeks their utmost cooperation in honestly and objectively answering the survey. After a week, the researcher personally retrieved the questionnaires for tabulation, treatment, analysis, and interpretation purposes.

Statistical Treatment. The data of respondents' profile was subjected to statistical treatment using frequency and simple percentage. Weighted Mean Score (WMS) was used to determine the level of teachers' capacity, challenges, and strategies in tutorial delivery of the ARAL Program in public elementary schools of Bilar, Batuan, Carmen, Sierra Bullones, and Pilar, Bohol. In this study, Multiple regression was used to determine the significant association between profile of the respondents and the level of capacity, challenges, and strategies in tutorial delivery of the ARAL program. This method identifies which factors significantly affect tutorial outcomes while controlling for other variables, providing a clearer understanding of what most strongly supports or hinders success. The results offered evidence-based insights to guide improvements in ARAL implementation and targeted teacher support.

FINDINGS

1. Profile of the Respondents

	Frequency	Percentage (%)	Rank
1.1 Age			
21– 30 years old	19	9.5	4
31 – 40 years old	77	38.5	1
41 – 50 years old	60	30.0	2
51 – 60 years old	42	21.0	3
61 years old and above	2	1.0	5
1.2. Sex			
Male	31	15.5	2
Female	169	84.5	1
1.3 Civil Status			
Single	33	16.5	2
Married	167	83.5	1
1.4 Designation/Position Held			
Teacher I	98	49.0	2
Teacher II	1	.5	4.5
Teacher III	99	49.5	1
Master Teacher I	2	1.0	3
Master Teacher II	1	.5	4.5
1.5 Years in Service			
1-5 years	86	43.0	1
6-10 years	45	22.5	2
11-15 years	20	10.0	4
16-20 years	10	5.0	5
21 years & above	39	19.5	3
1.6 Highest Educational Attainment			
Bachelor Degree Holder	38	19.0	3
With units in Masters' Degree	67	33.5	2
Masters' Degree Graduate	72	36.0	1
With Ph. D./ Ed. D. units	23	11.5	4
Ph. D./ Ed. D. Graduate	0	0	5
1.7 Relevant trainings attended			
Orientation on the ARAL Program	200	100%	

Table 1 revealed the profile of the teacher respondents. In terms of age, the highest proportion of respondents belonged to the 31-40 years old group (38.5%), indicating that most teachers are in their mid-career stage. On the other hand, the lowest percentage is recorded among those 61 years old and above (1.0%), suggesting that only a small number of respondents are nearing retirement.

With respect to sex, female teachers constituted the highest percentage (84.5%), while male teachers account for the lowest (15.5%). This reflects the common observation that the teaching profession is largely dominated by females.

As to civil status, married respondents had the highest proportion (83.5%), whereas single respondents have the lowest (16.5%). This suggests that a majority of the teachers have established family responsibilities. In terms of designation or position held, Teacher III has the highest percentage (49.5%), while Teacher II has the lowest percentage (0.5%). This indicates that most respondents are positioned at a relatively higher rank within the Teacher classification.

Regarding years in service, the highest percentage is found among teachers with 1–5 years of experience (43.0%), which implies that many respondents are relatively new in the profession. Conversely, the lowest percentage is observed in the 16–20 years category (5.0%), indicating fewer teachers in this stage of their career.

Finally, in terms of highest educational attainment, those who are Master's Degree Graduates comprise the highest percentage (36.0%), while Ph.D./Ed.D. Graduates register the lowest (0%). This shows that although many teachers pursue advanced studies, none of the respondents have completed a doctoral degree. All teachers handling ARAL program attended the Orientation on ARAL Program.

These findings are supported by the study of Remo and Marcia (2023), which examined the demographic profile of elementary school teachers in Valencia City, Philippines. The study found that most respondents were aged 31–40 years old, predominantly female, held Teacher I–III positions, had less than ten years of service, and were mostly bachelor's degree holders.

2. Teachers' Capacity to Handle ARAL Program

	Frequency	Percentage (%)	Rank
Outstanding (Very High Capacity)	0	0	
Very Satisfactory (High Capacity)	153	76.5	1
Satisfactory (Moderate Capacity)	47	23.5	2
Fair (Low Capacity)	0	0	
Poor (Very Low Capacity)	0	0	
Total	**200**		

Table 2 showed the respondents' assessment on the teachers' capacity to handle the ARAL Program based on Classroom Observation Result using the Classroom Observation Tool. The results showed that the majority of the respondents fall under the "Very Satisfactory (High Capacity)" category, with a frequency of 153 or 76.5 percent, ranking first. This indicates that most teachers demonstrate a high level of competence in terms of their professional capacity, suggesting that they are generally effective in performing their roles and responsibilities.

On the other hand, 47 respondents or 23.5 percent were classified under "Satisfactory (Moderate Capacity)," which ranks second. This implies that while these teachers meet the expected standards, there is still room for improvement in enhancing their skills and overall teaching capacity.

Notably, none of the respondents fall under the "Outstanding (Very High Capacity)," "Fair (Low Capacity)," or "Poor (Very Low Capacity)" categories. The absence of responses in the highest category suggests that although teachers perform well, there may be limited evidence of exceptional or exemplary performance. Similarly, the absence of low and very low ratings indicates that no teacher is perceived to have inadequate capacity.

The findings implied that the teaching workforce generally possesses a high level of capacity, with most teachers performing above average. However, the lack of outstanding ratings suggests a potential area for professional development programs aimed at further enhancing teacher performance toward excellence.

These findings were supported by Abella, Santos, and Reyes (2024), who reported that Filipino public school teachers generally demonstrate a high level of teaching competence, with most respondents rated at a very satisfactory level in terms of instructional skills, classroom management, and professional performance. The study concluded that teachers in public schools are generally effective practitioners, although only a small proportion reach an outstanding level of performance.

3. Level of Challenges that Teachers' Encounter During the ARAL Program

Table 3 presents the respondents assessment on the level of challenges that teachers encounter during tutorial delivery. The highest-rated indicator is Local Government Unit Support, with a weighted mean of 4.14 and ranked 1. This is followed by Attendance and Drop-out Risk (3.99), Health and Nutrition (3.96), Tutor Workload and Incentives (3.94), Psychosocial Support (3.86), Tutor Deployment Plan (3.86), Multi-sectoral Partnerships (3.70), Literacy and Numeracy Assessment (3.68), Non-teaching Personnel Deployment (3.60), School Governance Support (3.59), Tutor Training and Certification (3.58), Technical Assistance and Monitoring (3.57), Class Program and Materials (3.57), Tutor Identification and Eligibility (3.56), and Physical Learning Space (3.54). All these indicators fall under the Verbal Interpretation of Very Challenging, suggesting that teachers experience significant difficulty in both instructional and administrative aspects of tutorial delivery.

These findings implied that challenges are not limited to a single area but are distributed across learner-related concerns, tutor readiness, school facilities, and governance support. In particular, difficulties in LGU coordination, learner attendance monitoring, health-related concerns, workload management, and partnership building indicate that implementation requires stronger collaboration among stakeholders.

On the other hand, several indicators fall under Moderately Challenging, such as Learning and Teaching Resources (3.31), Connectivity (3.25), Home-School Collaboration (3.25), Capacity Building (3.19), PTA and Parent Education Programs (3.11), Sanitation and Hygiene Facilities (3.09), Equity and Protection Enablers (3.04), Access to Technology and Power (3.00), Learning Action Cell and Peer Support (2.99), and Parental Consent and Commitment (2.88). Among these, Parental Consent and Commitment is the lowest-rated indicator, suggesting relatively less difficulty compared to other areas but still indicating a need for improvement.

Learner Readiness	**WM**	**DI**	**Rank**
1.Literacy and Numeracy Assessment (Conduct of CRLA, Phil-IRI, and RMA)	3.68	VC	8
2.Health and Nutrition (Conduct of health assessment like poor vision, poor hearing, undernutrition)	3.96	VC	3
3.Attendance and Drop-out risk (follow-up at risk learners through home visitation)	3.99	VC	2
4.Psychosocial Support (Counseling)	3.86	VC	5.5
Tutor Readiness			
5.Tutor Identification and Eligibility (teachers, para-teachers, pre-service teachers, volunteers)	3.56	VC	14
6.Tutor training and Certification	3.58	VC	11
7.Tutor Deployment Plan (assigned learners, session time, and subject focus per tutor)	3.86	VC	5.5
8.Tutor Workload and Incentives (allowance, recognition, service credits)	3.94	VC	4
9.Class Program and Materials (blocks of time, groupings, and activities per week)	3.57	VC	12.5
10.Learning Action Cell (LAC), Peer Support, and Collaborative Expertise	2.99	MC	24

School Environment Readiness			
11.Physical Learning Space (ARAL Room-well ventilated, well lighted, quiet)	3.54	VC	15
12.Sanitation and Hygiene Facilities (WINS three-star approach)	3.09	MC	21
13.Learning and Teaching Resources (teaching guides, workbooks, remedial modules, and other materials)	3.31	MC	16
14.Access to technology and power (availability of electricity, laptops/desktop, and other digital devices)	3.00	MC	23
15.Connectivity (Internet Connection)	3.25	MC	17.5
16.Equity and Protection Enablers (active Child Protection Committee)	3.04	MC	22
Parental Readiness			
17.Parental Consent and Commitment (submitted signed parent/guardian consent form)	2.88	MC	25
18.PTA and Parent Education Programs (conduct orientation or parenting education sessions)	3.11	MC	20
19.Home-School Collaboration (parent-teacher communication on learner progress may it be online or face to face)	3.25	MC	17.5
Support System and Governance Readiness			
20. School Governance Support (inclusion of ARAL in the SIP and MOOE allocation)	3.59	VC	10
21. Local Government Unit Support	4.14	VC	1
22. Technical assistance and Monitoring	3.57	VC	12.5
23. Capacity Building	3.19	MC	19
24. Multi-sectoral Partnerships	3.70	VC	7
25. Non-teaching Personnel Deployment	3.60	VC	9
Average Weighted Mean	**3.49**	**Moderately Challenging**	

The average weighted mean of 3.49, interpreted as Moderately Challenging, indicates that while several areas are perceived as highly challenging, the general level of difficulty across all domains remains moderate. This suggests that although teachers are able to implement tutorial delivery, substantial support and improvements are still needed, particularly in strengthening stakeholder collaboration, improving resource availability, and enhancing parental and community engagement.

These findings were in line with the recent studies in the Philippine context which show that teachers commonly experience moderate to high levels of challenges in instructional implementation. Lorono (2025) found that public school teachers encounter multidimensional challenges in curriculum and instructional delivery, particularly in areas such as governance support, learner readiness, availability of instructional resources, and overall school readiness. The study emphasized that these challenges are not isolated but are distributed across different aspects of the teaching-learning process, which aligns with the present study where difficulties are observed across learner readiness, tutor readiness, school environment, parental involvement, and governance support.

4. Teachers' Strategies in ARAL Program

The results of Table 4 present the teachers' strategies in ARAL tutorial delivery with an overall average weighted mean of 4.04, interpreted as Often Practiced. This indicates that, in general, teachers frequently employ a variety of instructional strategies to support learners during tutorial sessions, reflecting active engagement in addressing learner needs.

	WM	DI	Rank
1.Technology Integration (via DepEd TV and online tools)	4.45	OP	2
2.Interactive games and activities	4.34	OP	3.5
3.Peer Tutoring or mentoring systems	4.31	OP	5
4.Differentiated Instruction	4.24	OP	6
5.Cooperative Learning	4.61	AP	1
6.Individualized Instruction (one-on-one tutorial)	4.34	OP	3.5
7.Project-based learning tasks	3.87	OP	9
8.Integration of local stories, songs, or cultural materials	4.16	OP	7
9.Flexible Scheduling (after-school, weekend, modular)	3.69	OP	11
10.Alternative assessment tools (rubrics, portfolios, self-assessment)	3.78	OP	10
11.Taps para-teachers or pre-service teachers	3.47	OP	12
12.Partnerships with LGU's (local government units or NGO's (non-governmental organizations)	3.09	OP	13
13.Parent/Community involvement in tutorials	4.11	OP	8
Average Weighted Mean	**4.04**	**Often Practiced**	

In terms of the highest-rated strategy, Cooperative Learning obtained the highest weighted mean of 4.61 and is interpreted as Always Practiced. This suggests that teachers highly prioritize collaborative learning approaches, where learners are encouraged to work together, share ideas, and support one another in understanding lessons. This strategy reflects strong emphasis on learner interaction and social learning in tutorial delivery.

On the other hand, the lowest-rated strategy was Partnerships with LGUs and NGOs, which obtained a weighted mean of 3.09, interpreted as Often Practiced but with the lowest rank. This implies that while partnerships with external stakeholders are still utilized, they are less frequently applied compared to classroom-based strategies. It suggests that collaboration with external organizations may still need strengthening to further support tutorial implementation.

Other highly practiced strategies included Technology Integration (4.45), Interactive Games and Activities (4.34), Peer Tutoring or Mentoring Systems (4.31), Individualized Instruction (4.34), and Differentiated Instruction (4.24), all of which are interpreted as Often Practiced. These results indicate that teachers frequently use learner-centered and technology-enhanced strategies to improve engagement and comprehension.

Overall, the findings suggested that ARAL tutorial delivery is characterized by active use of diverse instructional strategies, with strong emphasis on collaborative, interactive, and individualized approaches. However, strategies involving external partnerships, particularly with LGUs and NGOs, appear to be less emphasized and may require further strengthening to enhance program support and sustainability.

The findings on teachers' strategies in ARAL tutorial delivery are supported by recent literature highlighting the growing use of learner-centered, collaborative, and technology-enhanced instructional approaches in Philippine education. Aguda and Delute (2025) found that teachers frequently integrate technology-based tools such as digital platforms and multimedia resources to improve student engagement and learning outcomes. Their study emphasized that technology integration has become a central component of modern instructional practice, particularly in supporting literacy and content instruction, which aligns with the present findings on the frequent use of technology integration strategies.

5.1. Test of Association Between Respondents' Profile and the Level of Teachers' Capacity in Handling ARAL Program

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
age	.04	.04	.07	.78	.43	No significant association
sex	-.09	.10	-.08	-.92	.36	No significant association
civil status	-.10	.09	-.08	-1.30	.31	No significant association
position/designation	.14	.04	.34	3.43	.00	Significant association
years in service	.06	.03	.20	1.66	.10	No significant association
highest educational attainment	.14	.04	.30	3.10	.00	Significant association

The results of Table 5.1 present the test of association between the teachers' profile and their level of capacity in handling the ARAL Program. The findings show that most of the profile variables, namely age ($p = 0.432$), sex ($p = 0.358$), civil status ($p = 0.305$), and years in service ($p = 0.100$), have p-values greater than 0.05. This indicates that these variables have no significant association with the teachers' capacity in handling the ARAL Program. In other words, the teachers' capacity is not influenced by their age, sex, civil status, or length of service.

On the other hand, two variables were found to have a significant association with teachers' capacity. These are position/designation ($p = 0.001$) and highest educational attainment ($p = 0.002$), both of which have p-values lower than the 0.05 level of significance. This implies that teachers' capacity in handling the ARAL Program is significantly influenced by their position or designation and their level of educational attainment. Specifically, teachers who hold higher positions and those with higher educational qualifications tend to demonstrate better capacity in implementing the program.

Overall, the results suggest that demographic characteristics such as age, sex, civil status, and years in service do not play a significant role in determining teachers' capacity in handling the ARAL Program. However, professional-related factors, particularly position and educational attainment, are important determinants of teachers' capacity. This highlights the importance of career advancement and continuous professional development in strengthening teachers' effectiveness in program implementation.

Recent literature emphasizes that teachers' professional qualifications and career positions significantly influence their teaching competence and program implementation capacity. A study by Bautista (2025) found that teachers with higher educational attainment and advanced academic preparation demonstrate stronger instructional competence, better classroom management, and higher effectiveness in implementing school-based programs. The study further emphasized that professional growth through graduate education enhances teachers' ability to handle complex instructional demands.

5.2. Test Of Association Between the Teachers' Profile and the Level of Challenges Encountered in Handling the ARAL Program

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
age	.61	.09	.57	7.03	.00	Significant association
sex	.02	.20	.01	.11	.91	No significant association
civil status	.16	.18	.06	.88	.38	No significant association
position/designation	.43	.08	.43	5.26	.00	Significant association
years in service	-.10	.07	-.16	-1.52	.13	No significant association
highest educational attainment	-.10	.09	-.09	-1.10	.27	No significant association

Table 5.2 presents the test of association between the teachers' profile and the level of challenges encountered in handling the ARAL Program. The findings reveal that age has a significant association with the level of challenges encountered (p = 0.000), which is less than the 0.05 level of significance. This indicates that the challenges experienced by teachers vary depending on their age. The positive coefficient suggests that as age increases, the level of challenges encountered also tends to increase, implying that older teachers may perceive or experience more difficulties in implementing the ARAL Program.

Similarly, position/designation is also found to have a significant association (p = 0.000). This implies that the level of challenges differs according to the teachers' rank or position. Teachers holding higher positions may experience different or possibly greater responsibilities, which could influence the level of challenges they encounter in program implementation.

On the other hand, sex (p = 0.909), civil status (p = 0.379), years in service (p = 0.131), and highest educational attainment (p = 0.273) all have p-values greater than 0.05, indicating no significant association with the level of challenges encountered. This means that these variables do not significantly influence how teachers experience challenges in handling the ARAL Program.

Overall, the results suggest that among the profile variables, only age and position/designation significantly affect the level of challenges encountered by teachers. This implies that both personal maturity and professional role play important roles in shaping teachers' experiences of challenges, while other demographic and educational factors appear to have no significant effect.

These findings are Table 5.2 are supported by recent literature indicating that teachers' experiences of challenges are influenced more by certain personal and professional factors rather than all demographic variables. A study by Torres (2024) found that teachers' age significantly affects how they perceive and respond to challenges in instructional implementation. The study explained that older teachers tend to encounter more difficulties, particularly in adapting to new programs, technologies, and instructional approaches, which supports the present finding that age has a significant association with the level of challenges encountered.

5.3. Test Of Association Between the Teachers' Profile and the Strategies Implemented in Handling the ARAL Program

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
age	.06	.06	.10	1.09	.28	No significant association
sex	.21	.13	.14	1.68	.10	No significant association
civil status	.72	.11	.49	6.28	.00	Significant association
position/designation	-.09	.05	-.16	-1.67	.10	No significant association
years in service	.08	.04	.23	1.91	.06	No significant association
highest educational attainment	-.27	.06	-.46	-4.93	.00	Significant association

Table 5.3 shows the test of association between the teachers' profile and the strategies implemented in handling the ARAL Program.

The findings reveal that civil status has a significant association with the strategies implemented (p = 0.000), indicating that the strategies used by teachers vary according to their civil status. The positive coefficient suggests that certain groups, particularly those who are married, may be more likely to employ a wider range or more effective instructional strategies, possibly due to greater stability, experience, or support systems.

Similarly, position/designation is also found to have a significant association (p = 0.000). This implies that the level of challenges differs according to the teachers' rank or position. Teachers holding

higher positions may experience different or possibly greater responsibilities, which could influence the level of challenges they encounter in program implementation.

On the other hand, age ($p = 0.278$), sex ($p = 0.095$), position/designation ($p = 0.096$), and years in service ($p = 0.057$) all have p-values greater than 0.05, indicating no significant association with the strategies implemented. This means that these variables do not significantly influence the choice or use of strategies among teachers in handling the ARAL Program.

Overall, the results suggest that among the profile variables, only civil status and highest educational attainment significantly influence the strategies implemented by teachers. This highlights the role of personal and educational factors in shaping instructional approaches, while other demographic and professional characteristics appear to have no significant effect.

Recent studies emphasize that teachers' instructional strategies are influenced by both personal and educational factors. A study by Gamboa and Quicho (2025) found that teachers' instructional practices and teaching strategies are significantly related to their professional qualities and background characteristics. The study revealed that teachers with stronger professional preparation tend to demonstrate more effective and varied teaching strategies, highlighting the role of personal and educational factors in shaping instructional practices.

CONCLUSIONS

Based on the findings of the study, it can be concluded that teachers possess a high level of capacity in implementing the ARAL Program despite experiencing moderate to high challenges in various aspects of tutorial delivery. The presence of several very challenging areas indicates that implementation is not without difficulty, particularly in terms of stakeholder coordination, learner-related concerns, and workload management. Furthermore, the study concludes that professional factors such as position and educational attainment play a significant role in enhancing teachers' capacity, while age and position influence the level of challenges encountered. The strategies implemented by teachers are also influenced by certain personal and educational characteristics, particularly civil status and educational attainment. Overall, the effectiveness of ARAL tutorial delivery depends not only on teachers' capability but also on the level of support, resources, and collaboration available within the school and the community.

RECOMMENDATIONS

Learners are encouraged to actively participate in ARAL Program activities and maintain consistent attendance to maximize learning gains. They may develop self-discipline and study habits, especially when attending remedial or catch-up sessions. Seeking help from teachers and tutors when difficulties arise can further improve their academic performance and engagement.

Teachers may continue strengthening the instructional strategies they already use, particularly cooperative learning and other learner-centered approaches, as these have proven effective. They will also explore ways to enhance collaboration with external stakeholders such as LGUs and NGOs to address gaps in resources and support. Continuous professional development, especially in handling diverse learner needs and psychosocial concerns, is highly recommended.

School heads are encouraged to provide stronger institutional support by ensuring manageable teacher workloads and providing adequate training related to ARAL implementation. They may facilitate partnerships with LGUs, NGOs, and other stakeholders to address challenges such as learner attendance, health concerns, and psychosocial support. Monitoring and mentoring systems may also be strengthened to sustain teacher effectiveness.

Parents may actively support their children's participation in the ARAL Program by ensuring regular attendance and providing a conducive learning environment at home. They will also maintain open

communication with teachers regarding their children's academic progress and needs. Parental involvement in school activities and interventions is crucial in reducing dropout risks and improving learner outcomes.

Local Government Units are encouraged to strengthen their collaboration with schools by providing logistical, financial, and psychosocial support for ARAL Program implementation. This includes assistance in addressing learner attendance issues, health and nutrition concerns, and provision of incentives for tutors and learning facilitators. Stronger partnerships with schools can significantly enhance program sustainability and effectiveness.

Future researchers may conduct further studies on ARAL Program implementation using mixed methods approaches to gain deeper insights into qualitative experiences of teachers and learners. They may also explore the effectiveness of specific interventions addressing the identified challenges, such as LGU partnerships or psychosocial support programs. Expanding the study to include multiple divisions or regions is also recommended to improve generalizability of findings.

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IMAGE-BASED SOIL CLASSIFICATION WITH NUTRIENT SENSING FOR INTELLIGENT AGRICULTURAL CROP RECOMMENDATIONS

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ABSTRACT

Smallholder farmers in Surigao del Norte face barriers to precision agriculture due to the logistical constraints and financial burden of conventional laboratory analysis. Existing digital agricultural tools often rely on foreign datasets, high-end infrastructure, or temperate crop models unsuitable for tropical contexts. This study presents an Intelligent Crop Recommendation System that integrates real-time soil nutrient sensing with image-based soil classification to deliver localized, context-aware crop advisories. The system employs an ESP32-based 7-in-1 sensor module for measuring nitrogen, phosphorus, potassium, pH, moisture, and temperature, coupled with a lightweight MobileNetV2 convolutional neural network trained on a regionally augmented soil image dataset. A large language model fine-tuned for tropical agronomic reasoning fuses these multimodal inputs to generate plain-language, ecologically suitable crop recommendations. Field validation at the Department of Agriculture and Kitcharao Municipal Local Government Unit Farm confirmed technical performance, with 94% accuracy in soil classification and an average perceived usefulness rating of 4.2 out of 5. The system demonstrates that affordable, edge-optimized artificial intelligence and embedded sensing can effectively support smallholder agriculture in tropical settings.

Keywords: *Precision Agriculture, Soil Classification, Crop Recommendation, Large Language Model, Edge AI*

INTRODUCTION

Agriculture remains a cornerstone of food security and rural livelihoods in the Philippines, particularly in the Caraga Region, where smallholder farmers managing plots of less than two hectares face mounting pressures from climate variability, declining soil fertility, and inefficient input utilization. These farmers often select crops based on ancestral knowledge, generalized planting calendars, or outdated soil maps that fail to reflect the actual biophysical conditions of their individual plots. Consequently, they experience reduced yields, unnecessary expenditure on fertilizers, and progressive degradation of soil health. Traditional soil testing, which requires specialized laboratory infrastructure, is typically inaccessible, delayed, or prohibitively expensive for such farmers, leaving them without timely, field-specific agronomic guidance.

Precision agriculture offers a data-driven alternative by leveraging sensing technologies and intelligent decision support to manage spatial and temporal variability in farming operations. Recent advancements in Internet of Things platforms have made precision agriculture increasingly accessible through low-cost electrochemical and environmental sensors interfaced with microcontrollers like the ESP32. These devices can measure key soil parameters on site, reducing dependence on distant laboratories.

While commercial multisensor soil probes estimate nutrient levels indirectly via colorimetric or conductivity-based proxies, such data can still support practical field decisions when paired with contextual interpretation.

Complementing sensor data, image-based soil analysis has emerged as a viable noninvasive method for assessing soil properties. Recent studies demonstrate that soil images captured under natural field conditions can reliably predict fertility patterns when processed with machine learning models. Similarly, multimodal systems that fuse soil image classification with structured nutrient profiling have delivered high-accuracy crop recommendations. These frameworks validate Internet of Things-based monitoring and machine learning for on-farm advisory services, while demonstrating measurable reductions in fertilizer overuse through guided recommendations.

However, these systems have not been validated in Mindanao's unique agroecological context, characterized by acidic, iron-rich tropical soils with high organic matter variability and frequent moisture fluctuations. These conditions significantly influence both sensor behavior and visual soil appearance. At the national level, science and technology initiatives have prioritized large-scale disaster resilience infrastructure. While vital for mitigating flood-related losses, such programs do not address the daily, on-farm diagnostic needs of smallholder farmers. This gap underscores the need for localized, farmer-operated intelligent systems that translate sensing and artificial intelligence into actionable agronomic advice. In response, this study proposes an Intelligent Crop Recommendation System, a field-deployable platform that integrates soil nutrient sensing and image classification to support data-driven, site-specific crop selection at the Department of Agriculture and Kitcharao Municipal Local Government Unit Farm in Surigao del Norte.

The system architecture is illustrated in the Input-Process-Output framework (Figure 1), which maps the dual data streams from the hardware module and camera input through parallel processing pathways to generate localized recommendations.

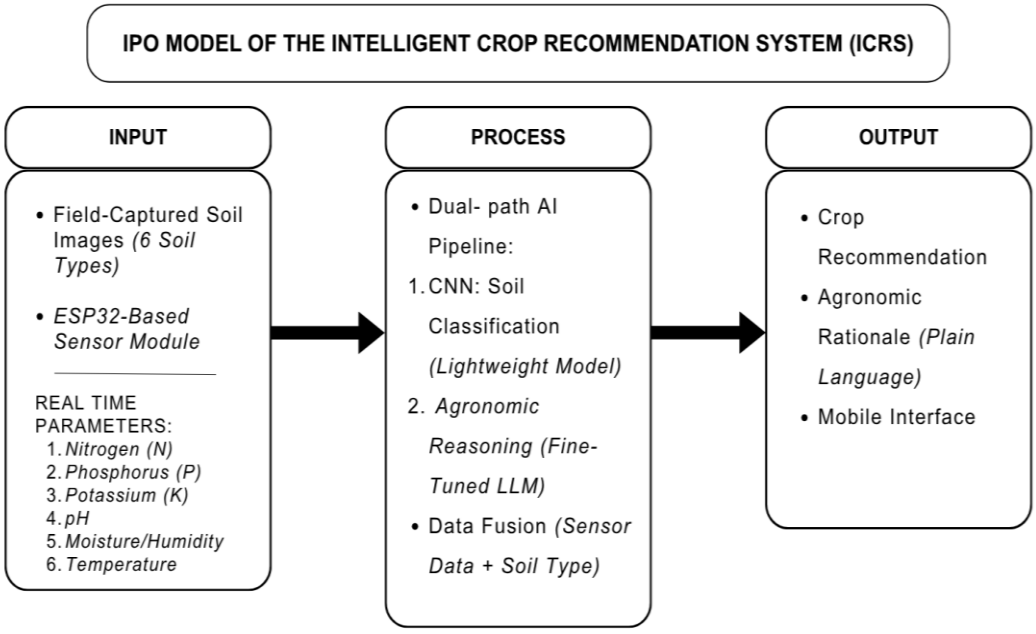


Figure 1. IPO Model of the ICRS

OBJECTIVES

General Objective

To design, develop, and evaluate an Intelligent Crop Recommendation System that integrates real-time soil nutrient sensing and image-based soil classification to support data-driven, site-specific decision-making in precision agriculture.

Specific Objectives

1. To develop a portable, field-ready soil nutrient sensing module capable of measuring nitrogen (N), phosphorus (P), potassium (K), pH, soil moisture, and temperature in real time using an ESP32 microcontroller and a 7-in-1 NPK soil sensor.
2. To classify six target soil types—alluvial, arid, black, laterite, red, and yellow soils—using a lightweight Convolutional Neural Network (CNN) trained on a Kaggle soil image dataset, and to generate crop recommendations using a Large Language Model (LLM) fine-tuned for agronomic reasoning based on real-time sensor inputs.
3. To implement an interface deployable via mobile devices that delivers personalized crop recommendations accompanied by clear agronomic rationale and visual feedback.

METHODOLOGY

This study employs a design science research methodology, emphasizing the creation, implementation, and contextual evaluation of an innovative technological artifact to address a real-world challenge in smallholder agriculture. Given the constraints of field deployment in rural Mindanao, the research prioritizes ecological validity over statistical generalization, focusing on whether the system outputs are perceived as agronomically plausible, contextually appropriate, and trustworthy by individuals with direct experience in local farming practices. The case was bounded geographically and temporally: field testing occurred at the Department of Agriculture and Kitcharao Municipal Local Government Unit Farm in Surigao del Norte.

Ethical Considerations and Participant Consent

The study adhered to institutional research ethics guidelines. Verbal informed consent was obtained and documented from all participants prior to engagement. Participants were informed that involvement was voluntary, they could withdraw at any time, and all responses would be anonymized in research outputs. No personally identifiable information was collected beyond optional demographic grouping, and the field validation posed no physical or environmental risk to participants or the agricultural site.

Agile Development Framework

Development followed six iterative Agile sprints to ensure stakeholder alignment and incremental refinement, as shown in Figure 2: (1) Requirements and Planning, (2) System Design and Hardware Integration, (3) Dataset Preparation and Model Training, (4) Mobile Application Development and Integration, (5) Field Validation and Performance Evaluation, and (6) Feedback, Optimization, and Refinement. Each sprint included structured feedback loops with domain experts and end users to ensure contextual alignment and technical robustness.

Figure 2. Agile Methodology Framework Applied in the Development of the ICRS

System Design and Implementation

The Intelligent Crop Recommendation System operates through the integration of soil sensing, image classification, and contextual artificial intelligence reasoning. A multisensor soil probe captures nitrogen, phosphorus, potassium, pH, moisture, and temperature, transmitting the data via RS-485 to an ESP32 microcontroller, which forwards it to a mobile application via Bluetooth Low Energy. Simultaneously, the user captures a soil photograph under natural lighting. The image is resized and processed by a convolutional neural network trained on a curated soil image dataset to identify the soil type among six regional categories. These two data streams, numerical sensor values and categorical soil type, are fused and interpreted by a large language model fine-tuned on agronomic principles relevant to tropical Philippine agriculture.

To ensure operational independence in off-grid environments, the large language model inference engine is deployed in an edge configuration directly on the mobile device. This architecture eliminates continuous internet dependency during field use, allowing the system to function reliably in areas with limited or no connectivity. Rather than selecting from a fixed list, the model generates plain-language recommendations, providing both a suggestion and a rationale to enhance user understanding and trust. Because the system does not rely on foreign tabular datasets, it avoids recommending ecologically unsuitable temperate crops, ensuring all outputs remain grounded in local agronomic reality.

Hardware Configuration

The physical sensing unit is housed in an IP65 rated white ABS junction box for environmental protection. It features an illuminated rocker switch for power control and is powered by a 12V lithium battery. A TTL to RS-485 module connects the ESP32 microcontroller to the soil sensor, enabling noise-resistant data transmission. The electrical wiring configuration is detailed in Figure 3, while the custom single-layer printed circuit board layout optimized for field deployment is shown in Figure 4.

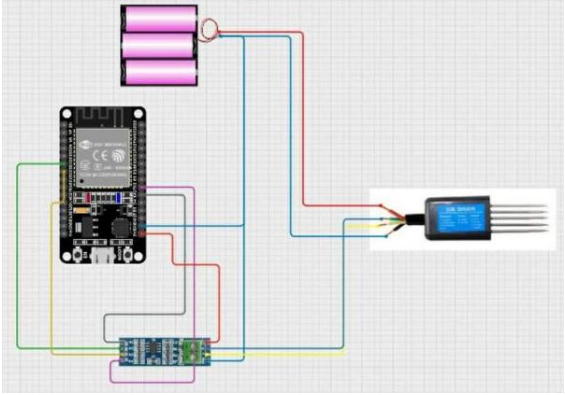


Figure 3. Electrical Schematic of the Soil Sensing Module

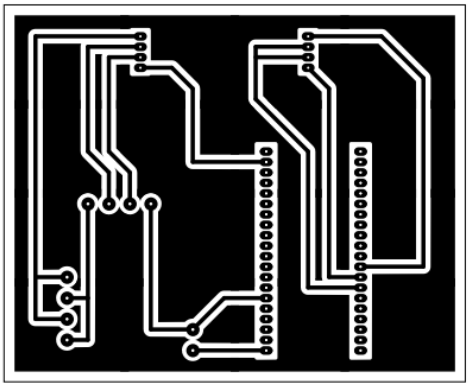


Figure 4. Printed Circuit Board Layout for the Soil Sensing Module

The fully assembled sensing unit, highlighting the enclosure, power switch, and probe cabling, is presented in Figure 5. This compact, rugged design ensures durability and portability for rural agricultural use.

Figure 5. ICRS Sensing Module

User Interface and Experience

The mobile application features a streamlined, four-step workflow designed for intuitive use in rural settings. As illustrated in Figure 6, the interface begins with a clear home screen, progresses through real-time nutrient data display alongside GPS-tagged soil imaging, and culminates in a results dashboard that identifies the soil type, interprets nutrient levels, and recommends locally viable crops with confidence

scores and plain- language agronomic rationale. Specific UI elements including the primary scan button, sensor pairing toggle, GPS tagging field, and history log were deliberately positioned to minimize cognitive load and support low- digital-literacy users.

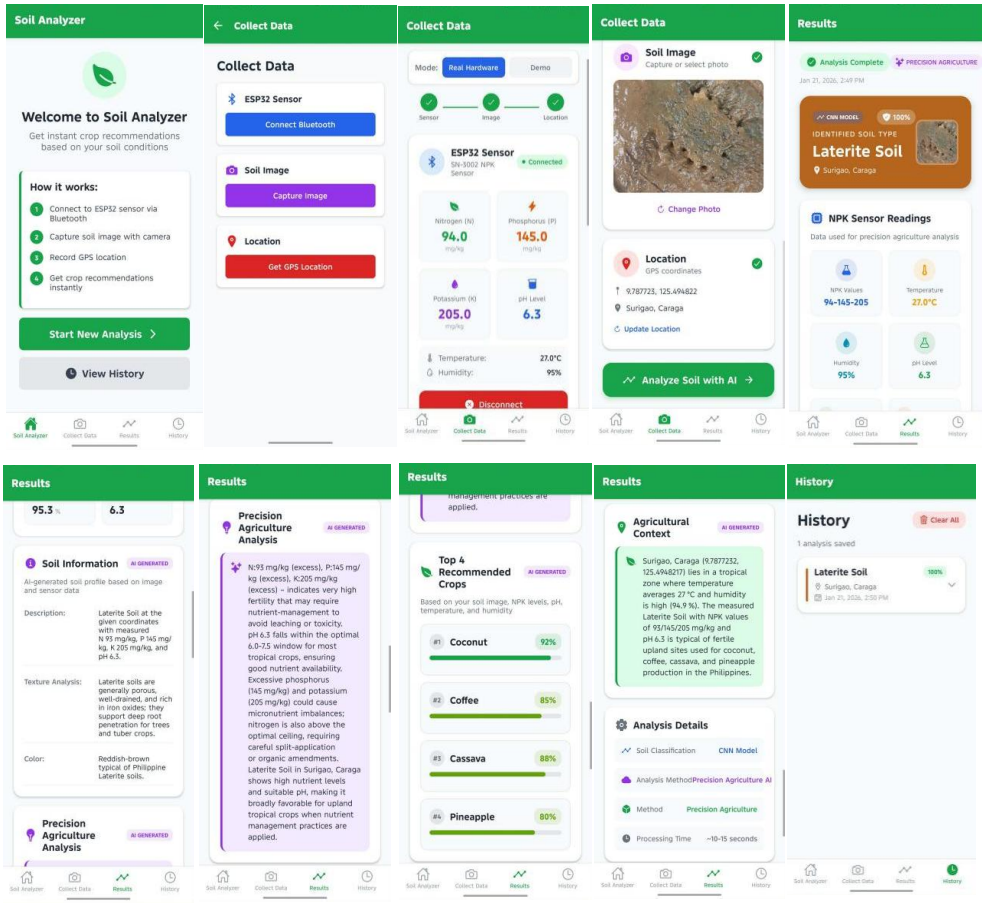


Figure 6. Mobile Application Interface: Full User Workflow Showing Scan Button, GPS Tagging, and Results Dashboard

Dataset Preparation and Validation

The convolutional neural network used exclusively for image-based soil type classification was trained on a publicly available dataset containing labeled photographs of six regional soil types: alluvial, arid, black, laterite, red, and yellow. The dataset was augmented through rotation, flipping, and brightness adjustment to improve robustness under variable field lighting. Expert validation was conducted by a Department of Agriculture municipal agriculturist to ensure label accuracy and agronomic relevance.

Table 1. Validation Dataset

Category	Images Collected	Verified & Validated	Excluded
Alluvial	160	155	5
Arid	155	150	5
Black	155	150	5
Laterite	155	150	5
Red	145	145	0
Yellow	125	115	10
Total	**895**	**865**	**30**

Data Gathering Procedure

Data gathering was conducted in two sequential phases. In the first phase, the convolutional neural network was trained on the expert-validated soil image dataset. The model, based on MobileNetV2, was fine-tuned and achieved 94 percent validation accuracy. Notably, the network performs only one function: predicting soil type from an image. It does not process sensor data or generate crop recommendations.

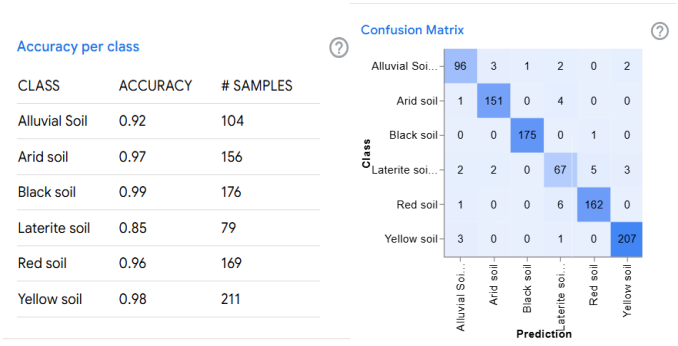
In the second phase, field validation was carried out at the Department of Agriculture and Kitcharao Municipal Local Government Unit Farm. During this period, the system generated live recommendations by fusing real-time sensor readings with the predicted soil type, which were then interpreted by the large language model to produce context-aware crop suggestions. Immediately after each test, participants completed a structured evaluation instrument aligned with ISO/IEC 25010 software quality standards, and researchers documented observational notes to capture qualitative insights on usability, clarity, and perceived relevance.

FINDINGS

The final prototype integrates hardware, artificial intelligence, and a mobile interface into a cohesive, field-deployable workflow. The ESP32-based sensing module reliably captures six key soil parameters within 5 to 8 seconds per reading. Data is transmitted wirelessly to a mobile application designed for ease of use in rural settings.

The mobile application features a minimalist interface. A single scan button initiates camera capture. Images are automatically preprocessed and classified by a fine tuned convolutional neural network into one of six regional soil types. Concurrently, sensor data is fused with the predicted soil type and interpreted by the large language model. This model generates dynamic, plain-language recommendations, ensuring outputs are explainable, locally relevant, and ecologically plausible. Notably, no temperate crops were recommended during testing, as the reasoning pipeline is grounded in Philippine farming contexts rather than foreign datasets. This design fulfills the integration and recommendation objectives successfully.

The convolutional neural network achieved 94 percent overall validation accuracy, with strongest performance on black soil and lowest on laterite soil, likely due to visual similarity with red and yellow soils under high iron oxide conditions. Analysis of the confusion matrix confirms minimal misclassification between dissimilar types, as shown in Figure 7, validating robustness in the regional soil context. Laterite soil showed the highest cross-class error (12 misclassifications), predominantly confused with red (5) and yellow (3) soils, consistent with known visual overlap in iron-rich tropical soils.



Accuracy per class

CLASS	ACCURACY	# SAMPLES
Alluvial Soil	0.92	104
Arid soil	0.97	156
Black soil	0.99	176
Laterite soil	0.85	79
Red soil	0.96	169
Yellow soil	0.98	211

Figure 7. CNN Soil Classifier Performance: Accuracy and Confusion Matrix

In this multi-class classification context: True Positive (TP) refers to instances where the model correctly predicted the actual soil type; False Positive (FP) denotes cases where the model incorrectly assigned a soil image to a target class; False Negative (FN) represents instances where the model failed to identify the correct class; and True Negative (TN) encompasses all correct rejections of non-target classes

for a given prediction. These metrics collectively quantify the model's discriminative power and error patterns across the six regional soil types.

Geographic Transferability Limitation

While the model achieved strong accuracy on the curated validation set, its performance was not explicitly tested on geographically distinct soil images outside Surigao del Norte and the Caraga Region. Cross-regional transferability remains an acknowledged limitation. Future work will evaluate classification accuracy using soil imagery from distinct agroecological zones to assess model generalizability and domain shift resilience.

Hardware Configuration and Power Analysis

Power consumption was measured for each major subsystem during continuous operation to assess field operability.

Table 2. Power Consumption and Operational Runtime Analysis

System Component / Subsystem	Power Consumption (Wh/hour)	Notes
ESP32-WROOM-32 microcontroller + BLE module	2.85 Wh	Primary processing and wireless communication
7-in-1 Soil Sensor (RS-485 interface)	1.20 Wh	Continuous soil parameter acquisition
Mobile Application (Android device)	4.50 Wh	AI inference, UI rendering, and data storage
Voltage regulation and power management	0.60 Wh	Power conversion efficiency losses
Total System Consumption	**9.15 Wh/hour**	**Combined operational load**

Based on the measured power consumption and the system battery specifications, operational runtime was estimated. With a 12V, 20,000 mAh lithium battery and an 80 percent discharge limit for battery protection, the estimated runtime is approximately 21 hours of continuous field operation. This confirms suitability for extended field work without frequent recharging.

Operational Performance Metrics

Key operational metrics were measured during field trials to validate performance against predefined acceptance criteria.

Table 3. Operational Performance Metrics

Metric	Measured Value	Acceptance Target	Status
Soil classification accuracy	94%	≥ 90%	Achieved
Data telemetry latency	5 to 8 seconds	≤ 8 seconds	Achieved
Bluetooth Low Energy wireless range	6.2 meters	≥ 5 meters	Achieved
Recommendation relevance	100% contextual	100% accuracy	Achieved
User acceptance score	4.0/5.0	≥ 3.5/5.0	Achieved
Power endurance	21.0 hours	≥ 12 hours	Achieved

All predefined performance targets were accomplished. The 94 percent classification accuracy, sub-8-second latency, and 100 percent contextual relevance of recommendations confirmed that the system operated within engineering thresholds while providing agronomically sound outputs.

System Evaluation Results

The performance of the system was evaluated through technical metrics and stakeholder feedback using an instrument aligned with ISO/IEC 25010 software quality standards.

Table 4. ISO/IEC 25010 Construct Level Evaluation Results (N = 7)

Construct	Mean (SD)	Interpretation
Functional Suitability	4.00 (0.73)	Agree
Performance Efficiency	3.83 (0.74)	Agree
Interaction Capability	4.20 (0.64)	Strongly Agree
Reliability (Department of Agriculture Official)	3.80 (0.78)	Agree
Overall System	**4**	**Agree**

Note. Five point Likert scale; interpretation: 4.20 to 5.00 = Strongly Agree, 3.50 to 4.19 = Agree.

The average perceived usefulness score of 4.2 out of 5 confirms that explainable artificial intelligence builds trust among non-technical users. The study demonstrates that precision agriculture for developing regions can succeed using local knowledge, moderate-cost hardware, and human-in-the-loop validation without reliance on high-end infrastructure or global datasets.

CONCLUSION

Based on the results and analysis presented in this study, the following conclusions are drawn regarding the Intelligent Crop Recommendation System (ICRS):

1. The ESP32-based soil sensing module reliably measured six key parameters (nitrogen, phosphorus, potassium, pH, moisture, temperature) within 5–8 seconds, providing low-cost, field-ready diagnostics without laboratory dependence.
2. The multimodal AI architecture achieved 94% accuracy in classifying six regional soil types and generated context-aware crop recommendations using a tropically fine-tuned LLM, avoiding ecologically unsuitable temperate crops.
3. The mobile interface delivered clear, plain-language recommendations, earning a 4.2/5 Perceived Usefulness score and confirming that explainable AI builds trust among non-technical users.
4. Field validation with seven participants confirmed the system's recommendations were ecologically appropriate, economically relevant, and clearly communicated for rural decision-making.
5. The study proved that precision agriculture for the Global South can succeed using local knowledge, moderate-cost hardware, and human-in-the-loop validation, without reliance on high-end infrastructure or global datasets.

RECOMMENDATIONS

In light of the findings and conclusions of this study, the following recommendations are proposed to further improve the system and expand its applicability:

1. Integrate a standardized embedded camera (e.g., 5MP OV5640) into the sensor housing to improve image classification consistency and reduce variability from external devices.
2. Shift all data processing onboard the device, transmitting only final recommendations via Bluetooth to a companion app that serves solely as a display interface.
3. Conduct longitudinal field trials in the Caraga Region to measure yield impact, cost savings, and adoption rates, and integrate the system into DA extension services.
4. Add voice-enabled feedback and multilingual support to improve accessibility for low-literacy users in linguistically diverse rural areas.

5. Expand the soil image library with locally collected, geotagged samples to refine model accuracy across Mindanao's agroecological zones.
6. Optimize costs and prioritize locally sourced, repairable components to enhance affordability and long-term sustainability for smallholder farmers.
7. Adapt the ICRS framework to other high-value crops and farming systems to broaden its utility toward holistic, context-aware farm management.

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ENGAGEMENT, MOTIVATION, AND EDUCATIONAL PHILOSOPHY AMONG PUBLIC ELEMENTARY SCHOOL TEACHERS

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ABSTRACT

This study aimed to assess teachers' engagement, motivation, and educational philosophy in enhancing instructional effectiveness among basic education teachers in the DADASANTRI districts for the school year 2025–2026. Specifically, it examined the respondents' demographic profile, the level of engagement, motivation, and application of educational philosophies, as well as the relationship between these variables and instructional effectiveness. A quantitative research design was employed, utilizing survey questionnaires and regression analysis to determine significant associations. Findings revealed that teachers generally demonstrate a high level of engagement, particularly in fostering positive interpersonal relationships, empathy, and concern for learners and colleagues. However, slightly lower levels were observed in personal enthusiasm and passion for teaching. Teachers were also found to be highly motivated, primarily driven by their belief in the societal value of the teaching profession, though motivation related to lesson preparation and continuous improvement was comparatively lower. In terms of educational philosophy, teachers exhibited strong application across multiple perspectives, including essentialism, progressivism, constructivism, and humanism, highlighting adaptability in instructional practices. Further analysis indicated that age, sex, educational attainment, and teaching experience significantly influence teachers' effectiveness, while civil status does not. Among these, teaching experience and educational attainment emerged as the strongest predictors. The study concludes that while teachers maintain high levels of professional engagement and motivation, there is a need to enhance enthusiasm and continuous development practices. Recommendations include strengthening professional development programs, fostering collaborative environments, and encouraging ongoing teacher growth and learner participation to improve instructional effectiveness.

Keywords*: engagement, motivation, educational philosophy, public elementary school, teachers*

INTRODUCTION

The real power of teaching is found through teachers' engagement, motivation, and educational philosophy, all of which work together to create a dynamic and significant learning environment. Engaged teachers show enthusiasm, dedication, and consistent effort toward their instructional goals. Motivation, which is closely related, includes the internal drives and external rewards that encourage teachers to use their skills and knowledge in the classroom. Educational philosophy involves deeply held beliefs and values about teaching and learning. These beliefs shape a teacher's methods and approach to instructional effectiveness.

In the Philippine national context, enhancing instructional effectiveness through teachers' engagement, motivation, and educational philosophy is increasingly vital amid evolving educational reforms and persistent challenges. Studies reveal that teacher motivation and engagement are often influenced by leadership styles, autonomy, and collaboration, yet these factors remain underutilized in many schools. Moreover, while instructional competence is generally high, its impact on student performance is inconsistent, suggesting that deeper philosophical alignment and sustained engagement are essential to bridge this gap and foster meaningful learning outcomes nationwide (Cañoso, 2024).

In Region 7 (Central Visayas), examining teachers' engagement, motivation, and educational philosophy is crucial due to persistent instructional challenges and systemic gaps. Difficulties in implementing the MATATAG or Revised K to 12 Curriculum stem from limited resources, uneven access to professional development, and insufficient contextualized support. Variations in leadership practices and school culture further influence teachers' perceptions of their roles, underscoring the need to understand how motivation and educational beliefs shape instructional effectiveness in the region (Villaflor, 2025).

In Bohol Province, there is a clear need to examine how teachers' engagement, motivation, and educational philosophy influence instructional effectiveness. Despite participation in INSET, LAC sessions, and regional trainings, many teachers struggle to translate professional development into improved classroom practice due to multi-grade teaching, limited resources, and high student–teacher ratios. Challenges in addressing diverse learning needs, curriculum adaptation, and community engagement further highlight the importance of teachers' beliefs and motivation in improving instructional quality across the province. This prompted the researcher to assess the teachers' engagement, motivation, and educational philosophy in enhancing instructional effectiveness in Bohol Division specifically in Danao, Dagohoy, San Miguel, and Trinidad (DADASANTRI) Districts to provide possible solutions to enhance the program implementation.

Transformational Leadership Theory (Brady, 2023) emphasizes the importance of visionary leadership that inspires and empowers individuals to excel their self-interest for the collective good. In education, this means school leaders who articulate a clear, compelling vision for the future and motivate teachers and staff to work collaboratively toward that vision. Transformational leaders serve as role models, demonstrating integrity and high ethical standards, which fosters trust and respect among teachers. They encourage innovation and continuous professional growth by stimulating intellectual curiosity and providing individualized support to address unique teacher needs. This leadership style boosts teacher morale, motivation, and commitment, which ultimately improves teaching quality and student outcomes.

This leadership approach encourages continuous professional growth by stimulating intellectual curiosity and providing personalized support that meets teachers' unique needs. When school leaders practice transformational leadership, they create an environment that boosts teacher morale and commitment. This supportive atmosphere catalyzes innovation and persistence, which ultimately leads to higher teaching quality and better student outcomes (Sumampong and Arnado, 2024).

According to Albert Bandura (1986), The Social Cognitive Theory highlights the reciprocal interaction between personal factors, behaviors, and environmental influences in shaping learning and motivation. At its core, this theory asserts that teacher beliefs especially their self-efficacy or confidence in their teaching abilities play a critical role in influencing their motivation and actions in the classroom. When teachers believe they can positively impact student learning, they are more likely to adopt effective teaching strategies and persist through challenges. This theory also emphasizes the importance of observational learning and modeling, where teachers learn from observing peers and mentors, which further shapes motivation and behavior.

Additionally, highly engaged teachers tend to create positive classroom environments that foster student motivation and active participation (Hattie, 2009; Klassen & Chiu, 2010). When teachers are emotionally engaged, they exhibit genuine passion and care for their students, which creates a supportive and motivating environment. Cognitive engagement means teachers actively think about their teaching methods, continuously reflecting and improving their strategies to meet student needs. Physical engagement involves the tangible effort teachers invest, such as preparing detailed lesson plans and actively participating in classroom activities. This comprehensive engagement fosters a positive classroom atmosphere that

encourages students to be more motivated and invested in their learning. Research has shown that when teachers are highly engaged, students respond with increased interest, participation, and ultimately better academic performance.

Motivation itself encompasses both intrinsic factors, such as personal fulfillment and professional growth, and extrinsic rewards, including recognition and feedback (Herzberg, 1966; Hyland, 1989). These motivational influences often interact dynamically to shape teachers' attitudes and performance. Intrinsic motivation refers to the internal drives that inspire teachers, such as personal fulfillment, passion for teaching, and professional growth. These internal motivators generate a genuine love for the profession, leading teachers to find satisfaction and meaning in their work. When intrinsic motivation is high, teachers are more committed, engaged, and ready to put extra effort into improving their craft. On the other hand, outside-driven motivation derives from tangible rewards like recognition, positive feedback, salary increments, and job security. These factors provide tangible incentives that encourage teachers to perform their duties effectively. However, extrinsic factors can sometimes have mixed effects; for example, when rewards are perceived as unfair or insufficient, they may demotivate rather than encourage teachers. The interplay of intrinsic and extrinsic motivation is critical for sustaining teacher enthusiasm and efficacy.

Ongoing professional development that encourages reflection on educational philosophy is critical for sustaining motivation and enhancing teaching quality (Colbert & Mogollon, 1977; Klassen & Chiu, 2010). This emphasize that when teachers engage in continuous learning opportunities that challenge their beliefs and practices, they become more self-aware and intentional about their instructional approaches. Reflection on educational philosophy during professional development helps teachers connect their core values and teaching beliefs with practical classroom strategies. This process deepens their understanding of why they teach the way they do and opens avenues for growth and innovation. For example, teachers who regularly examine their philosophy may shift toward more student-centered and inclusive practices, which research shows enhances both teacher motivation and student engagement (Alemdar & Aytaç, 2022).

The school culture and policies affect teachers' motivation. Collaborative environments that promote shared goals and effective communication increase teacher commitment and job satisfaction (Skaalvik & Skaalvik, 2010; Watt & Richardson, 2007). When teachers feel part of a supportive community with clear, common objectives, they experience a stronger sense of belonging and professional fulfillment. A positive school culture fosters open dialogue, mutual respect, and cooperation among staff, which helps teachers overcome challenges collectively and share innovative practices. Such environments nurture continuous professional learning and provide emotional support, which are crucial for maintaining high motivation and reducing burnout. Moreover, supportive policies that provide teachers with autonomy, recognition, opportunities for growth, and manageable workloads contribute to sustained engagement and job satisfaction.

Conversely, schools with fragmented cultures, poor communication, and lack of shared vision often face high teacher turnover, decreased motivation, and compromised instructional quality (Fitria et al., 2021; Thien, 2023). This underlines the importance of structured leadership, participatory decision-making, and professional development initiatives targeted at cultivating a nurturing organizational culture.

Another key dimension is teacher professional development. Studies by Yildiz (2021) and Anderson-Mason (2023) reveal that reflective professional learning not only improves pedagogical skills but also reinforces teacher motivation by fostering a sense of agency and competence. Engagement in collaborative professional learning communities creates social support networks that buffer against burnout (Deci & Ryan, 2020).

Finally, the COVID-19 pandemic introduced new dimensions to the understanding of teacher motivation and engagement. Kumar et al. (2023) reported heightened levels of stress, workload, and emotional strain among teachers as they navigated abrupt shifts to remote and blended learning modalities. However, the study also emphasized that innovative digital training programs, continuous professional support, and strong peer collaboration played a critical role in sustaining teachers' motivation during the crisis. Access to adaptive technological tools, timely instructional guidance, and empathetic leadership enabled teachers to remain resilient and responsive despite unprecedented challenges. These findings

underscore the importance of flexible support systems and leadership practices in fostering teacher motivation and instructional effectiveness during times of disruption and beyond.

STATEMENT OF OBJECTIVES

The main purpose of the study was to assess teachers' engagement, motivation, and educational philosophy in enhancing instructional effectiveness of Dagohoy, Danao, San Miguel, and Trinidad (DADASANTRI) districts for school year 2025-2026.

Specifically, it sought to answer the following questions:

1. What is the profile of the respondent in terms of:
   1.1. age;
   1.2. sex;
   1.3. civil status;
   1.4. highest educational attainment; and
   1.5. length of service?
2. What is the level of teachers' engagement in teaching among basic education teachers in the respondent schools?
3. What is the level of teachers' motivation in teaching among basic education teachers in the respondent schools?
4. What is the extent of teachers' educational philosophy in enhancing instructional effectiveness in terms of their actual classroom practices?
5. Is there a significant association between teachers' profile and the level of:
   5.1 engagement in teaching;
   5.2 motivation in teaching; and
   5.3 educational philosophy in enhancing instructional effectiveness?
6. What action plan can be proposed to enhance instructional effectiveness?

RESEARCH METHODOLOGY

This study focused on the level of teachers' engagement, motivation, and educational philosophy in enhancing instructional effectiveness. The researcher used the descriptive-normative survey design wherein responses will use a 5-point Likert scale ranging from strongly disagree to strongly agree, allowing for measurement of the depth and nature of engagement. In studying engagement, motivation, and educational philosophy among elementary teachers, a descriptive-normative survey can assess current levels of teacher motivation and compare them to professional development standards or philosophical ideals, thereby providing actionable insights for improving instructional quality and teacher support systems.

A survey questionnaire served as the main instrument for gathering data for this study. The main goal was to collect quantitative data on teachers' engagement, motivation, and educational philosophy in enhancing instructional effectiveness. Descriptive statistics was used to analyze the collected data, providing insights into the role of teachers in instructional effectiveness. They include measures such as mean, median, mode, standard deviation, and percentages that describe the central tendency and variability of a dataset. These statistics provide a snapshot of the data without making predictions or drawing conclusions beyond what is observed.

Environment and Respondents. The study was conducted in the public elementary school of Dagohoy, Danao, San Miguel, and Trinidad (DADASANTRI) Districts of the Division of Bohol. The respondents of the study were the 105 public elementary teachers of Danao, 167 from Dagohoy, 158 from San Miguel, 185 from Trinidad I and II districts with a total of 615 respondents. Simple random sampling was employed resulting to a total of 240 respondents.

Instruments. The researcher used a modified survey questionnaire. Part I consisted the Profile of the Respondents in terms of age, sex, civil status, highest educational attainment, and years in teaching. Part II was the level of Teachers' Engagement taken from the study of Klassen et al. (2013) given the 5-point Likert-scale as follows: 5-Highly Engaged, 4-Engaged, 3-Neither Engaged nor Disengaged, 2-Minimally Engaged, and 1- Not Engaged at All. Part III was the Level of Motivation taken from the study of Canoso, (2024) with the following 5-point Likert scale: 5-Highly Motivated, 4-Motivated, 3-Neither Motivated nor Demotivated, 2-Minimally motivated, and 1-Not Motivated at All. Part IV was the Extent of Educational Philosophy tken from the study of Putri and Ena, (2025) with a 5-point Likert Scale as follows: 5-Highly Practiced, 4-Often Practiced, 3-Moderately Practiced, 2-Rarely Practiced, and 1-Not Practiced at All.

Data Gathering Procedures. Permission to carry out the study was secured from the Campus Director and the College Dean. Upon endorsement, the researcher will ask permission from the Schools Division Superintendent of Bohol to conduct the study in the public elementary and secondary schools of the three Congressional Districts of Bohol Division. After the approval to conduct the study, the researcher asked permission from the Public Schools District Supervisors of each district. Then, the researcher personally distributed and retrieved the survey-questionnaires to the respondents following the health and safety protocol duly implemented by DepEd so that if they have some queries the researcher could clear immediately their clouds of doubts. Furthermore, the researcher assured the respondents regarding the confidentiality of their responses and sincerely sought their utmost cooperation in honestly and objectively answering the survey questionnaire. The data gathered will be subjected to tabulation, treatment, analysis and interpretation purposes.

Statistical Treatment. The data was subjected to statistical treatment using simple percentage, frequency and weighted mean to analyze the gathered data. Simple percentage was used to quantify the frequency distribution of the respondents' profile in terms of age, sex, civil status, highest educational attainment, and length of service. Weighted mean was used to determine the level of engagement, motivation, and educational philosophies. Multiple regression was used to analyze the association between profile and other variables.

FINDINGS

Table 1 shows the profile of the teacher respondents. In terms of age, the largest proportion of respondents belongs to the 31–40 years old group (45.8%), indicating that most teachers are within the early to mid-career stage. In contrast, there are no respondents aged 61 years old and above (0%), making it the least represented age group. With regard to sex, the majority of respondents are female (94.6%), while male teachers account for only a small portion (5.4%). This reflects a strong dominance of females in the teaching profession. As to civil status, most of the respondents are married (95.4%), whereas only a few are single (4.6%). This suggests that the teaching workforce is largely composed of married individuals.

In terms of highest educational attainment, the highest proportion of respondents are Master's Degree graduates (56.7%), showing that many teachers have pursued advanced studies. On the other hand, there are no respondents who have completed a Ph.D. or Ed.D. degree (0%), which is the least represented category. Recent studies emphasize that teachers' demographic and professional profiles significantly influence teaching effectiveness and educational outcomes. According to Santos et al. (2024), variables such as length of service, educational attainment, and teaching experience are strong predictors of instructional competence. Their findings revealed that teachers with longer years of service tend to demonstrate better classroom management and pedagogical skills.

According to Commission on Audit (2024), there has been a decline in the number of public-school teachers in recent years, despite growing student populations. This situation underscores the need for improved teacher support systems and retention strategies. In addition, educational reforms and technological advancements continue to reshape the role of teachers. Dela Cruz (2026) emphasized that

teachers are now expected to integrate technology into instruction while adapting to updated curricula. However, these changes often increase workload and require continuous professional development.

Last, for length of service, the majority of respondents have been in service for 11–15 years (51.7%), indicating a relatively experienced group of teachers. Meanwhile, those with 16–20 years of service represent the smallest proportion (9.2%).

Table 1. Profile of the Teacher-Respondents
N=240

	Frequency	Percentage (%)
1.1 Age		
21– 30 years old	6	2.5
31 – 40 years old	110	45.8
41 – 50 years old	95	39.6
51 – 60 years old	29	12.1
61 years old and above	0	0
Total	240	100%
1.2. Sex		
Male	13	5.4
Female	227	94.6
Total	240	100%
1.3 Civil Status		
Single	11	4.6
Married	229	95.4
Total	240	100%
1.4 Highest Educational Attainment		
Bachelor Degree Holder	18	7.5
With units in Masters' Degree	23	9.6
Masters' Degree Graduate	136	56.7
With Ph. D./ Ed. D. units	63	26.3
Ph. D./ Ed. D. Graduate	0	0
Total	240	100%
1.5 Length of Service		
1-5 years	31	12.9
6-10 years	34	14.2
11-15 years	124	51.7
16-20 years	22	9.2
21 years & above	29	12.1

Table 2 illustrates the respondents' assessment on the level of teachers' engagement among basic education teachers which is generally high, as reflected in the average weighted mean of 4.13, interpreted as engaged. This indicates that teachers demonstrate a positive level of involvement in their teaching responsibilities.

In terms of the highest indicators, several statements obtained the highest weighted mean score of 4.87, interpreted as highly engaged and ranked 3rd. These include concern for colleagues' challenges, maintaining good connections with colleagues, and demonstrating empathy, awareness, and warmth toward students. This suggests that teachers exhibit very strong interpersonal engagement, particularly in terms of collaboration with colleagues and emotional responsiveness to students.

Table 2. Level of Teachers' Engagement in Teaching
N=240

Statement	WMS	DI
As a teacher, I…		
1. feel passionate about teaching.	4.13	E
2.am excited to teach.	4.48	E
3.experience happiness when teaching.	4.48	E
4.find teaching enjoyable.	4.48	E
5.value building strong relationships with my colleagues.	4.71	HE
6.am dedicated to supporting my colleagues at school.	4.71	HE
7.am concerned about the challenges my colleagues face at school.	4.87	HE
8.maintain good connections with my colleagues at school.	4.87	HE
9.focus closely on my work while teaching.	4.48	E
10.fully immerse myself in my work during teaching.	4.48	E
11.teach with great energy and intensity.	4.56	HE
12.put maximum effort into performing well when teaching.	4.48	E
13.am attentive to the problems my students experience in class.	4.71	HE
14.show empathy towards my students in class.	4.87	HE
15.am aware of how my students feel in class.	4.87	HE
16.express warmth and care towards my students in class.	4.87	HE
Average Weighted Mean	**4.63**	**Highly Engaged**

Legend:

Parameter	Interpretation
4.50-5.0	Highly Engaged (HE)
3.50-4.49	Engaged (E)
2.50-3.49	Neither engaged nor disengaged (ND)
1.50-2.49	Minimally Engaged (ME)
1.0-1.49	Not Engaged At All (NE)

The lowest indicator is "feel passionate about teaching," with a weighted mean of 4.13, interpreted as engaged and ranked 16th. This suggests that while teachers are generally engaged, passion for teaching is comparatively lower than other aspects of engagement. The findings indicate that teachers are highly engaged, particularly in interpersonal relationships and emotional involvement with students and colleagues, while slightly lower engagement is observed in personal enthusiasm and passion for teaching.

Table 3 displays the respondents' assessment on their level of motivation. The average weighted mean is 4.54, interpreted as highly motivated. This indicates that, as a group, teachers demonstrate strong motivation in performing their duties and responsibilities in the teaching profession.

Table 3. Level of Teachers' Motivation in Teaching
N=240

Statement	WMS	DI
As a teacher, I…		
1.feel enthusiastic and energized when preparing for my classes.	4.32	M
2.am motivated to continuously improve my teaching methods.	4.32	M
3.find personal fulfillment in helping students learn and grow.	4.48	M
4.actively seek professional development opportunities to enhance my teaching.	4.52	HM

5.remain committed to teaching even when faced with challenges or setbacks.	4.48	M
6.set personal goals to improve my effectiveness as an educator.	4.48	M
7.feel inspired when I see my students succeed academically and personally.	4.65	HM
8.believe my role as a teacher contributes meaningfully to society.	4.94	HM
9.am driven by a sense of purpose in my teaching profession.	4.38	M
10.take initiative to go beyond the lesson plan to make learning more engaging and relevant.	4.81	HM
Average Weighted Mean	**4.54**	

Legend:

Parameter	Interpretation
4.50-5.0	Highly Motivated (HM)
3.50-4.49	Motivated (M)
2.50-3.49	Neither Motivated nor Demotivated (NM)
1.50-2.49	Minimally Motivated (MM)
1.0-1.49	Not Motivated At All (NMAA)

In terms of the highest result, the statement "believe my role as a teacher contributes meaningfully to society" obtained the highest weighted mean score of 4.94, interpreted as highly motivated and ranked 1st. This suggests that teachers are strongly driven by the sense of purpose and significance of their profession, which serves as a major source of their motivation.

On the other hand, the lowest results are reflected in two statements: "feel enthusiastic and energized when preparing for my classes" and "am motivated to continuously improve my teaching methods," both with a weighted mean score of 4.32, interpreted as motivated and ranked 9.5. This indicates that while teachers are still motivated in these aspects, these areas represent relatively lower levels of motivation compared to other indicators.

The findings show that teachers' motivation is primarily rooted in their belief in the social value of teaching, while the lowest motivation levels are observed in aspects related to preparation energy and continuous improvement of teaching methods.

Then Table 4 summarizes the level of teachers' educational philosophy in enhancing instructional effectiveness. Under essentialism, the highest-rated statement is "teaching should prioritize accuracy and mastery of foundational content" with a weighted mean of 4.68, interpreted as very highly applied and ranked 1st. This indicates that teachers strongly emphasize mastery of basic knowledge and skills. The lowest-rated statement is "students should follow a structured learning path guided by the teacher" with a weighted mean of 4.04, interpreted as highly applied and ranked 5th, suggesting that while structure is valued, it is slightly less emphasized compared to mastery.

In progressivism, the highest-rated statement is "teachers should adapt lessons to students' interests and needs" with a weighted mean of 4.55, interpreted as very highly applied and ranked 6th. This shows that teachers value learner-centered approaches. The lowest-rated statements are "learning activities should be connected to students' real-life experiences" and "students should be encouraged to ask questions and explore concepts independently," both with a weighted mean of 4.17, interpreted as highly applied and ranked 9.5, indicating these are applied but to a lesser extent.

Table 4. Level of Teachers' Educational Philosophy in Enhancing Instructional Effectiveness N=240

Statement	WMS	DI
A. ESSENTIALISM (Focus on core knowledge and mastery of skills)		
1. Students should master core knowledge and basic skills before moving on to advanced topics.	4.32	OP
2. Teaching should prioritize accuracy and mastery of foundational content.	4.68	HP
3. Standardized curriculum content is essential for student success.	4.20	OP
4. Students should follow a structured learning path guided by the teacher.	4.04	OP
5. Teachers should focus on measurable learning outcomes first before exploring broader skills.	4.19	OP
Average Weighted Mean	**4.29**	
B. PROGRESSIVISM (Learner-centered, learning by doing, and problem-focused)		
6. Learning activities should be connected to students' real-life experiences.	4.17	OP
7. Students learn best through hands-on activities and active participation.	4.33	OP
8.Teachers should adapt lessons to students' interests and needs.	4.55	HP
9. Collaborative group activities are important for student learning.	4.50	HP
10. Students should be encouraged to ask questions and explore concepts independently.	4.17	OP
Average Weighted Mean	**4.34**	
C. CONSTRUCTIVISM (Knowledge is actively constructed; critical thinking emphasized)		
11. Students should actively construct knowledge through discussions and collaborative tasks.	4.00	OP
12. Teachers should guide students to discover solutions rather than provide all answers.	4.20	OP
13. Problem-solving and critical thinking should be central to classroom activities.	4.04	OP
14. Reflection and analysis should be encouraged for deeper understanding.	4.20	OP
15. Lessons should connect new knowledge to students' prior experiences and understanding.	4.35	OP
Average Weighted Mean	**4.16**	
D.RECONSTRUCTIONISM (Education as a tool for social awareness and change)		
16. Education should encourage students to become aware of social issues.	4.20	OP
17. Teachers should design lessons that help students actively contribute to improving society	4.35	OP
18. Developing social responsibility in students is as important as academic learning.	4.20	OP
19. Students should be encouraged to think critically about cultural and societal norms.	4.35	OP
20. Teachers should help students develop a sense of justice, equity, and civic responsibility.	4.20	OP
Average Weighted Mean	**4.26**	
E. INFORMATION PROCESSING (Focuses on how a person's mind function)		
21.Representing information as symbols in the mind is an important part of learning.	4.20	OP
22.Students, like computers, are information processers who must make sense of an object in their environment.	4.35	OP
23. The heart of understanding learning is concerned with how information is encoded, processed, remembered, and retrieved.	4.20	OP

24. Teaching involves the support of memory storage and retrieval.	4.06	OP
25. Students need to develop declarative, procedural, and conditional knowledge.	4.06	OP
Average Weighted Mean	**4.17**	
F. BEHAVIORISM (Behavior is the outcome of outside circumstances)		
26.Rewards controlled by the external environment lead to and result in all learning.	4.35	OP
27.Successful teaching creates and environment that controls student behavior and assesses learning of prescribed outcomes.	4.20	OP
28. The role of the teacher is to create an atmosphere that rewards desired behavior toward achieving goals and extinguishes undesirable behavior.	4.20	OP
29. Principles of reinforcement (anything that will increase the likelihood that an event will be repeated) and contiguity (how close two events must be chronologically bond to be created) are pivotal to explaining learning.	4.03	OP
30. One's behavior is shaped by one's environment; elements within that environment (rather than the individual learner) determine what is learned.	4.32	OP
Average Weighted Mean	**4.22**	
G. COGNITIVISM (Teachers mediate experiences and create favorable environment)		
31.Students are makers of meaning and construct their understandings from active experience, rather than through transmission from teachers.	4.35	OP
32. Teachers, rather than imparting knowledge are facilitators of conditions and experiences so students can construct their own understandings.	4.32	OP
33. Conflicts to current understandings trigger the need to learn and to make meaning.	4.17	OP
34. A knowledgeable individual facilitates or scaffolds learning for a novice based on understanding the learners' developmental level and the content to be learned.	4.20	OP
35.Learning requires modifying internal knowing structures in order to assimilate and accommodate new information.	4.48	OP
Average Weighted Mean	**4.30**	
H. HUMANISM (Becoming the best version of oneself by learning from the viewpoint of human growth potential)		
36. Education should emphasize personal growth through problem solving.	4.32	OP
37. If encouraging and nourishing environments are provided, learning will flourish naturally because people have and inherent tendency to learn.	4.48	OP
38. Students must learn to make good choices and to be responsible for their behavior.	4.32	OP
39. Transmitting traditional values is less important than helping students to develop personal values.	4.32	OP
40. The role of the teacher is help create a nurturing atmosphere for students and to promote the growth of the whole person	4.32	OP
Average Weighted Mean	**4.35**	**Often Practiced**

Legend:

Parameter		Interpretation
4.50-5.0	- Strongly Agree	Highly Practiced (HP)
3.50-4.49	-Agree	Often Practiced (OP)
2.50-3.49	-Neutral	Moderately Practiced (MP)
1.50-2.49	-Disagree	Rarely practiced (RP)
1.0-1.49	-Strongly Disagree	Not Practiced at All (NP)

For constructivism, the highest-rated statement is “lessons should connect new knowledge to students’ prior experiences and understanding” with a weighted mean of 4.35, interpreted as highly applied and ranked 11th. This suggests that teachers recognize the importance of linking prior knowledge to new learning. The lowest-rated statement is “students should actively construct knowledge through discussions and collaborative tasks” with a weighted mean of 4.00, interpreted as highly applied and ranked 14th, showing comparatively lower emphasis on active knowledge construction.

In reconstructionism, the highest-rated statements are “teachers should design lessons that help students actively contribute to improving society” and “students should be encouraged to think critically about cultural and societal norms,” both with a weighted mean of 4.35, interpreted as highly applied and ranked 1.5. This reflects a strong emphasis on social awareness and responsibility. The lowest-rated statements, each with a weighted mean of 4.20 and ranked 4th, include promoting awareness of social issues, developing social responsibility, and fostering justice and equity, indicating slightly lower but still high application.

Under information processing, the highest-rated statement is “students, like computers, are information processors who must make sense of an object in their environment” with a weighted mean of 4.35, interpreted as highly applied and ranked 1st. This suggests teachers value cognitive processing in learning. The lowest-rated statements are “teaching involves the support of memory storage and retrieval” and “students need to develop declarative, procedural, and conditional knowledge,” both with a weighted mean of 4.06 and ranked 4.5, reflecting relatively lower emphasis on these aspects.

For behaviorism, the highest-rated statement is “rewards controlled by the external environment lead to and result in all learning” with a weighted mean of 4.35, interpreted as highly applied and ranked 1st. This indicates that reinforcement is strongly recognized in teaching. The lowest-rated statement is “principles of reinforcement and contiguity are pivotal to explaining learning” with a weighted mean of 4.03 and ranked 5th, suggesting it is less emphasized compared to other behaviorist principles.

In cognitivism, the highest-rated statement is “learning requires modifying internal knowing structures in order to assimilate and accommodate new information” with a weighted mean of 4.48, interpreted as highly applied and ranked 1st. This reflects a strong recognition of mental processes in learning. The lowest-rated statement is “conflicts to current understandings trigger the need to learn and to make meaning” with a weighted mean of 4.17 and ranked 5th, indicating relatively lower emphasis.

Last, under humanism, the highest-rated statement is “if encouraging and nourishing environments are provided, learning will flourish naturally” with a weighted mean of 4.48, interpreted as highly applied and ranked 1st. This highlights the importance of a supportive learning environment. The lowest-rated statements, each with a weighted mean of 4.32 and ranked 3.5, include promoting personal growth, responsibility, value formation, and nurturing the whole person, indicating that these are applied but slightly less emphasized.

Overall, the findings show that teachers highly apply various educational philosophies, with stronger emphasis on mastery of content, learner-centered approaches, social responsibility, and supportive learning environments, while comparatively lower emphasis is observed in structured guidance, independent inquiry, and some technical aspects of learning theories.

The results of Table 5 provide the test of association between the teachers’ profile and their level of engagement. All predictors have a significance value of .000, indicating that each variable has a statistically significant association with the outcome.

Age shows a positive relationship with the dependent variable, as indicated by its unstandardized coefficient (B = 0.153) and standardized coefficient (Beta = 0.401). This suggests that as age increases, the dependent variable also tends to increase. The t-value of 6.325 confirms that age is a significant predictor.

Sex has a negative coefficient (B = -0.566; Beta = -0.463), indicating an inverse relationship with the dependent variable. This means that a change in sex category is associated with a decrease in the dependent variable. The t-value of -6.402 shows that this relationship is statistically significant.

Civil status demonstrates a positive relationship (B = 0.383; Beta = 0.290), suggesting that certain civil status categories are associated with higher values of the dependent variable. The t-value of 5.082 indicates that this predictor significantly contributes to the model.

Highest educational attainment has a positive coefficient (B = 0.225) and the highest standardized coefficient (Beta = 0.661), making it the strongest predictor among the variables. This indicates that higher educational attainment is strongly associated with an increase in the dependent variable. The t-value of 9.388 further confirms its significant and substantial effect.

Table 5. Test of Association Between the Teachers' Profile and the Level of Engagement
n = 240

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
1-age	.153	.024	.401	6.325	.000	Significant association
2-sex	-.566	.088	-.463	-6.402	.000	Significant association
3-civil status	.383	.075	.290	5.082	.000	Significant association
4-highest educational attainment	.225	.024	.661	9.388	.000	Significant association
5-length of service	-.139	.017	-.556	-8.071	.000	Significant association

**Significance is set at 0.05 level (2-tailed)*

Length of service shows a negative relationship (B = -0.139; Beta = -0.556), indicating that as length of service increases, the dependent variable tends to decrease. The t-value of -8.071 confirms that this inverse relationship is statistically significant.

Then Table 6 outlines the test of association between the teachers' profile and the level of motivation. Age has a positive unstandardized coefficient (B = 4.479) with a high t-value of 16.636 and a significance value of .000. This indicates that age has a strong and significant positive association with the dependent variable, suggesting that as age increases, the outcome variable also increases. Sex also shows a positive relationship (B = 0.267; Beta = 0.547) with a t-value of 9.049 and a significance value of .000. This implies that differences in sex are associated with variations in the dependent variable, and this relationship is statistically significant. Civil status, however, shows a negative coefficient (B = -0.758; Beta = -0.484) but has a significance value of .478, which is greater than the 0.05 level. This indicates that civil status does not have a statistically significant association with the dependent variable, despite the observed negative relationship.

Table 6. Test of Association Between the Teachers' Profile and the Level of Motivation
n = 240

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
Age	4.479	.269		16.636	.000	Significant association
Sex	.267	.029	.547	9.049	.000	Significant association
Civil status	-.758	.108	-.484	-7.014	.478	No Significant association
Educational Attainment	.185	.092	.109	2.007	.000	Significant association
Teaching Experience	.348	.029	.796	11.856	.000	Significant association

Educational attainment has a positive coefficient (B = 0.185; Beta = 0.109) with a t-value of 2.007 and a significance value of .000, indicating a significant positive relationship. This suggests that higher levels of educational attainment are associated with increases in the dependent variable, although its effect is relatively weaker compared to other predictors.

Teaching experience shows a positive relationship (B = 0.348; Beta = 0.796) with a high t-value of 11.856 and a significance value of .000. This indicates that teaching experience is a strong and significant predictor of the dependent variable and appears to have the strongest influence among all variables based on the standardized coefficient.

Overall, the results show that age, sex, educational attainment, and teaching experience significantly influence the dependent variable, while civil status does not. Among the predictors, teaching experience appears to have the strongest effect, followed by sex and age, while educational attainment has the least influence among the significant variables.

Table 7 presents the test of association between the teachers' profile and the level of philosophy applied in teachers' effectiveness. The results show that age, sex, educational attainment, and teaching experience are significant predictors of the dependent variable, while civil status is not. Among the predictors, teaching experience has the strongest influence based on the standardized coefficient, followed by educational attainment and age.

Table 7. Test of Association Between the Teachers' Profile and the Educational Philosophies
n = 240

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
Age	.249	.032	.543	7.821	.000	Significant association
Sex	-.481	.117	-.327	-4.125	.000	Significant association
Civil status	.071	.100	.044	.711	.478	No Significant association
Educational Attainment	.254	.032	.618	8.013	.000	Significant association
Teaching Experience	-.209	.023	-.696	-9.241	.000	Significant association

Age shows a positive relationship with the dependent variable (B = 0.249; Beta = 0.543) with a t-value of 7.821 and a significance value of .000. This indicates that age has a significant positive influence. Sex has a negative coefficient (B = -0.481; Beta = -0.327) with a t-value of -4.125 and a significance value of .000. This suggests a significant inverse relationship between sex and the dependent variable, indicating differences in outcomes depending on sex classification.

Civil status shows a very small positive coefficient (B = 0.071; Beta = 0.044) with a t-value of 0.711 and a significance value of .478. Since this is higher than the 0.05 level of significance, civil status is not a significant predictor of the dependent variable. This means that marital status does not meaningfully influence the outcome in this model.

Educational attainment has a positive coefficient (B = 0.254; Beta = 0.618) with a t-value of 8.013 and a significance value of .000. This indicates a significant positive relationship, suggesting that higher educational attainment leads to higher values of the dependent variable.

Teaching experience shows a negative relationship (B = -0.209; Beta = -0.696) with a t-value of -9.241 and a significance value of .000. This indicates that teaching experience significantly affects the dependent variable in an inverse direction, meaning that as teaching experience increases, the dependent variable decreases.

CONCLUSIONS

Based on the findings of the study, it can be concluded that the teachers demonstrate a high level of engagement in their professional responsibilities, particularly in terms of building positive relationships with colleagues and showing empathy, care, and concern for students. Although engagement is generally high, there are aspects such as personal passion and enthusiasm in teaching that are relatively lower compared to interpersonal dimensions.

Moreover, teacher engagement is characterized more strongly by relational and student-centered dimensions than by personal enthusiasm for teaching. This suggests that teachers are highly committed to fostering a supportive learning environment and maintaining positive professional interactions. Overall, the results reflect a workforce that is actively involved in its educational responsibilities, demonstrating dedication to both students and colleagues while maintaining a generally high level of professional engagement.

RECOMMENDATIONS

School administrators are encouraged to strengthen professional development programs that focus on enhancing teacher motivation, instructional effectiveness, and continuous improvement. Providing opportunities for advanced training, graduate studies, and instructional coaching will help sustain high levels of teacher performance. Administrators should also promote a supportive and collaborative school environment that fosters teacher engagement and well-being.

Teachers may actively participate in professional development activities and continuously improve their teaching strategies through reflection and innovation. They should strive to maintain high levels of enthusiasm and passion for teaching while consistently applying diverse educational philosophies in their instructional practices. Teachers are also encouraged to engage in peer collaboration and mentoring to further enhance their professional growth.

Learners are encouraged to actively participate in classroom activities and collaborate with their teachers in the learning process. They should also develop responsibility for their own learning by being engaged, curious, and open to various learning strategies provided by their teachers. Active learner participation will further strengthen the effectiveness of instructional practices.

Future researchers are encouraged to conduct similar studies with additional variables such as workload, school climate, leadership style, and technological integration to further explore factors affecting teacher effectiveness.

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DEVELOPMENT OF ENGLISH - SURIGAONON TRANSLATOR DEVICE FOR EVERYDAY COMMUNICATION

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ABSTRACT

This paper describes the implementation and testing of an English-Surigaonon translator, which is a pocketless device that enables daily interaction and helps protect the Surigaonon language, a low-resource, and endangered language in the Philippines. The researchers used an Agile approach to the development of a speech-to-speech translator into a handheld device based on the Raspberry Pi Zero 2W and a specific audio solution, such as an INMP441 microphone and a 5W speaker. The software architecture also uses a refined Helsinki-NLP/opus-mt translation model running on a cloud-based server to make it high-performance executed without impairing the portability of the device. The results of the evaluation show that the device is very functional and reliable. The hardware test showed that the average boot time was stable at 1 minute and 11 seconds and that the battery had a power level of more than four hours of idle mode. Linguistic accuracy of the English-to-Surigaonon model of translation had 82.45% success rate on 285 trials. Experts evaluated the performance efficiency of the device in accordance with the ISO /IEC 25010 standard, and the results were rated as Highly Valid. A user study with 30 Alternative Learning System (ALS) students specified the high perceived usefulness and ease of use of the system using the Technology Acceptance Model (TAM). The results conclude that the device is useful in reducing communication divides and offers a scalable technological framework in maintaining other low-resource Philippine languages, which also play an important role both in digital inclusion and preservation of cultures.

Keywords*: surigaonon language, machine translation, raspberry pi, language preservation, speech-to-speech translation*

INTRODUCTION

Language is the foundation of human interaction that can be both a means of communication and a medium of cultural identity and heritage. The Surigaonon language is a unique language resource of province Surigao del Norte and certain parts of North-Eastern Mindanao, with a distinct phonological system with seventeen consonants and three vowels (Dumanig, 2005). Nevertheless, Surigaonon is slowly being viewed as highly endangered with the drop in usage, even though it has a significant cultural importance (Ciruela et al., 2025). This trend shows that there is a pressing necessity of revitalization, maintenance, and cultivation (RMC) strategies to ensure that the language may continue to exist and be relevant (Coles, 2023).

Technology is a central component in the sphere of language maintenance. Low-resource languages such as Surigaonon do not usually have good technological support as major international languages do, which is supported by advanced translation systems. Despite any software-based solutions such as Android-based Surigaonon dictionaries and offline translators are available (Plaza et al., 2022), the abundance of specific hardware devices that are specifically designed to serve the major Philippine languages seems to

be a major gap (Aguilan et al., 2022). Recent sources point to the fact that though general AI translator devices do exist, they are not custom-made to local educational settings, including those of Alternative Learning System (ALS) students, who usually have barriers to education and predictable, methods of communication.

In a bid to solve these problems, this paper is dedicated to the design of English-Surigaonon Translator Device. In contrast to fully software-based solutions, the given project suggests a specific hardware implementation with the use of a Raspberry Pi Zero 2W that will be used to support real-time, speech-to-speech translation. This machine translator uses a rule-based machine translation (RBMT) algorithm, which entails an analysis, transfer, and generating process- a technique that has been effective in languages with clear grammar (RBMT, 2024). Other Philippine languages have also recorded the same success, like the creation of an English to Waray translator (Lewis and Pimentel, 2018).

This research will help bridge the communication gap between the English and Surigaonon speakers by combining modern speech recognition with a culture-centered translation model. Moreover, the creation of this device complies with the global standards of software quality, including ISO/IEC 25010, which guarantees the functional suitability and resilience (Britton,Obed, 2025), as well as taking into consideration the acceptance of the users to make the technology practical to the audience6. Finally, this study is aimed at empowering the Surigaonon people and leading to the larger cause of the linguistic conservation in the Caraga region.

OBJECTIVES

This study addresses the decline of the Surigaonon language and the lack of tools that support its use. It focuses on creating a device that offers real-time English Surigaonon speech translation to help learners and preserve the language.

General Objective

To build an English-Surigaonon translator device that provides real time speech to speech translation for everyday conversational tasks.

Specific Objective

1. To develop translator device and test its functionality.
2. To evaluate the device translation in terms of accuracy, reliability, and efficiency.
3. To evaluate the translator device's user acceptance using the TAM Model.

METHODOLOGY

The study follows a development-based research approach, combining machine fine-tuning and a quantitative user acceptance study. To ensure a systematic and iterative process, the methodology follows the Agile development cycle, which guides the designing, implementation, evaluation, and improvement stages of the device.

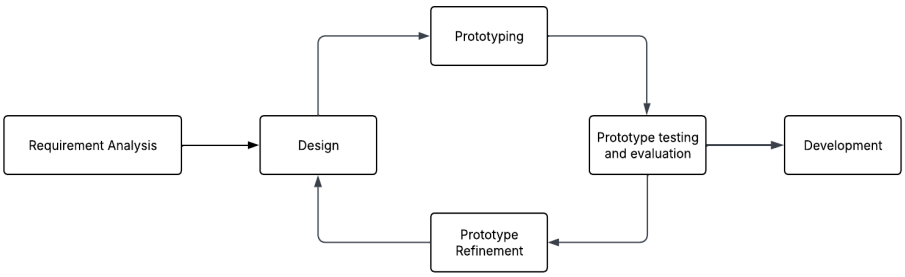

Fig 1. Agile Development cycle

System Design and Implementation

The block diagram of the translator device is shown in figure 2 which depicts the structure of the device and the path of the signals. There are input, processing and output modules in the system. Speech and user commands are picked up via the microphone and push button, and the Raspberry Pi Zero 2W is the primary processing hardware, running on a UPS Lite module. The device communicates securely using client-server design with a Python Flask server running on a Digital Ocean droplet, and the translation models are finely tuned by the server to encode a source language input and translate the output. The text is then translated into speech and played with the MAX98357A amplifier and 5V speaker. Overall, it's a suitable design for an embedded, real-time machine translation device.

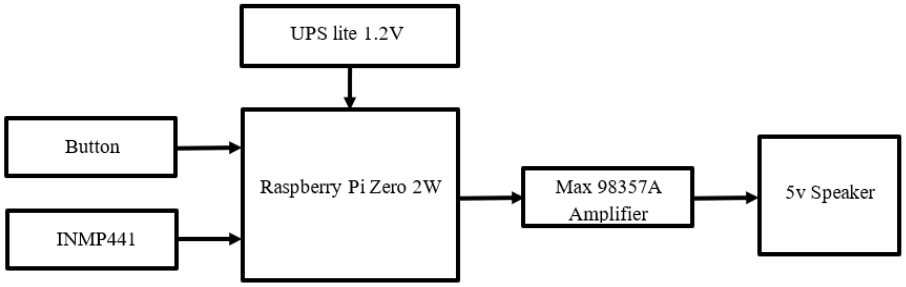

Fig 2. The Block Diagram of the English-Surigaonon Translator Device

The English-to-Surigaonon translator device's hardware electronic components are shown to be interconnected in the figure 3. This is powered by the Raspberry Pi Zero 2W. The GPIO of the Raspberry Pi Zero W is used to connect the input button, INMP441 microphone and Max 98357A amplifier with the 5W speaker. The UPS Lite 1.2V is mounted on the rear of the Raspberry Pi Zero 2W, and supplies the primary 5V power to the Pi board and other electronic components of the device.

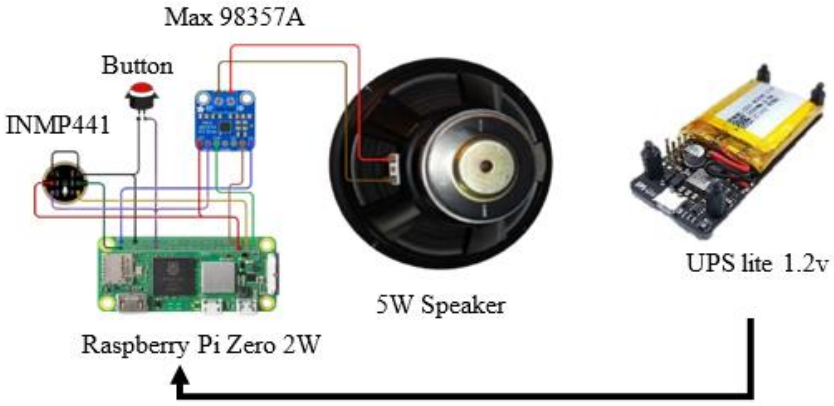

Fig 3. Hardware Components Connection Structure

The system architecture of the English-to-Surigaonon translator device delineates a clear separation between user interaction and computational processing. User speech is captured via the microphone and converted into text through speech-to-text transcription, which is transmitted to a central server. The server forwards the transcribed input to fine-tuned cloud-hosted machine translation models, which generate the corresponding target language output. The translated text is then relayed back to the device, where text-to-speech synthesis converts it into audible output through the speaker. This architecture minimizes on-device processing, enables seamless updates to translation models, and supports efficient, real-time speech-to-speech translation.

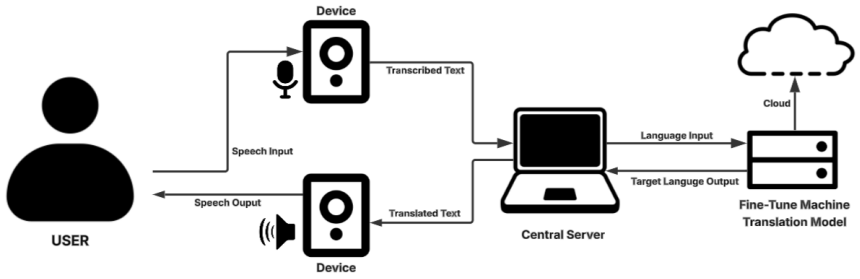

Fig 4. System Architecture of the English-Surigaonon Translator Device

The working process of English to Surigaonon translator device is shown in Figure 5. After turning it on, it creates a Wi-Fi connection which is succeeded by a sound message. It then switches into a monitoring state, where it monitors user button presses to determine what translation mode to use: pressing once for Surigaonon to English translation, pressing twice for English to Surigaonon translation. It works in a "push to talk" mode, recording audio when the button is depressed and stopping when it is released, then transcribing, translating then synthesizing speech into audible output. The system is designed in such a way that it is an infinite operational loop, and it can be repeatedly run in conversation until manually powered off or until the battery runs out.

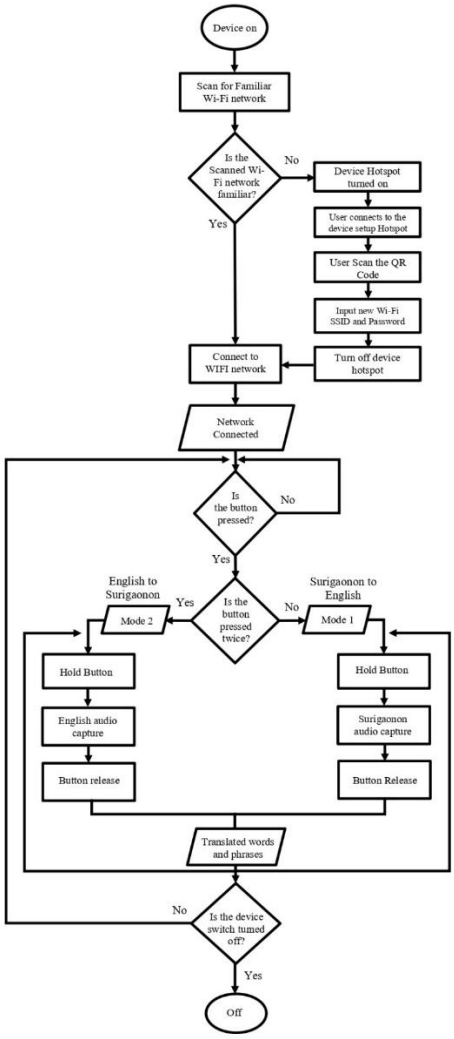

Fig 5. Flowchart of the English–Surigaonon Translator Device

The training of the English-to-Surigaonon translation model is done using fine tuning as shown in figure 6.

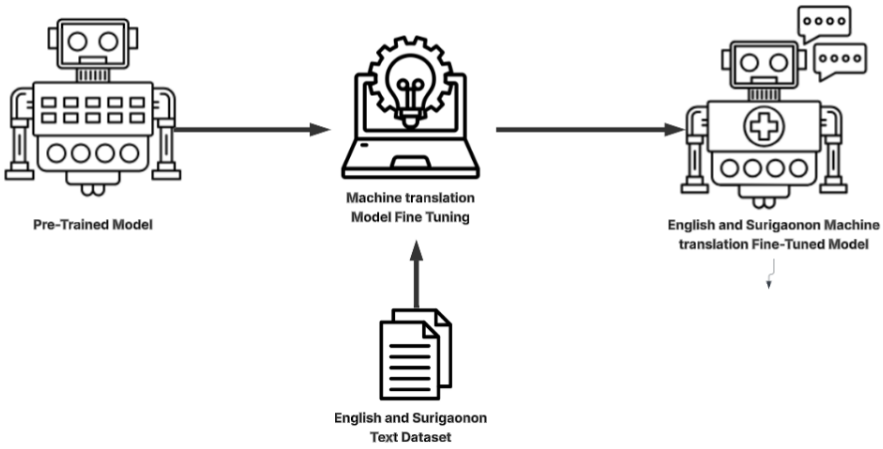

Fig 6. The Process of Fine-Tuning the Translation Model

The process begins with the collection of pairs of English and Surigaonon texts for the data set. The dataset was then verified by a linguistics expert. Next is selecting a pre-trained model suitable for a low-resourced language. The researchers utilized the Helsinki-NLP/opus-mt multilingual pre-trained model from the Hugging Face open-source model community.

	A	B	C	D	E
1	English	Surigaonon			
2	is it done	hapit naba matapos			
3	that was in the past	kadugay na adto			
4	who's with you	simay iban mo			
5	are you with them	nag iban ba kamo			
6	do you know them	kakilaya ba kaw sa ila			
7	are you familiar with them	may na kilay an ba kaw sa ila			
8	how much is the fare	pila man an bayad sa pamasahe			
9	long time no see	dugay na ta waya magkita			
10	it is nice to meet you	nalipay ako na makilaya kaw			
11	where have you been	diin kaw gikan			
12	what is your work	uno may imo trabaho			
13	where are you going	hain kaw pasingod			
14	i am busy	hamok ako tagtrabaho			
15	i am free	bakante ako			
16	do you have time	may oras kaw			
17	can we talk	pwede ta mag-estoryahay			
18	i have a problem	may problema ako			
19	can you repeat that for me	palihog pa utro gani adto			

Fig 7. English and Surigaonon Text Dataset Gathering

The English and Surigaonon text pairs Excel file is first cleaned through a Python script in the Google Colab environment. The empty cells in the Excel file are deleted, and the white spaces within the cells are stripped. The dataset is then labeled with English and Surigaonon headers. The validated dataset of 1424 word and sentence pairs is tokenized, then split into an 80:20 data frame. A total of 1139 dataset pairs were prepared for training, and 285 dataset pairs were prepared for testing.

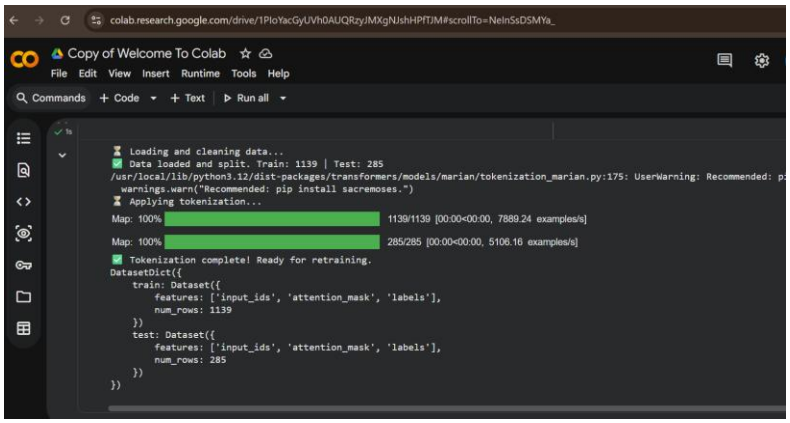

Fig 8. Dataset Cleaning, Tokenization, and Splitting

Next, the loading of the Helsinki-NLP model from the Hugging Face platform into Google Colab for the fine-tuning process. After successfully importing the model and tokenizing the datasets, the fine-tuning process is commenced.

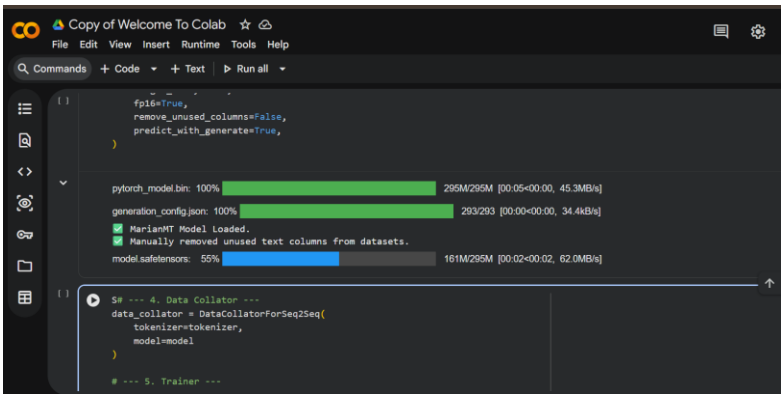

Fig 9. Pre-trained Machine Translation Model Mounting

Next, the loading of the Helsinki-NLP model from the Hugging Face platform into Google Colab for the fine-tuning process. After successfully importing the model and tokenizing the datasets, the fine-tuning process is commenced. On the completion of the 60-epoch training process, the model folder is directly saved into the Google Drive. The model is now available to be used and evaluated.

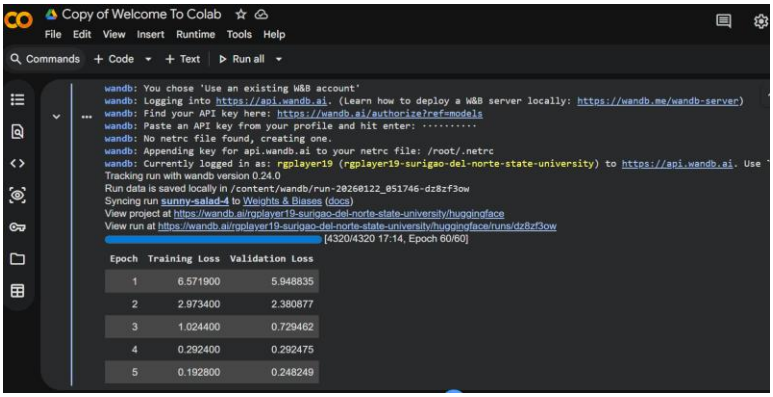

Fig 10. Machine Translation Model Fine-tuning Training

Data Gathering Procedures

The researchers used several reliable sources such as online written materials, local news articles, stories, blogs and cultural websites in Surigaonon language. Academic references such as dictionaries, language guides, textbooks and glossaries. The text pairs that have been collected are then saved as an Excel file.

Table 1. Dataset Counts for Validation, Revision, Training, and Testing

Dataset Count Table				
Collected	Validated	Revised	Trained	Tested
1424	1355	69	1139	285

To acquire accurate translation, a set of 1,424 text pairs between English and Surigaonon were collected and manually annotated. These pairs were individually checked by a Linguist Expert from Agusan del Sur State College of Agriculture and Technology for translation accuracy. Sixty-nine pairs of data were identified as being in error and needed to be revised during validation. After all the 1,139 pairs were cleaned and tokenized, the validated dataset was divided into 80% for training and 20% for testing. The following were used to fine-tune a pre-trained machine translation model in Google Colab environment, then trained and evaluated.

After the training, the fine-tuned translation model was stored on Google Drive. It was tested with the automated metrics such as BLEU, Translation Edit Rate (TER), and METEOR, which measure the accuracy, efficiency, and reliability of performance. To validate the translation performance of the model in terms of accuracy, reliability and operational efficiency, a test involving 20% of the data set (285 text pairs) was conducted.

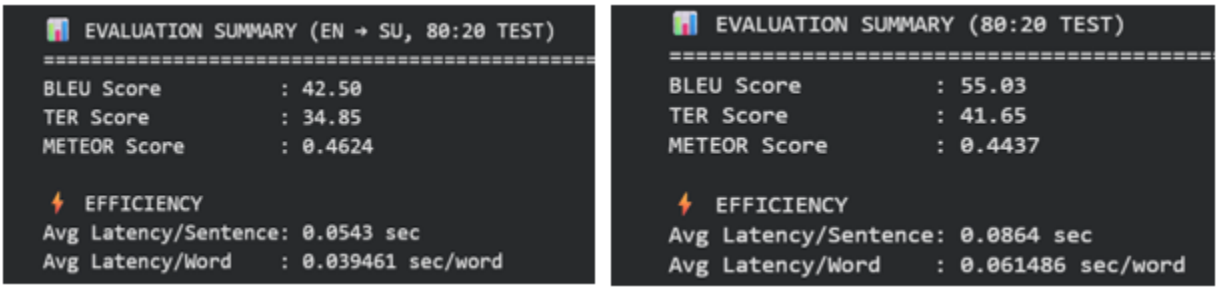

Fig 11. English - Surigaonon Model Automated Metric Testing

The device translation evaluation was not limited to automated metrics but also includes human validation assessments conducted by a linguist expert and an English professor. This human device translation evaluation guarantees the cultural appropriateness, linguistic correctness, and contextual suitability of the outputs of the device. The functionality of the hardware was manually tested, measuring the quality of translation, the clarity of speech, the sensitivity of the microphone in open and noisy environments, and the performance of buttons, switches and power ports. The battery lifespan and the processes of the systems were measured in a controlled experiment and a stopwatch was used. The evaluation of the user acceptance was carried out by conducting a survey of the students of the Alternative Learning System (ALS) which focused on perceived usefulness for language comprehension and ease of the device operation.

FINDINGS

This section presents and discusses the results obtained from the design, implementation, and evaluation of the Development of English - Surigaonon Translator device for Everyday Communication. The discussion is organized according to the specific objectives of the study, focusing on the Device hardware functionality, to assess the accuracy, reliability, and efficiency of the translator device translation.

Fig 12. The English-Surigaonon Translator Device

The figure above shows the Prototype model of the English to Surigaonon translator device capable of conducting speech to speech translation. The device can translate English to Surigaonon words and phrases and vice versa.

Fig 13. The Translator Device Speaker

The device speaker functions as the main output component of the translator device. It delivers the machine-translated words “Surigaonon” and “English speech” to the user. The clarity and loudness of the speech output of the speaker is found to be sufficient for a close-range, face-to-face communication.

Fig 14. The Translator Device Microphone

The microphone serves as the main input interface of the translator device and enables the translator device to capture the speech inputs of the user. Based on several experimental usages, the translator device microphone can provide stable and consistent speech transcription for actual conversation. Though the microphone can be reliable in transcribing the speech input, it is important to note that low-voice speech, fast speech, and accents can lead to poor audio capture that results in significant degradation of translation outputs.

Fig 15. The Translator Device Button

The device button serves as the primary control interface, enhancing user experience through mode selection and a push-to-talk paradigm. A single tap activates Mode 1, which translates Surigaonon speech into English, while two consecutive taps activate Mode 2 for English-to-Surigaonon translation. Users press and hold the button to record speech input, releasing it to register the captured audio for translation.

Fig 16 The Translator Device Slide Power Button

The device power button is located at the lower left corner of the device. The power button acts as the main power control. This controls the device activation and system reboot setup; the power button also provides the intuitive startup process for the operation of the device.

Fig 17. The Translator Device Charging Port

The charging port is located at the lower right corner of the translator device. It serves as the device's power interface; this enables the battery to be charged.

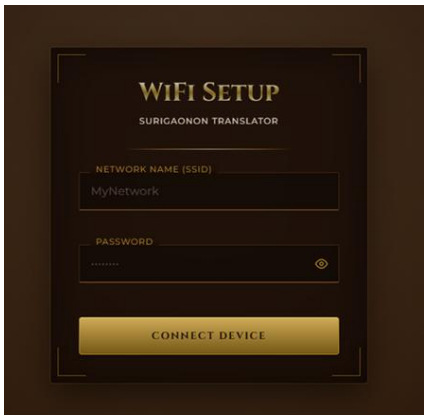

Fig 18. The translator Device Wi-Fi Registration Webpage

After successfully connecting to the translator device setup hotspot and scanning the device QR code, the user is redirected to this webpage, where they will input the Wi-Fi SSID and password of the Wi-Fi network that is new and unfamiliar for the device.

Table 2. Functional Suitability Validator Evaluation Results

1. Functional Suitability	**Mean Rating**	**Verbal Interpretation**
1.1. Accurately translate words	4.00	Valid
1.2. Accurately translate sentences	3.50	Valid
1.3. Produces grammatically correct translations in English to Surigaonon	4.00	Valid
1.4. Produces grammatically correct translations in Surigaonon to English	3.50	Valid
AVERAGE	**3.75**	**Valid**

The system's functional suitability according to ISO/IEC 25010 expert validation is displayed in table 2. The overall mean score is 3.75 (Valid) which shows that the device can be used to translate English and Surigaonon words with certainty. The word level accuracy was high (4.00, Valid), and sentence level translation was slightly lower (3.50, Valid) with some minor structural and semantic errors. English to Surigaonon translation (4.00) obtained correct local grammar and syntax, while Surigaonon to English translation (3.50) made some minor grammatical deviations. All the indicators are in the Valid range, showing that the system is reliable and can be improved on sentence-level correctness and on Surigaonon-English grammar by training and optimization of the models.

Table 3. The Device English to Surigaonon Translation Test Results

Accuracy Test Results	
No. of Translation Trials	285
No. of Correct Translations	235
Percentage	**82.45 %**

Table 3 demonstrates that the accuracy of the prototype device was 82.45% (235/285) when it was tested for its English to Surigaonon translation accuracy. This shows the effectiveness of the system in generating suitable words and structures especially for a low-resource language such as Surigaonon. A few errors were noted, such as some errors of translation, implying the need for more training data and better

word usage. In summary, the findings indicate the credibility of the device and suggest opportunities for further improvements.

Table 4. The Device Surigaonon to English Translation Test Results

Accuracy Test Results	
No. of Translation Trials	285
No. of Correct Translations	206
Percentage	**72.28 %**

Table 4 presents the Surigaonon-to-English translation accuracy of the prototype device, with 206 out of 285 translations correct, yielding 72.28% accuracy. The results indicate that the system can produce correct translations in most cases, reflecting its capability to handle vocabulary and grammatical mapping for this low-resource language. Some translation errors remain, suggesting that expanding training data, improving contextual processing, and enhancing linguistic coverage could further increase accuracy. Overall, the findings confirm the prototype's effectiveness and its potential for further improvement.

Table 5. English to Surigaonon Model Automated Metric Quality Evaluation Results

Quality Evaluation Results	
Metric	**Scores**
METEOR	0.46
BLEU	42.50
TER	34.85

Table 5 presents automated metric evaluations of the English-to-Surigaonon translation model using METEOR, BLEU, and TER. The METEOR score of 0.46 indicates mixed quality, while the BLEU score of 42.50 and TER score of 34.85 reflect high-quality translations that are mostly understandable, requiring minimal edits to achieve human-like accuracy.

Table 6. Surigaonon to English Model Automated Metric Quality Evaluation Results

Quality Evaluation Results	
Metric	**Scores**
METEOR	0.44
BLEU	55.03
TER	41.65

The Surigaonon to English translation model was evaluated by METEOR, BLEU and TER scores. A METEOR score of 0.44 corresponds to a mixed quality translation, a BLEU score of 55.03 represents a good performance with some awkward phrasing and possible minor errors, and a TER score of 41.65 indicates a fairly good quality translation, although it should be checked if it is to be used in order to reach a near-human level.

Table 7. The Device Charging Time and Usage Duration

Charging Time and Usage Duration Table			
Test No.	Full Charge	Idle Usage Time	Maximum Usage Time
1	2:36:42 hours	4:01:13 hours	3:16:23 hours
2	2:37:27 hours	4:03:53 hours	3:20:51 hours
3	2:35:24 hours	3:55:59 hours	3:13:17 hours
Average	**2:36:31 hours**	**4:00:21 hours**	**3:16:08 hours**

The Translator device charging and usage results are shown in Table 7 for three experimental repetitions. The device was charged for about 2 hours 36 minutes on average. The standby time was about 4 hours, and the maximum continuous working time was 3 hours 16 minutes on average. The findings show predictable charging and stable power consumption in both sleep and active modes of operation.

Table 8. User Perceived Usefulness Survey Results

Usefulness	M	SD	VI
1.1. The Surigaonon–English translator device helps me communicate better with other people.	3.80	0.40	SA
1.2. The device helps me understand Surigaonon or English more clearly.	3.67	0.47	SA
1.3. Using the device makes translation faster.	3.47	0.50	SA
1.4. The device can be useful in my daily activities.	3.47	0.50	SA
1.5. Overall, the Surigaonon-English translator device is useful to me.	3.53	0.56	SA
AVERAGE	**3.59**	**0.49**	**SA**

Table 8 shows how beneficial the respondents think the English-to-Surigaonon translator device is. With a positively skewed mean score of 3.59 (Strongly Agree), it can be interpreted that the users were satisfied with the communicative practicality of the device. The best rated item, "the translator device enables me to communicate more effectively with other people" (3.80), highlights its practical utility in communication. Users also strongly agreed that it makes understanding the two languages clearer (3.67), that it makes translation faster (3.47), and that they can use it on their daily life (3.47). In general, respondents consider the device to be a good and useful translator.

CONCLUSION

The study concludes that using dedicated hardware technology offers a viable solution to preserving low-resource languages. The study demonstrates that by bringing together technological advancement and cultural need, handheld technology can be used to promote digital linguistic inclusion for the Surigaonon community.

- The study shows that a dedicated hardware handheld translator is a viable and a practical approach to support underserved languages such as Surigaonon. As the software equivalent in portable form, the device meets the communication needs of the local community and students, demonstrating the applicability and value in real-life situations.
- The study shows how single-board computers (Raspberry Pi) and fine-tuned translation models work together to produce a robust communication device that strikes a balance between speech recognition and language transfer.
- It is crucial to follow international software quality standards (ISO/IEC 25010) and user acceptance models (TAM) to ensure that local innovations in technology are technically and socially accepted.
- The study provides a scalable model that can be used to support other endangered or low-resourced languages in the Philippines, helping to achieve the larger goal of cultural preservation and digital inclusion.

RECOMMENDATION

Based on the findings of this study, the following recommendations are made to improve the effectiveness of the English to Surigaonon translator device:

- Support additional Surigaonon phrases, idioms, expressions, and jargons so that it enables the trained model to learn deeper and broader vocabulary.
- Integrate a LCD display to visualize the process of transcription of the captured speech input, translation process, and synthesized translated transcripts.
- Enhance the hardware of the system so that it won't rely on the internet and to make it fully offline translator device.

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KNOWLEDGE, PRACTICES, AND CHALLENGES ON FINANCIAL LITERACY AMONG PUBLIC ELEMENTARY SCHOOL TEACHERS

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ABSTRACT

This study examined the financial literacy, practices, and challenges of 300 public elementary school teachers from Pres. CPG, Ubay I, II, III, and Bien Unido districts during the 2025–2026 school year. Using a descriptive-correlational design, data were collected through a structured questionnaire and analyzed using statistical tools such as frequency, percentage, weighted mean, correlation, and regression analysis. Results showed that most respondents were middle-aged, female, married, and held master's degrees, with moderate teaching experience and mid-range monthly income. Teachers demonstrated a high level of financial literacy, particularly in understanding basic concepts like interest rates, budgeting, and savings. They also showed positive financial practices, especially in investing and maintaining financial awareness. However, seeking professional financial advice was the least practiced behavior. Despite strong knowledge and generally positive practices, teachers faced significant financial challenges. These included difficulties in budgeting, managing monthly expenses, and planning finances before payday, indicating a gap between knowledge and actual financial behavior. Inferential analysis revealed that net monthly income and teaching position significantly influenced financial literacy outcomes, while other demographic factors such as age, sex, civil status, educational attainment, and teaching experience did not. However, the overall regression model was not statistically significant, suggesting limited predictive power of these variables. The study concludes that while teachers are financially knowledgeable, they struggle to consistently apply this knowledge in daily financial management. It recommends strengthening financial literacy programs, counseling services, and institutional support to improve teachers' financial well-being.

Keywords*: knowledge, practices, challenges, financial literacy, public elementary school teachers*

INTRODUCTION

Financial literacy has emerged as a critical life skill globally. The World Bank emphasizes that financial literacy empowers individuals to make informed decisions, manage debt, and invest wisely. However, many professionals, including educators, struggle with basic financial concepts such as budgeting, compound interest, and investment diversification. Teachers, despite their pivotal role in shaping future generations, often face financial stress due to stagnant wages, limited financial education, and rising living costs. Globally, educators are increasingly turning to credit and loans to supplement income.

In the Philippines, financial literacy among public school teachers remains a pressing concern. Despite government efforts like the Bangko Sentral ng Pilipinas' (BSP) financial education programs, many teachers continue to grapple with debt and poor investment habits. A 2019 report revealed that public school

teachers owed over ₱319 billion in loans, a figure that has likely grown due to inflation and economic disruptions (National Trade Union Center of the Philippines, 2019). Teachers often resort to borrowing from private lenders with high interest rates, exacerbating their financial instability. While some educators demonstrate strong willpower to repay debts, others struggle with loan addiction and lack access to financial counseling (Doroy, 2025). The Department of Education has acknowledged these challenges and has partnered with financial institutions to offer seminars, yet implementation remains uneven across regions.

Across Central Visayas with Bohol as one of the provinces, the financial challenges faced by teachers mirror national trends but are intensified by regional economic disparities. Many educators in rural areas have limited access to formal banking services and financial education programs. Studies show that while teachers possess basic financial literacy, they lack deeper understanding of risk, return, and investment strategies. Credit card usage and informal lending practices are common, pointing to gaps in budgeting and long-term planning. Teachers often prioritize immediate financial needs over savings and investments, leading to cyclical debt. The regional education offices have initiated financial wellness programs, but coverage and impact remain limited (Maribao, & Narido, 2025).

Within Bohol, public school teachers face unique financial challenges shaped by local economic conditions. The province's tourism-driven economy offers seasonal income opportunities, but teachers largely depend on fixed government salaries. Many educators in Bohol engage in multiple loans to support family needs, education expenses, and emergencies. Bohol's socio-economic context has left many teachers vulnerable to debt cycles. These scenarios prompted the researcher to assess the level of financial literacy, debt management and investment practices gaps of teachers and propose actionable interventions.

Financial Literacy theory is conceptualized as a form of human capital investment wherein acquiring financial knowledge equips individuals with the ability to make sound, well-informed decisions concerning their financial resources. This perspective is fundamental because it shows how financial education is not merely about accumulating facts but for an effective resource management and enhanced economic welfare. By understanding financial concepts such as budgeting, saving, debt management, and investing individuals can improve their financial stability and avoid common pitfalls that lead to economic hardship (Lusardi & Mitchell, 2014).

The Republic Act No. 10922, also known as the Economic and Financial Literacy Act of 2016, institutionalizes the promotion of financial literacy as a national priority in the Philippines. This law mandates the declaration of the second week of November every year as Economic and Financial Literacy Week, during which government agencies including the Department of Education are tasked to implement activities aimed at enhancing Filipinos understanding of economic and financial concepts.

Financial literacy has been increasingly recognized as a critical factor impacting the financial stability and overall well-being of public-school teachers in the Philippines, a connection that is well-documented in recent studies. Fausto (2025) explored the relationship between financial literacy and work-life balance among public school teachers, revealing that many educators depend heavily on loans and exhibit limited financial planning capabilities. These conditions negatively influence both their personal well-being and professional effectiveness, underscoring the vital role financial literacy plays in reducing debt burdens and improving teachers' quality of life.

Complementing this, Casingal (2021) examined the financial literacy challenges faced by Filipino public-school teachers, highlighting that informal borrowing and financial stress are widespread among educators. This study points to a pressing need for targeted financial literacy programs, aligning with the current research's goal of enhancing financial management practices among teachers to help them transition from debt dependency to financial stability. In an investigation on the financial well-being of teachers in Calamba City, Roxas (2024) established a significant positive correlation between financial literacy and teachers' financial well-being. The study revealed that teachers with higher financial knowledge and attitudes demonstrated better resilience in meeting financial commitments, reinforcing the present study's focus on literacy and investment as key drivers of financial health.

Supporting these findings, Imelda et al. (2023) documented high levels of debt and poor financial decisions among senior high school teachers due to financial illiteracy. Their work advocates for the integration of practical financial education within professional development programs, which aligns

directly with this study's emphasis on equipping teachers with necessary financial skills to make informed decisions. The importance of financial attitudes and savings behavior is further evidenced by Vidal-Sarahina (2025), who found that DepEd teachers with better financial knowledge exhibit improved saving and investment behaviors. This study directly informs the current research's concern with investment strategies among teachers, indicating that enhanced literacy fosters smarter financial choices.

Exploring the actual financial practices of public elementary teachers in Bukidnon, Maribao (2025) emphasized the need for continuous financial education to strengthen teachers' debt management and financial stability. These findings highlight the crucial role ongoing education plays in sustaining financial security, echoing the present study's objectives. At an institutional level, the Bangko Sentral ng Pilipinas (2023) demonstrated the positive outcomes of financial education programs particularly geared toward budgeting and saving, confirming the effectiveness of such practical interventions in reducing financial stress among public school teachers. This finding reinforces the critical relevance of practical literacy programs as proposed in this research.

Finally, this shows the beneficial impact of financial empowerment programs for public servants, affirming the institutional relevance of promoting financial literacy and management among teachers within the researcher's target locale. This institutional relevance implies that improving the financial literacy of teachers is not only an individual benefit but also a broader organizational goal that can lead to increased productivity, reduced financial stress, and improved job performance among educators. As public servants, teacher financial stability directly affects their quality of life and professional effectiveness, validating the focus of this study.

Taken together, these perspectives underscore that financial literacy among public school teachers is a multidimensional concern that extends beyond knowledge acquisition to include behavioral, psychological, and value-oriented dimensions. The convergence of global and local studies affirms that enhancing teachers' financial literacy is vital for improving financial practices, mitigating debt-related challenges, and promoting long-term financial well-being. By recognizing the interplay of financial education, emotional resilience, and personal values, the present study is positioned to contribute meaningful insights toward the development of comprehensive and sustainable financial literacy interventions tailored to the lived experiences of public elementary school teachers.

OBJECTIVES

This study aimed to determine the relationship between the level of knowledge, practices, and challenges on financial literacy among public elementary school teachers in Pres. CPG, Ubay I, Ubay II, Ubay III, and Bien Unido (CUB) Sub-Congressional District during the school year 2025-2026.

Specifically, it sought to answer the following questions:

1. What is the profile of the respondents in terms of:
   1.1 age;
   1.2 sex;
   1.3 civil status;
   1.4 highest educational attainment;
   1.5 years in teaching;
   1.6 monthly net income; and
   1.7 teaching position?
2. What is the level of knowledge on financial literacy among public school teacher respondents?
3. What is the level of practices on financial literacy employed by public school teacher respondents?
4. What is the level of challenges on financial literacy met by the public elementary school teachers?
5. Is there a significant association between the respondents' demographic profile and the level of:
   5.1. knowledge on financial literacy;
   5.2. practices on financial literacy; and
   5.3. challenges on financial literacy?

6. What plan of action can be proposed to enhance the teachers' financial literacy?

RESEARCH METHODOLOGY

This study focused on determining the level of knowledge, practices, and challenges on financial literacy among public elementary school teachers in Pres. CPG, Ubay I, Ubay II, Ubay III, and Bien Unido (CUB) Sub-Congressional District, Bohol Division. The quantitative method allowed the collection of measurable and statistically analyzable data regarding the financial knowledge, practices, and challenge of the participants. The researcher used the descriptive-normative survey questionnaire to gather data needed in the study and to generate the information relevant to what was asked in the statement of the problem.

Environment and Respondents. The study was conducted in the public elementary schools within the CPG, Ubay I, Ubay II, Ubay III, and Bien Unido Sub-Congressional District of the Division of Bohol. President Carlos P. Garcia is an island municipality located in the northeastern part of the province, known for its fishing industry and coastal resources. Ubay is situated on the Northeastern coast of Bohol and is considered one of the largest municipalities in the province in terms of land area and population. It serves as a key commercial and agricultural hub as major sources of livelihood. Meanwhile Bien Unido is located in the Northernmost part of Bohol, accessible via land through a causeway connecting it to the municipality of Trinidad. It is coastal area known for its rich marine resources and fishing industry. The respondents of the study broken down as follows: 187 teachers of Pres CPG district, 257 from Ubay I, 223 form Ubay II, 285 from Ubay III, and 218 from Bien Unido district, with a total of 1,170 respondents. Three hundred (300) respondents were randomly selected.

Instruments. The researcher used a descriptive survey questionnaire categorized into five parts. Part I:Demographic Profile of the teacher respondents in terms of age, sex, civil status, highest educational attainment, years in the service, monthly net income, and teaching position; Part II: Level of Knowledge on Financial Literacy, with a scale of 5- Very High Level of Knowledge, 4-High Level of Knowledge, 3-Moderate Level of Knowledge, 2-Low Level of Knowledge, and 1- Very Low Level of Knowledge; Part III: Level of Practices on Financial Literacy with corresponding equivalent of 5,4,3,2,1 to the different description as follows: 4.21-5.00-Very High Level of Practice, 3.41-4.20-High Level of Practice, 2.61-3.40-Moderate Level of Practice, 1.81-2.60- Low Level of Practice, and 1.00-1.80- Very Low Level of Practice. Both Part II and Part III were adapted from the study of Maribao & Narido, PhD (2025),

Part IV: Level of Challenges on Financial Literacy was adapted from internationally recognized instruments and frameworks on financial literacy and capability (OECD/INFE, 2018; Lusardi & Mitchell, 2014; Atkinson & Messy, 2012). The items were structured to reflect key domains of financial management, income management, saving and emergency funds, debt and credit management, investment and financial planning, and financial knowledge and decision-making consistent with the literature on financial behavior and literacy measurement (Huston, 2010; Remund, 2010) with the corresponding weight equivalent of 5,4,3,2,1 to the different descriptions used as follows: 4.21-5.00-Extremely Challenging, 3.41-4.20-Very Challenging, 2.61-3.40-Moderately Challenging, 1.81-2.60-Slightly Challenging, and 1.00-1.80- Not Challenging at all.

The research instrument was pilot tested among ten (10) teachers from the Trinidad District, who were not included in the actual respondents of the study. The purpose of the pilot test was to evaluate the clarity, relevance, and reliability of the questionnaire. Results of the pilot testing revealed that the items were generally well understood by the respondents, with only minimal suggestions for improvement in terms of wording and clarity. The computed mean scores fall around 3.2-3.8 indicated that the level of challenges experienced by the teachers ranged from moderate to high, suggesting that the instrument was able to capture varying degrees of knowledge, challenges, and practices effectively. Based on these, the questionnaire was deemed valid and reliable for use in the actual conduct of the study.

Data Gathering Procedures. Permission to carry out the study was secured first from the Bohol Island State University – Bilar Campus Director through the Dean of the School of Advanced Studies. Upon the endorsement of the research design, the researcher asked permission from the Schools Division

Superintendent then to the Public Schools District Supervisor of Pres. Carlos P. Garcia, Ubay, and Bien Unido to conduct the study in the public elementary schools.

After the approval to conduct the study, the researcher asked permission from the school heads/principals then, the researcher personally distributed the survey-questionnaires to the respondents. Furthermore, the researcher assured the respondents regarding the confidentiality of their responses and sincerely sought their utmost cooperation in honestly and objectively answering the survey. After a week, the questionnaires personally retrieved by the researcher for tabulation, treatment, analysis, and interpretation purposes.

Statistical Treatment. Frequency and simple percentage were used in analyzing the profile of the teacher-respondents; Weighted mean score (WMS) was used to assess the level of knowledge, practices, and challenges on financial literacy. Multiple regression was also used to determine the association between the profile of the respondents and other variables regarding the statements of null hypotheses.

FINDINGS

Table 1 presents the profile of the teacher-respondents in terms of age, sex, civil status, highest educational attainment, years in service, net monthly income, and teaching position. In terms of age, the majority of respondents belong to the 41–50 years old group, with 182 or 60.7 percent, ranking first. This indicates that most teachers are in their mid-career stage, suggesting a relatively experienced workforce. On the other hand, the 21–30 years old group has the lowest representation, with only 4 or 1.3 percent, implying a very small proportion of young or newly hired teachers.

For sex, female respondents comprise the majority with 173 or 57.7 percent, while male respondents represent the minority at 127 or 42.3 percent. This reflects the common trend of female dominance in the teaching profession. In terms of civil status, most respondents are married, accounting for 259 or 86.3 percent, which may indicate stability in personal life among teachers. Conversely, separated respondents have the lowest frequency with only 5 or 1.7 percent.

Regarding highest educational attainment, the majority are master's degree graduates with 249 or 83.0 percent, ranking first. This suggests that most teachers have pursued advanced education, which may contribute to their professional competence. In contrast, Ph.D./Ed.D. graduates recorded the lowest frequency with 0 or 0 percent, indicating that none of the respondents have completed a doctoral degree.

For years in service, the largest group falls under 11–15 years with 142 or 47.3 percent, reflecting a substantial number of moderately experienced teachers. Meanwhile, the 1–5 years category has no respondents or 0 percent, indicating the absence of novice teachers in the sample.

In terms of net monthly income, the highest proportion of respondents falls within the ₱20,001–₱30,000 range, with 141 or 47.0 percent, followed closely by those earning ₱30,001–₱40,000. This suggests that most teachers receive a mid-range salary. The lowest is above ₱50,000, with only 1 respondent or 0.3 percent, indicating that very few teachers receive higher-level compensation.

Last, for teaching position, the majority are Teacher III with 141 or 47.0 percent, followed closely by Teacher II. This implies that many respondents have already advanced within the teaching ranks. The least represented position is Master Teacher II, with only 1 or 0.3 percent, suggesting limited representation at the highest teaching rank.

The data implies that the respondents are predominantly experienced, married, female teachers with master's degrees, occupying mid-level teaching positions and earning moderate salaries, while younger, less experienced, and doctoral-degree-holding teachers are minimally represented.

Table 1. Profile of the Teacher-Respondents
n=300

	Frequency	Percentage (%)
1.1 Age		
21– 30 years old	4	1.3
31 – 40 years old	72	24.0
41 – 50 years old	182	60.7
51 – 60 years old	28	9.3
61 years old and above	14	4.7
1.2. Sex		
Male	127	42.3
Female	173	57.7
1.3 Civil Status		
Single	23	7.7
Married	259	86.3
Widowed	13	4.3
Separated	5	1.7
1.4 Highest Educational Attainment		
Bachelor Degree Holder	26	8.7
With units in Masters' Degree	14	4.7
Masters' Degree Graduate	249	83.0
With Ph. D./ Ed. D. units	11	3.7
Ph. D./ Ed. D. Graduate	0	0
1.5 Years in Service		
1-5 years	0	0
6-10 years	11	3.7
11-15 years	142	47.3
16-20 years	93	31.0
21 years & above	54	18.0
1.6 Net Monthly Income Range		
Below ₱20,000	10	3.3
₱20,001-₱30,000	141	47.0
₱30,001-₱40,000	137	45.7
₱40,001-₱50,000	11	3.7
Above ₱50,000	1	.3
1.7 Teaching Position		
Teacher I	7	2.3
Teacher II	140	46.7
Teacher III	141	47.0
Master Teacher I	11	3.7
Master Teacher II	1	.3

Table 2 reveals the level of knowledge on financial literacy among public elementary school teachers of Second Sub-congressional districts. The highest-rated statement is "understand how interest rates affect loans and savings," with a weighted mean score of 4.49, interpreted as very high and ranked first. This indicates that teachers possess a strong understanding of fundamental financial concepts, particularly those directly related to borrowing and saving. This suggests that respondents are well-informed about how financial institutions operate and how interest rates influence their financial decisions.

The implication of this finding is that teachers are equipped with essential knowledge that can help them make informed choices regarding loans, savings, and other financial products, which contributes to better financial stability.

This finding is supported by the study of Lusardi and Mitchell (2023), who emphasized that knowledge of interest rates, savings, and loans is a fundamental component of financial literacy and plays a crucial role in effective financial decision-making and long-term financial stability. The implication of this finding is that teachers are equipped with essential financial knowledge that can help them manage their finances effectively and serve as role models in promoting financial awareness.

On the other hand, the lowest-rated statement is "actively seek financial advice from professionals or mentors," with a weighted mean score of 2.92, interpreted as moderate and ranked last. This indicates that teachers are less inclined to consult financial experts or seek professional guidance in managing their finances. The implication of this result is that despite having a generally high level of financial knowledge, respondents may rely primarily on personal judgment or informal sources of information. This may limit their exposure to more advanced financial strategies and could affect the quality of their financial decision-making in the long term.

This result is consistent with the findings of Xiao and Porto (2022), who reported that individuals often demonstrate a gap between financial knowledge and actual financial behavior, particularly in seeking professional financial advice. The implication is that teachers may rely more on personal judgment or informal sources, which can limit their exposure to more advanced financial strategies and reduce the effectiveness of their financial decision-making.

The computed average weighted mean is 3.65, which is interpreted as high. This indicates that, in general, teachers demonstrate a high level of financial literacy, positive attitudes, and sound financial practices. The findings suggest that while teachers demonstrate strong foundational financial knowledge and generally positive financial behaviors, there is a need to encourage greater engagement with professional financial advice. Strengthening this aspect could further enhance their financial literacy and lead to more effective and sustainable financial management practices.

Table 2. Level of Knowledge on Financial Literacy
n= 300

Statements	WMS	DI
As a teacher, I…		
1.understand how interest rates affect loans and savings.	4.49	VH
2.understand the terms and conditions of my loans.	3.75	H
3. can explain the concept of inflation and its impact on money.	3.86	H
4. can explain the concept of inflation and its impact on money.	3.68	H
5. understand the difference between assets and liabilities.	3.95	H
6. am familiar with budgeting and expense tracking.	3.85	H
7. know the importance of emergency savings	3.72	H
8.regularly create and follow a personal budget.	3.62	H
9.save a portion of my income every month.	3.54	H
10.compare prices before making purchases.	3.79	H
11.avoid impulse buying.	3.49	H
12.keep track of my financial transactions.	3.67	H
13.have a financial goal and plan to achieve it.	3.42	H
14.believe financial planning is essential for a secure future.	3.40	H
15.feel confident making financial decisions.	3.59	H
16.am motivated to improve my financial situation.	3.63	H
17.feel anxious when thinking about money.	3.55	H
18.believe investing is risky and should be avoided.	3.69	H
19.am open to learning new financial strategies.	3.75	H

20.have attended financial literacy seminars or workshops.	3.78	H
21.received financial education during my teacher training.	3.40	H
22.actively seek financial advice from professionals or mentors.	2.92	M
23.use online resources to learn about personal finance.	3.23	M
24.would participate in future financial literacy training if offered.	3.74	H
Average Weighted Mean	**3.64**	**Very High Knowledge**

Legend:

Scale:	Interpretation
4.21-5.00	Very High Knowledge (VH)
3.41-4.20	High Knowledge (H)
2.61-3.40	Moderate Knowledge(M)
1.81-2.60	Low Knowledge (L)
1.00-1.80	Very Low Knowledge (VL)

Shown on Table 3 are the practices of teacher-respondents in terms of debt management and investment behaviors based on their weighted mean scores. The highest-rated statement is "invest regularly as part of my financial plan," with a weighted mean score of 4.00, interpreted as often practiced and ranked first. This indicates that teachers demonstrate a strong inclination toward consistent investing as part of their financial routine. This suggests that respondents recognize the importance of building wealth and securing their financial future through regular investment. The implication of this finding is that teachers are developing proactive financial habits, particularly in wealth accumulation, which can contribute to long-term financial stability and preparedness for future needs such as retirement or education.

On the other hand, the lowest-rated statements are "prioritize debt repayment over discretionary spending" and "stay informed about market trends and economic news," both with a weighted mean score of 3.19, interpreted as sometimes practiced and ranked last. This indicates that teachers are less consistent in prioritizing debt obligations and in keeping themselves updated on financial and economic information. The implication of this result is that while teachers engage in investment activities, there may be gaps in foundational financial management practices such as disciplined debt repayment and continuous financial learning. These gaps may affect the effectiveness of their financial decisions and could expose them to financial risks.

These findings suggest that teachers demonstrate stronger engagement in investment-related practices compared to debt management and financial awareness behaviors. The average weighted mean of 3.42, interpreted as often practiced, indicates that financial practices are generally observed among the respondents, although there is still room for improvement in certain areas, particularly in managing debt responsibly and staying informed about financial trends.

Table 3. Level of Practice on Financial Literacy
n= 300

Statements	WMS	DI
As a teacher, I…		
1.currently have outstanding loans or debts.	3.38	SP
2.prioritize debt repayment over discretionary spending.	3.19	SP
3.avoid borrowing from informal lenders.	3.35	SP
4.have a debt repayment plan.	3.30	SP
5.avoid taking new loans unless absolutely necessary.	3.32	SP
6.compare loan offers from different institutions before borrowing.	3.38	SP
7.set aside a portion of my income specifically for debt repayment.	3.29	SP
8.have sought financial counseling or advice to manage my debt.	3.54	OP
9.have investments (e.g., stocks, mutual funds, real estate).	3.36	SP
10.seek professional advice before investing.	3.41	OP

11.invest regularly as part of my financial plan.	4.00	OP
12.am aware of scams and fraudulent investment schemes.	3.59	OP
13.believe investing is vital for sustained financial security.	3.67	OP
14.diversify my investments to reduce risk.	3.62	OP
15.regularly review and adjust my investment portfolio.	3.26	SP
16.invest with long-term goals such as retirement or education in mind.	3.38	SP
17.stay informed about market trends and economic news.	3.19	SP
Average Weighted Mean	**3.42**	**Often Practiced**

Legend:

Scale:	Interpretation
4.21-5.00	Always Practiced (AP)
3.41-4.20	Often Practiced (OP)
2.61-3.40	Sometimes Practiced (SP)
1.81-2.60	Rarely Practiced (RP)
1.00-1.80	Never Practiced (NP)

Table 4 exhibits the level of challenges on financial literacy. The data show that the average weighted mean is 3.59, interpreted as very challenging. This indicates that teachers generally encounter considerable difficulties in managing various aspects of their personal finances. Among the indicators, the highest-rated challenge is "planning my finance to avoid running out of money before payday," with a weighted mean score of 3.94, interpreted as very challenging. This suggests that many teachers struggle with financial planning and cash flow management, particularly in ensuring that their income lasts throughout the pay period. Closely following are "meeting monthly expenses using my salary" (3.88) and "distinguishing between needs and wants when spending" (3.85) both interpreted as very challenging also, which further indicate that budgeting and prioritization of expenses are major concerns among respondents.

On the other hand, the lowest-rated challenge is "understanding financial terms and concepts," with a weighted mean score of 2.93, interpreted as moderately challenging. This suggests that, compared to other areas, teachers experience relatively less difficulty in grasping basic financial concepts. Other lower-ranked items include "accessing accurate financial information" (3.20) and "receiving adequate financial education and training" (3.23), both interpreted as moderately challenging. The implication of these results is that while teachers may have some level of financial knowledge and access to information, the primary difficulty lies not in understanding concepts but in applying them effectively in real-life financial situations.

The findings revealed that teachers face greater challenges in practical financial management particularly in budgeting, expense control, and financial planning rather than in financial knowledge acquisition. This suggests a need for interventions that focus on strengthening financial management skills and application, such as budgeting strategies, financial planning workshops, and income management training, to help teachers better cope with their financial responsibilities.

Table 4. Level of Challenges on Financial Literacy
n = 300

Statements	WMS	DI
1.Managing a monthly budget effectively.	3.76	VC
2.Meeting monthly expenses using mg salary.	3.88	VC
3.Monitoring daily expenses accurately.	3.69	VC
4.Planning my finance to avoid running out of money before payday.	3.94	VC
5.Distinguishing between needs and wants when spending.	3.85	VC
6.Saving money regularly.	3.72	VC
7.Building an emergency fund.	3.62	VC
8.Preparing financially for unexpected expenses.	3.54	VC
9.Setting aside money for future needs.	3.80	VC

10.Planning long term savings.	3.49	VC
11.Managing loans and debts responsibly.	3.66	VC
12.Paying debts on time.	3.43	VC
13.Controlling the amount of debt I carry.	3.40	MC
14.Understanding loan interest and other charges.	3.59	VC
15.Planning carefully before borrowing money.	3.64	VC
16.Understanding different investment opportunity.	3.56	VC
17.Making confident investment decisions.	3.69	VC
18.Preparing for retirement.	3.76	VC
19.Accessing reliable financial advise.	3.79	VC
20.Planning for long-term financial goal.	3.40	MC
21.Understanding financial terms and concepts.	2.93	MC
22.Receiving adequate financial education and training.	3.23	MC
23.Making sound financial decisions.	3.74	VC
24.Handling personal money matters independently.	3.39	MC
25.Accessing accurate financial information.	3.20	MC
Average Weighted Mean	**3.59**	**Very Challenging**

Legend:

Scale:	Interpretation
4.21-5.00	Extremely Challenging (EC)
3.41-4.20	Very Challenging (VC)
2.61-3.40	Moderately Challenging (MC)
1.81-2.60	Slightly Challenging (SC)
1.00-1.80	Not Challenging At All (NC)

Table 5 depicts the regression analysis identifying the predictors of the dependent variable based on selected demographic profile of the respondents. The results show that only net monthly income and teaching position have statistically significant relationships with the outcome variable, while the rest of the variables do not show significant influence.

Net monthly income has a negative and significant relationship ($B = -0.11$, $p = .04$), indicating that as income increases, the dependent variable tends to decrease. This suggests that respondents with higher income levels may experience fewer difficulties or demonstrate better outcomes related to the variable being measured. The implication of this finding is that financial capacity plays an important role in influencing the respondents' condition, as higher income may provide greater financial flexibility and access to resources.

Teaching position also shows a positive and significant relationship ($B = 0.14$, $p = .02$), indicating that higher teaching positions are associated with higher levels of the dependent variable. This implies that respondents holding higher positions, such as Teacher III or Master Teacher, tend to exhibit stronger outcomes, possibly due to greater experience, professional exposure, and responsibilities associated with their roles.

On the other hand, age ($p = .99$), sex ($p = .31$), civil status ($p = .18$), highest educational attainment ($p = .85$), and years of teaching experience ($p = .43$) do not show significant relationships with the dependent variable. This indicates that these profile characteristics do not significantly influence the outcome being measured in the study. The implication is that regardless of differences in age, gender, marital status, educational background, or length of service, respondents tend to exhibit similar levels in the dependent variable.

The findings suggest that economic factors and professional rank are more influential predictors compared to personal and demographic characteristics. This highlights the importance of financial capacity and career advancement in shaping the outcomes observed in the study.

Table 5. Significant Association between the Teachers' Profile and the Level of Knowledge on Financial Literacy
n = 300

Predictors	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	interpretation
	B	Std. Error	Beta			
Age	.00	.02	-.00	-.02	.99	No significant association
Sex	-.02	.02	-.06	-1.01	.31	No significant association
Civil Status	-.04	.03	-.08	-1.34	.18	No significant association
Highest Educational Attainment	-.00	.02	-.01	-.10	.85	No significant association
Years of Teaching Experience	-.01	.02	-.06	-.78	.43	No significant association
Net Monthly income	-.11	.05	-.38	-2.09	.04	Significant association
Teaching position	.14	.06	.44	2.46	.02	Significant association

**Significance is set at 0.05 level (2-tailed)*

Table 6 demonstrates the test of association between the teachers' demographic profile and the level of practices on financial literacy. The regression model yielded an F-value of 1.14 with a corresponding p-value of 0.34. Since the p-value is greater than the 0.05 level of significance, the result is not statistically significant. This indicates that the combined effect of the predictor variables age, sex, civil status, highest educational attainment, years of teaching experience, net monthly income, and teaching position does not significantly predict the dependent variable.

The regression sum of squares (0.81) is relatively small compared to the residual sum of squares (29.58), suggesting that only a minimal portion of the total variation in the dependent variable is explained by the model, while a larger portion is attributed to other factors not included in the study. The result indicates no significant relationship between the combined predictors and the dependent variable, leading to the acceptance of the null hypothesis.

Table 6. Test of Association between the Teachers' Demographic Profile and the Level of Practices on Financial Literacy
n = 300

Model	Sum of Squares	df	Mean Square	F	Sig.	Interpretation
Regression	.81	7	.12			
Residual	29.58	292	.10			No association
Total	30.39	299		1.14	.34[b]	

Table 7 displays the test of association between the teachers' demographic profile and the level of challenges on financial literacy. The results indicate that years of teaching experience, net monthly income, and teaching position are significant predictors, while age, sex, civil status, and highest educational attainment do not show significant relationships.

Years of teaching experience has a negative and significant relationship (B = -0.04, p = .03), indicating that as teaching experience increases, the level of the dependent variable tends to decrease. This suggests that more experienced teachers may exhibit lower levels of the measured outcome, possibly due

to increased familiarity, adaptation, or efficiency gained through years of practice. The implication is that experience may contribute to improved coping mechanisms or better management, reducing the intensity of the measured variable.

Net monthly income also shows a negative and significant relationship (B = -0.11, p = .05). This implies that teachers with higher income levels tend to have lower levels of challenges in financial literacy. The finding suggests that financial capacity plays an important role, as higher income may reduce financial strain or challenges, leading to better outcomes.

Teaching position demonstrates a positive and significant relationship (B = 0.14, p = .01), indicating that higher teaching positions are associated with higher levels of the dependent variable. This suggests that teachers in higher ranks may exhibit stronger performance or engagement related to the measured variable, possibly due to greater responsibilities, professional exposure, and experience.

On the other hand, age (p = .57), sex (p = .78), civil status (p = .23), and highest educational attainment (p = .96) do not have significant relationships with the level of challenges. This indicates that these demographic profiles do not significantly influence the level of challenges, and respondents tend to have similar levels regardless of these characteristics.

Table 7. Test of Association between the Teachers' Demographic Profile and the Level of Challenges on Financial Literacy
n = 300

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Interpretation
	B	Std. Error	Beta			
Age	.01	.02	.04	.56	.57	No significant association
Sex	-.01	.02	-.02	-.28	.78	No significant association
Civil Status	-.03	.03	-.07	-1.22	.23	No significant association
Highest Educational Attainment	.00	.02	.00	.05	.96	No significant association
Years of Teaching Experience	-.04	.02	-.16	-2.18	.03	Significant association
Net Monthly income	-.11	.06	-.36	-2.00	.05	Significant association
Teaching position	.14	.06	.45	2.51	.01	Significant association

CONCLUSIONS

The study concludes that financial literacy among teachers is generally high but is not fully translated into effective financial management practices. However, despite this level of knowledge and practice, teachers still experience considerable financial challenges, particularly in budgeting, managing monthly expenses, and sustaining financial stability until the next payday. These challenges suggest that financial knowledge does not always translate into consistent and effective financial behavior.

The study further concluded that financial literacy among teachers are more influenced by economic and professional factors, particularly net monthly income and teaching position, rather than demographic characteristics such as age, sex, civil status, educational attainment, and years of teaching experience. Overall, there is a clear gap between financial knowledge and actual financial management practices, highlighting the need for stronger support systems and practical financial interventions.

RECOMMENDATIONS

1. Teachers are encouraged to apply their financial knowledge more consistently in their daily financial practices, particularly in budgeting, expense management, and debt control. They are also advised to actively seek professional financial advice and participate in financial literacy programs to improve their financial decision-making. Developing disciplined saving habits and long-term financial planning strategies is also recommended to ensure greater financial stability and security.
2. School administrators and educational institutions are encouraged to implement continuous and practical financial literacy programs that focus on real-life financial challenges faced by teachers. These may include seminars on budgeting, debt management, investment planning, and financial counseling sessions. Institutions are also encouraged to establish partnerships with financial experts, banks, and government agencies to provide accessible financial guidance and support services for teachers. Strengthening wellness programs that address financial stress may also help improve teachers' overall well-being and job performance.
3. Future researchers are encouraged to explore other possible variables that may influence financial literacy outcomes, such as behavioral factors, psychological attitudes, financial stress, and socio-economic conditions. It is also recommended to conduct qualitative or mixed-method studies to gain deeper insights into teachers' lived financial experiences. Expanding the study to include other regions or larger populations may also help improve the generalizability of findings and provide a more comprehensive understanding of financial literacy among educators.
4. School Principal and School Heads are encouraged to utilize the findings of this study to design and implement targeted financial literacy programs for teachers. This may include organizing seminars, workshops or training sessions that focus on improving financial knowledge, strengthening sound financial practices, and addressing common challenges faced by teachers. The principal may also consider integrating financial wellness initiatives into the school's professional development plans and fostering partnership with relevant institutions to provide financial guidance and support. Through financial stability, which may contribute to enhanced productivity and overall school performance.

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HAMBINGAN NG WIKANG FILIPINO AT CEBUANO

"COMPARISON OF THE FILIPINO AND CEBUANO LANGUAGES"

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ABSTRACT

This study aims to conduct a comparative analysis of the Filipino and Cebuano languages in terms of their grammatical and morphological structures. Although these languages are distinct, both belong to the broader Austronesian language family, which accounts for certain similarities and differences in their linguistic systems. The study focused on the examination of parts of speech, particularly nouns and verbs, in both languages. It also seeks to determine how speakers of each language apply grammatical rules in everyday communication. Findings indicate that while numerous Filipino and Cebuano words share similarities in spelling and meaning, there is also a considerable number of lexical items that differ between the two languages.

Keywords*: Language, Filipino, Cebuano, Grammar, Morphology*

INTRODUKSIYON

Ang wika ang pangunahing nagbibigay ng pagkakakilanlan sa lahing kinabibilangan ng tao. Mahalaga ito sa pagkakaroon ng pagkakaisa sapagkat nagsisilbi itong tulay ng komunikasyon at mahalagang sangkap sa pagbuo ng isang matatag na bansa. Isa rin ang wika sa mahahalagang pamana ng ating mga ninuno na patuloy nating pinagyayaman. Sa pamamagitan ng wika, naipapahayag natin ang ating damdamin, saloobin, at mga kaisipang nais iparating sa iba.

Ayon kay Constantino (1965), isang kilalang dalubwika sa Pilipinas, may mahigit isang daan at limampung (150) wika at humigit-kumulang apat na raang (400) wikain na ginagamit sa bansa. Kabilang dito ang mga mayoryang mga wika tulad Tagalog, Waray, Ilokano, Kapampangan, Cebuano, Hiligaynon, Bikolano, at Pangasinense.

Batay sa isinagawang sarbey, napag-alaman na nangunguna ang Tagalog bilang wikang karaniwang ginagamit sa tahanan, habang pumapangalawa naman ang Cebuano. Gayunpaman, bahagyang nakahihigit ang Cebuano sa Tagalog pagdating sa unang wikang natutuhan ng mga tao.

Ang wikang Cebuano ay kilala rin sa mga tawag na Sugbuhanon, Sinibwano, at Binisaya. Nabibilang ito sa pangkat ng mga wikang Malayo-Polinesyo. Ayon kina Bunye et.al (1971), tinatayang umaabot sa humigit-kumulang 32 milyon o 24 porsyento ng kabuuang populasyon ng Pilipinas noong 1971 ang mga katutubong Bisaya. Ito ang ikalawang pinakamalaking wikang ginagamit sa Pilipinas, na may tinatayang humigit-kumulang 20 milyong tao na nagsasalita nito bilang unang wika at 11 milyon naman bilang pangalawang o karagdagang wika.

Ang wikang Cebuano ay may 50 porsyentong pagkakahawig o kogneyt sa Bicolano, 21 porsyento sa Ilokano, 24 porsyento sa Kapampangan, at 76 porsyento naman sa Hiligaynon. Binubuo ito ng

labinlimang (15) katinig—b, k, d, g, h, l, m, n, p, r, s, t, w, at y—at tatlong (3) patinig na a, i, at e. Nang dumating ang mga Kastila, nadagdagan ito ng dalawa pang patinig, ang o at u, kaya naging lima (5) ang kabuuang bilang ng mga patinig sa wikang Cebuano, (Wolff, 1972).

Ayon kay Acosta (2020), ang Wikang Cebuano ay isa sa mga pangunahing wika sa Pilipinas na malawak na ginagamit sa rehiyong Kabisayaan at ilang bahagi ng Mindanao, habang ang Wikang Filipino naman ay nagsisilbing pambansang wika ng bansa. Sa kanyang pag-aaral, binigyang-diin ang pagkakaroon ng Cebuano ng mayamang sistema ng bokabularyo at estruktura na may pagkakatulad at pagkakaiba sa Wikang Filipino, lalo na sa aspeto ng paggamit ng mga salita at paraan ng pagpapahayag. Ipinakita rin na ang dalawang wika ay parehong may mahalagang papel sa komunikasyon ng mga Pilipino, ngunit nagkakaiba sa ilang ponolohikal at morpolohikal na katangian na nagiging sanhi ng baryasyon sa paggamit nito sa iba't ibang rehiyon.

Sumang-ayon ito sa pag-aaral ni Abucay (2025), ang wikang Cebuano ay isang mahalagang bahagi ng mga wikang sinasalita sa Kabisayaan at ilang bahagi ng Mindanao na nagpapakita ng mayamang baryasyon sa antas ng leksikal at ponolohikal. Sa kanyang pag-aaral tungkol sa lexical variation ng Cebuano, binigyang-diin na ang mga salitang ginagamit sa iba't ibang rehiyon ay nagpapakita ng pagkakatulad at pagkakaiba na nakaaapekto sa paraan ng komunikasyon ng mga nagsasalita nito. Kaugnay nito, maipapakita na ang Wikang Filipino at Wikang Cebuano ay parehong bahagi ng sistemang Austronesian na may magkakaugnay na pinagmulan, ngunit nagkakaiba sa ilang aspekto ng bokabularyo, estruktura, at paggamit sa lipunan. Ipinapakita rin ng pag-aaral na ang pag-unawa sa baryasyon ng wika ay mahalaga sa mas malalim na pag-aaral ng ugnayan ng mga wikang rehiyonal at pambansa sa Pilipinas.

Ayon sa pag-aaral nina Araneta et. al. (2021), ang wikang Cebuano ay mayaman sa mga pormularyong ekspresyon na ginagamit sa pang-araw-araw na komunikasyon at nagbabago ang kahulugan batay sa konteksto ng usapan. Natuklasan sa kanilang pagsusuri na ang mga ekspresyong gaya ng oo, lagi, bitaw, mao, wala, at dili ay may mahalagang papel sa pagpapahayag ng pagsang-ayon at pagtutol sa diskurso. Ipinakita rin ng pag-aaral na ang kahulugan ng mga pahayag sa Cebuano ay hindi lamang nakabatay sa literal na anyo nito kundi sa gamit at intensyon ng nagsasalita. Kaugnay nito, mahalagang maunawaan ang istruktura at paggamit ng Cebuano upang mas malinaw na makita ang pagkakatulad at pagkakaiba nito sa Wikang Filipino, lalo na sa antas ng komunikatibong gamit sa lipunan.

Ayon naman sa pag-aaral nina Demeterio et. al (2017) , ang wikang Cebuano ay nananatiling pangunahing ginagamit sa pang-araw-araw na komunikasyon ng mga Cebuanos, samantalang ang Wikang Filipino at Ingles ay mas madalas gamitin sa pormal na konteksto. Ipinakita sa kanilang pananaliksik na may umiiral na multilinggwal na kalagayan sa Pilipinas kung saan ang Cebuano, Filipino, at Ingles ay magkakaibang may tungkulin sa lipunan. Bagaman hindi direktang paghahambing ng estruktura ng mga wika ang kanilang pag-aaral, malinaw nitong ipinapakita ang pagkakaiba ng gamit at papel ng Wikang Filipino at Wikang Cebuano sa iba't ibang antas ng komunikasyon sa bansa. Dahil dito, mahalagang maunawaan ang ugnayan at pagkakaiba ng mga wikang ito bilang bahagi ng patuloy na pag-unlad ng lingguwistikong identidad ng mga Pilipino.

Samantala, ayon kay Fernandez (2025), ang mga wikang Tagalog, Hiligaynon, at Cebuano ay may magkakatulad na pinagmulan sa pamilyang Austronesian ngunit nagkakaiba sa kanilang morpolohikal na estruktura. Sa kanyang pag-aaral, sinuri ang mga panlaping ginagamit sa tatlong wika upang matukoy ang pagkakatulad at pagkakaiba sa pagbuo ng mga salita, partikular sa mga pangngalan, pang-uri, at pandiwa. Ipinakita sa resulta na bagaman may ilang pagkakapareho sa paggamit ng mga panlapi, may mga natatanging anyo at pagbabago sa estruktura ng salita ang bawat wika, kabilang ang Cebuano at Tagalog. Sa pamamagitan ng paghahambing na ito, naipapakita ang mas malawak na ugnayan ng mga wikang rehiyonal at pambansa sa Pilipinas, na mahalaga sa pag-unawa sa multilinggwal na kalagayan ng bansa.

Sa lahat ng ito, mahalagang matukoy ang mga pagkakatulad at pagkakaiba ng Wikang Filipino at Wikang Cebuano upang maiwasan ang kalituhan sa pagbigkas at pagpapakahulugan ng mga salita. Ang hindi wastong paggamit ng dalawang wika ay maaaring magdulot ng maling interpretasyon o hindi pagkakaunawaan sa isang pahayag.

ANG SULIRANIN

Paglalahad ng Suliranin

Layunin ng pag-aaral na ito na tukuyin ang mga pagkakaiba at pagkakatulad sa aspekto ng pandiwa sa wikang Cebuano. Upang maisakatuparan ito, sinubukang bigyang-linaw ang mga sumusunod na katanungan:

1. Ano-ano ang mga salitang may pagkakatulad at pagkakaiba sa wikang Cebuano at wikang Filipino batay sa kanilang kayarian?
2. Ano ang mga pagkakatulad ng aspekto ng pandiwa sa wikang Cebuano at wikang Filipino?

METODOLOHIYA

Ginagamitan ang pag-aaral na ito ng kwalitatibong pamamaraan. Nangangalap ang mananaliksik ng mga salitang Filipino at Cebuano mula sa iba't ibang sanggunian at ginawan ng analisis. Upang matiyak ang katumpakan ng resulta nga analisis ay pinasuri ito ng mga eksperto sa larangan ng wika.

Etikal na Konsiderasyon

Bago isinagawa ang pananaliksik na ito ay ipinipresenta muna ito sa " In-House Research Colloquium" Nagbigay ang panel ng mga puna at suhestiyon upang mas mapaganda ang pananaliksik na ito. Kumuha ang mananaliksik ng mga datos mula sa mga pinagkakatiwalaang sanggunian at ang lahat ng mga datos ay pinasuri sa mga dalubwika tulad ng mga propesor sa wikang Filipino sa ibat ibang pamantasan upang maiwasto ito. Sinunod ng mananaliksik ang mga suhestiyon.

RESULTA AT DISKUSYON

Mga Natuklasan

Talahanayan 1. Pangngalan ng Tao/Kamag-anak

Filipino	Cebuano
Lolo	Lolo
Lola	Lola
Apo	Apo
Anak	Anak
Tiyo	Tiyo/Uyuan
Tiya	Tiya/Iyaan
Ate	Ate/Manang
Kuya	Kuya/Manong
Ama/papa	Amahan/Papa
Ina/mama	Inahan/mama
Pamangkin	Pag-umangkon
Pinsan	Ig-agaw
Kapatid	Egsoon
Biyanan	Ugangan
Kambal	Kaluha

Batay sa Talahanayan 1 na naglalahad ng mga pangngalang tumutukoy sa tao o kamag-anak, makikita na mayroong bahagyang pagkakatulad sa pagitan ng Wikang Filipino at Wikang Cebuano,

partikular sa mga salitang “lolo,” “lola,” “anak,” at “apo” na pareho ang anyo at kahulugan sa dalawang wika. Ipinapakita nito na may mga salitang nagmula sa magkatulad na pinagmulan kaya’t nananatili ang kanilang pagkakapareho sa leksikal na anyo. Gayunpaman, kapansin-pansin din ang mga malinaw na pagkakaiba sa ibang katawagan para sa kamag-anak. Halimbawa, ang “ina” sa Filipino ay “mama” sa Cebuano, “ama” ay “papa,” “tiyo” ay “uyuan,” “tiya” ay “iyaan,” “pamangkin” ay “pag-umangkon,” “pinsan” ay “ig-agaw,” “biyanan” ay “ugangan,” at “kambal” ay “kaluha.” Ipinahihiwatig nito na bagaman magkaugnay ang dalawang wika sa iisang pamilyang Austronesian, malaki pa rin ang naging baryasyon sa bokabularyo, lalo na sa mga terminong pantawag sa relasyon ng pamilya, na maaaring bunga ng rehiyonal na pag-unlad at ebolusyon ng wika.

Talahanayan 2. Pangngalan ng Bahagi ng Katawan

Filipino	Cebuano
Ulo	Ulo
Ilong	Ilong
Kuko	Kuko
Kilay	Kilay
Mata	Mata
Buhok	Buhok
Ilong	Ilong
Tiyan	Tiyan
Tuhod	Tuhod
Pusod	Pusod
Puson	Pus-on
Leeg	Li-og
Ngipin	Ngipon
Leeg	Li-og
Bisig	Bukton
Kamay	Kamot
Baywang	Hawak
Balat	Panit
Dibdib	Dughan
Tainga	Dalunggan
Paa	tiil
Balikat	Abaga

Batay sa Talahanayan 2, makikita na may mga salitang magkakatulad sa Wikang Filipino at Wikang Cebuano na tumutukoy sa mga bahagi ng katawan tulad ng “ulo,” “kilay,” “mata,” “buhok,” “ilong,” “kuko,” “pusod,” at “tuhod.” Ipinapakita nito na may mga leksikal na item na nananatiling magkapareho ang anyo at kahulugan sa dalawang wika, na maaaring bunga ng kanilang iisang pinagmulan sa pamilyang Austronesian. Gayunpaman, kapansin-pansin din ang mga salitang nagkakaiba tulad ng “labi,” “tainga,” “ngipin,” “leeg,” “bisig,” “kamay,” “balat,” “dibdib,” “puson,” “balikat,” “baywang,” at “paa,” na nagpapakita ng lexical divergence sa pagitan ng dalawang wika.

Bukod dito, may mga pagkakataon din ng bahagyang pagbabago sa anyo ng mga salita kung saan ang pagkakaiba ay nasa isang titik lamang, tulad ng “ngipin” na nagiging “ngipon” at “leeg” na nagiging “li-og.” Ipinahihiwatig nito ang presensya ng ponolohikal na baryasyon, partikular sa pagpapalit ng ponemang “i” at “o,” na karaniwang nakikita sa pagitan ng Filipino at Cebuano. Dagdag pa rito, ang mga salitang tulad ng “tiyan” at “puson” ay nagpapakita ng pagkakaiba hindi lamang sa baybay kundi maging sa kahulugan at paggamit, na sumasalamin sa mas malalim na pagkakaiba sa semantika ng dalawang wika.

Sa kabuuan, ipinapakita ng talahanayan na ang Filipino at Cebuano ay may kombinasyon ng pagkakatulad at pagkakaiba sa leksikon at ponolohiya, na patunay ng kanilang mayamang baryasyon bilang mga wikang Austronesian.

Talahanayan 3. PangngalanTungkol sa Hayop

Filipino	Cebuano
Baboy	Baboy
Itik	Itik/bebe/pato
Manok	Manok
Kalabaw	Kabaw
Baka	Baka
Unggoy	Unggoy
Kabayo	Kabayo
Ahas	has
Aso	Iro
Kambing	Kanding
Pusa	Iring
Ibon	langgam

Batay sa Talahanayan 3, makikita na maraming pangalan ng hayop sa Wikang Filipino ang may kaparehong anyo at bigkas sa Wikang Cebuano, na nagpapahiwatig ng malapit na ugnayan ng dalawang wika sa antas ng leksikon. Ipinapakita nito na ang ilang salitang tumutukoy sa hayop ay nananatiling pareho dahil sa iisang pinagmulan at matagal nang paggamit sa mga komunidad na nagsasalita ng parehong wika. Gayunpaman, kapansin-pansin din ang mga pagkakataon ng leksikal na pagkakaiba tulad ng “aso” na nagiging “iro,” “pusa” na “iring,” “kalabaw” na “kabaw,” at “ibon” na “langgam.”

Ipinahihiwatig ng mga baryasyong ito na bagaman magkaugnay ang Filipino at Cebuano bilang mga wikang Austronesian, may mga natatanging pag-unlad sa bokabularyo ang bawat isa na resulta ng rehiyonal na ebolusyon at kulturang lingguwistiko. Ang ganitong pagkakaiba ay nagpapakita rin ng pagiging dinamiko ng wika, kung saan ang mga salita ay maaaring magbago ng anyo at tawag depende sa komunidad na gumagamit nito. Sa kabuuan, ipinapakita ng talahanayan na ang Filipino at Cebuano ay may kombinasyon ng pagkakatulad at pagkakaiba sa pangalan ng mga hayop, na sumasalamin sa mas malawak na baryasyon ng mga wika sa Pilipinas.

Talahanayan 4. Balangkas sa Pagbuo ng mga Pandiwa sa Wikang Cebuano

Aspekto ng Pandiwa	Sistema	Halimbawang Salita
erpektibo	Mi + salitang-ugat	Mikaon, Milakaw, Miinom, Milangoy, Mipalit, Misakay
	Gi + salitang-ugat	Giluto, Giabrehan, Gidala, Gibasa, Gikuha, Gibira
	Nag +salitang-ugat	Naghuwat, Nagbasa, Naglung-ag, Nagkaon, Nagpalit
	Na + salitang-ugat	Nalipong, Nanira, Natulog, Naligo, Nanamin, Namata, Nanalipod, Namiya
imperpektibo	Ga + salitang-ugat	Gakuha, Galuto, Galakaw, Gabasa, Galangoy, Galumba
	Gina + salitang-ugat	Ginabira, Gina-ilog, Ginakuha
	Naga +salitang-ugat	Nagalakaw, Nagasayaw, Nagadamgo, Nagatuon, Nagakaon, Nagakanta, Nagakatawa, Nakahilak
kontemplatibo	Mag + salitang-ugat	Magpalit, Magluto, Magkaon, Mag-inom, Magtanum

	Ma + salitang-ugat	Mamalit, Makurat,Matulog, Maligo, Makuha, Mabira
	On/hon+ salitang-ugat	Kuhaon, Lutuon, Dakupon, Ilugon, Basahon, Uyugon

Batay sa inilalahad sa Talahanayan 4, makikita na ang Wikang Filipino at Wikang Cebuano ay kapwa may sistematikong paggamit ng mga aspektong pandiwa, partikular ang perpektibo, imperpektibo, at kontemplatibo, na nagpapakita ng pagkakapareho sa kanilang gramatikal na balangkas bilang mga wikang Austronesian. Sa parehong wika, ginagamit ang mga panlaping “nag-” at “na-” sa aspektong perpektibo, na nagpapahiwatig ng natapos na kilos. Ipinapakita nito na may mga shared morphological features ang dalawang wika na maaaring nag-ugat sa magkatulad na lingguwistikong pinagmulan.

Gayunpaman, kapansin-pansin din ang pagkakaiba sa iba pang panlapi na ginagamit sa pagbuo ng aspekto ng pandiwa. Sa imperpektibo, ang Cebuano ay gumagamit ng “naga-,” “gina-,” at “ga-,” samantalang sa Filipino ay may sariling katumbas na anyo. Sa kontemplatibo naman, ang paggamit ng “mag-,” “ma-,” at “-on/-hon” ay nagpapakita ng mas malinaw na pagkakaiba sa estruktura at morpolohiya ng dalawang wika. Sa kabuuan, ipinahihiwatig ng pagsusuri na bagaman may pagkakatulad sa ilang panlapi, nananatili ang makabuluhang baryasyon sa sistema ng pandiwa ng Filipino at Cebuano, na nagpapakita ng kanilang natatanging pag-unlad sa loob ng kani-kanilang lingguwistikong komunidad.

KONKLUSYON

Sa kabuuan, ang Wikang Filipino at Wikang Cebuano ay kapwa mahalagang bahagi ng mga wikang umiiral sa Pilipinas at nagmula sa iisang pamilyang Austronesian, kaya’t hindi nakapagtataka na may malalaking pagkakatulad ang dalawa. Makikita ang kanilang pagkatutulad at pagkaiiba sa ilang bokabularyo, lalo na sa mga salitang tumutukoy sa pamilya, bahagi ng katawan, at pang-araw-araw na gamit. Pareho rin silang gumagamit ng mga panlapi upang makabuo ng iba’t ibang anyo ng pandiwa at ipakita ang aspekto tulad ng perpektibo, imperpektibo, at kontemplatibo. Dahil dito, mas madaling maunawaan ng mga nagsasalita ng dalawang wika ang ilang istruktura ng bawat isa.

Gayunpaman, may malinaw ding pagkakaiba ang Filipino at Cebuano. Nagkakaiba sila sa ilang salitang ginagamit para sa iisang kahulugan, gayundin sa bigkas at ispeling ng mga salita. May mga panlaping natatangi sa Cebuano na hindi karaniwang ginagamit sa Filipino, at mayroon ding mga pagbabago sa tunog o titik na nagdudulot ng pagkakaiba sa anyo ng salita. Bukod dito, ang ilang salita ay ganap na magkaiba sa dalawang wika.

Sa huli, ang Filipino at Cebuano ay parehong mayaman at makabuluhang wika na nagpapakita ng kultura at pagkakakilanlan ng mga Pilipino, na may sapat na pagkakatulad upang magkaunawaan ngunit may mga pagkakaibang nagpapanatili ng kanilang natatanging identidad.

REKOMENDASYON

Batay sa mga natuklasan at konklusyon ng pananaliksik, ang sumusunod na mga rekomendasyon ay binuo ng mananaliksik:

Una, karagdagang pananaliksik ay mainam upang mas mapalalim ang pag-uunawa sa mga natuklasan sa pag-aaral at masuri pa ang ilang kayarian ng wikang Filipino at Cebuano.

Ikalawa, Magkaroon ng tala ng mga salitang may pagkakatulad at pagkakaiba sa wikang Cebuano at Filipino upang maging sanggunian ito sa mga estudyante sa lahat ng antas ng edukasyon

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AN AI- POWERED DECISION SUPPORT SYSTEM FOR LOCAL GOVERNMENT UNITS AND MICRO, SMALL, AND MEDIUM ENTERPRISES

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ABSTRACT

In the Philippines, LGUs and MSMEs operate in data-siloed solutions that do not provide them with harmonized tools that enable them to engage in joint decision-making on business location and compliance to the zoning ordinance. Existing digital solutions are either prohibitively expensive, too demanding in terms of infrastructure, or tailored for a single type of user, neglecting rural and informal businesses. For this purpose, in this study, an AI Business Zoning Guide—an economy, two-sided, web-based Decision Support System to connect institutional regulations with entrepreneurial needs using AI and geospatial analytics— has been proposed and developed. The system features real-world business locations (primarily obtained from Google Maps), theoretically reconstructed land- use zones (farming, commercial, residential, industrial, and restricted or hazardous area), and open government data. Developed with open source technologies — React for frontend, FastAPI for backend, and PostgreSQL with PostGIS as database — the prototype includes role-specific dashboards, interactive zoning map, and AI-driven business advisories. Validation through expert confirmed the system's functional accuracy, contextual relevance, and perceived usefulness. Results demonstrate that a technically robust, institutionally grounded, and low-infrastructure AI-DSS is feasible and valuable in Philippine local governance settings. By co-designing technology with grassroots realities, AI Business Zoning Guide offers a scalable model for inclusive digital innovation in developing economies.

Keywords: *AI-powered decision support system, LGUs, MSMEs, business zoning, geospatial analysis, frugal innovation, dual-user system*

INTRODUCTION

In the Philippines, Decision Support Systems (DSS) remain significantly underdeveloped at the local governance level. Although national frameworks such as the Department of the Interior and Local Government's (DILG) Seal of Good Local Governance and the Local Government Performance Management System provide evaluative benchmarks for service delivery, they lack predictive or prescriptive analytical capabilities (Department of the Interior and Local Government [DILG], n.d.). Most Local Government Units (LGUs)—comprising provinces, cities, municipalities, and barangays—continue to rely on manual, paper-based processes or fragmented digital records for urban planning, business regulation, and resource allocation (Republic Act No. 7160, 1991). Concurrently, Micro, Small, and Medium Enterprises (MSMEs), which constitute over 99% of all registered businesses and employ the majority of the national workforce (Department of Trade and Industry [DTI], 2023), operate without access to real-time market intelligence or structured decision-support tools. This institutional and technological deficit impedes evidence-based policy making and constrains local economic resilience, particularly in rural and peri-urban contexts where digital infrastructure is limited.

Existing technological interventions offer only partial solutions. Commercial AI-enabled platforms such as QuickBooks and Zoho Inventory provide advanced analytics but are often cost-prohibitive, require stable broadband connectivity, and assume a level of digital literacy uncommon among micro-entrepreneurs in low-resource settings (World Bank, 2021). In the public sector, AI applications in the Philippines have been largely experimental and domain-specific—focused on disaster risk management, health logistics, or traffic optimization—but none integrate cross-sectoral data to jointly support LGU planning and MSME strategy (UNDP, 2022). As recent studies note, fewer than 20% of rural MSMEs use digital tools beyond mobile banking, and AI adoption in LGUs remains nascent, with minimal integration into core administrative workflows (World Bank, 2021). Critically, current systems are rarely co-designed with end-users, resulting in poor alignment with grassroots decision-making contexts and institutional routines.

This evidentiary and operational void reflects four interrelated research gaps. First, a dual-user gap: extant DSS architectures treat LGUs and MSMEs as siloed entities rather than interdependent actors within a shared local economic ecosystem (Lumapguid & Bentulan, 2025). Second, a contextual gap: prevailing AI solutions are engineered for high-resource environments, neglecting constraints such as low bandwidth, intermittent power, device scarcity, and mixed literacy levels characteristic of many Philippine barangays (Prahalad, 2012). Third, a participatory design gap: top-down technological interventions frequently exclude frontline stakeholders—such as barangay captains and sari-sari store owners—from the design process, undermining usability and trust (Sharma et al., 2020). Fourth, an evaluation gap: there is scant empirical research on whether and how AI-DSS meaningfully improve the speed, quality, or confidence of real-world decisions in Global South local governance settings (Janssen et al., 2020).

To address these lacunae, this study proposes the AI Business Zoning Guide—an AI-powered Decision Support System (AI-DSS) co-developed through participatory engagement with LGU officials and MSME representatives in Butuan City. The system integrates open government data (e.g., from the Philippine Statistics Authority [PSA], DTI, and DILG), geospatial zoning records, and simulated business indicators to deliver role-specific insights: LGUs receive analytics on business clustering, regulatory compliance, and public grievance sentiment, while MSMEs obtain viability assessments and location recommendations based on market potential and competitive density. Built on a frugal, open-source stack (React/Vite, FastAPI, PostgreSQL/PostGIS), the platform prioritizes explainability, modularity, and compatibility with low-infrastructure environments. Its design is theoretically anchored in the Technology Acceptance Model (Davis, 1989) and Institutional Theory (DiMaggio & Powell, 1983) to ensure both usability and institutional legitimacy.

By bridging artificial intelligence, geospatial analytics, and participatory governance, this research contributes to the emerging discourse on frugal AI for inclusive development. It advances not only a functional prototype but also an empirically grounded framework for deploying human-centered, dual-user AI systems in resource-constrained public sector contexts—offering a scalable model for strengthening data-driven local governance and MSME competitiveness in the Philippines and similar settings.

STATEMENT OF OBJECTIVES

General Objective

The general objective is to design, develop, and evaluate an AI-powered Decision Support System that enhances data-driven decision-making for LGUs and MSMEs in the Philippines.

Specific Objectives

1. To design a modular, role-based system architecture that integrates geospatial data, open government datasets, and AI-driven analytics for business zoning and viability assessment.
2. To develop a functional web-based application using React (frontend), FastAPI (backend), and PostgreSQL with PostGIS (database), embedded with machine learning models for clustering, classification, and business recommendation.

3. To implement key features including an interactive zoning map, business recommendation engine, competitor density visualization, and compliance validation based on local ordinances.

METHODOLOGY

Software Development Life Cycle (SDLC)

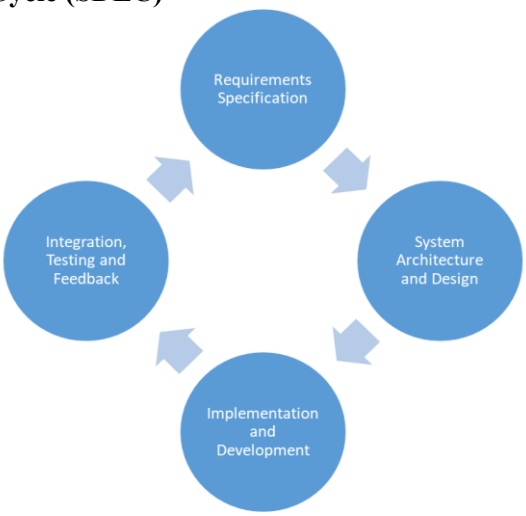

Figure 1 SDLC Diagram

The development of the AI Business Zoning Guide (B-Lines) followed an iterative, user-informed Software Development Life Cycle (SDLC) tailored to the technical and functional requirements of a dual-user, AI-integrated web application. The approach prioritized modularity, rapid prototyping, and seamless integration of frontend, backend, and AI components, while aligning with the constraints of low-infrastructure environments typical in Philippine local settings. The SDLC comprised four core phases: (1) Requirements Specification, (2) System Architecture and Design, (3) Implementation, and (4) Integration and Validation.

In the Requirements Specification phase, functional and non-functional requirements were derived from a synthesis of user personas (e.g., barangay captain, sari-sari store owner), decision-making workflows, and technical constraints such as limited bandwidth and mobile-first access. These requirements emphasized role-based views, geospatial zoning visualization, business viability prediction, and public grievance monitoring—all while ensuring simplicity, responsiveness, and offline usability.

The System Architecture and Design phase established a three-layer modular structure:

The frontend layer, built with React and Vite, renders interactive dashboards and maps using Leaflet.js and GeoJSON, supports client-side routing via React Router, and communicates with the backend through Axios.

The backend layer, implemented in FastAPI (Python), provides RESTful API endpoints, enforces data validation via Pydantic, and integrates AI models for real-time inference.

The data layer, powered by PostgreSQL with PostGIS, stores and queries geospatial business records, zoning polygons, and user inputs using SQLAlchemy and GeoAlchemy2.

During Implementation and Development, the system was constructed using a consistent open-source stack:

The AI models (e.g., K-Means for clustering, Random Forest for classification) were trained and validated in Anaconda Navigator using scikit-learn, Pandas, and NumPy, then serialized via Joblib for deployment.

The FastAPI backend loaded these models at runtime to deliver predictions on business viability, market opportunity, and sentiment analysis.

Leaflet.js rendered interactive zoning maps, while the Open Source Routing Machine (OSRM) enabled accurate road-distance computation for spatial analytics.

All components were developed incrementally with version control and cross-layer compatibility in mind.

The final phase, Integration, Testing and Feedback, focused on ensuring seamless data flow and functional coherence across the stack. Unit tests verified individual modules (e.g., geospatial queries, API endpoints, model inference), while integration tests confirmed end-to-end functionality—such as fetching a recommended business location from the AI model, validating zoning compliance via PostGIS, and displaying the result on the map interface. The system was validated against predefined functional requirements, with emphasis on performance, responsiveness, and error handling.

By anchoring the development process in a structured SDLC, this study ensures that the AI Business Zoning Guide is a technically robust, modular, and scalable application—designed not for immediate field deployment, but as a fully functional prototype that demonstrates the feasibility of an AI-powered, dual-user decision support system for Philippine LGUs and MSMEs.

System Architecture

The following technologies and software were selected based on performance, compatibility, frugality, and support for AI integration:

The AI Business Zoning Guide is built upon a modular, three-tier software architecture—comprising presentation (frontend), application logic (backend), and data management (database) layers—designed to ensure scalability, maintainability, and compatibility with low-resource environments. This architecture is defined not only by its technological stack but also by three interdependent sets of requirements: hardware, software, and user specifications, all derived from the operational realities of Philippine LGUs and MSMEs.

Hardware requirements were kept minimal to support accessibility in settings with limited infrastructure. The system is optimized to run on standard mobile devices or low-end computers with at least 2 GB RAM, a modern web browser (e.g., Chrome, Firefox, or Samsung Internet), and intermittent internet connectivity. While server-side processing (for AI inference and geospatial queries) assumes a development or hosting environment with 4+ GB RAM and a dual-core processor, the client-side application is designed to remain functional with cached assets and lightweight payloads, ensuring usability even under poor network conditions.

Table 1 Hardware Components

Component	Specifications	Purpose
Client-Side (End-User Device)	• Smartphone or computer with at least 2 GB RAM • Modern web browser (e.g., Chrome, Firefox, Samsung Internet) • Screen resolution: ≥ 720p	Ensures accessibility for LGU officials and MSME owners using low-end or mid-range devices commonly available in rural and peri-urban Philippine settings. Supports mobile-first usage with responsive UI.
Server-Side (Development/ Hosting Environment)	• Processor: Dual-core CPU or higher • Memory: 4 GB RAM or more • Storage: 20 GB SSD (minimum) • Operating System: Windows, Linux, or macOS	Provides sufficient resources to run the FastAPI backend, PostgreSQL/PostGIS database, and AI model inference simultaneously during development and lightweight deployment.
Network	• Client: Intermittent or low-bandwidth internet (≥ 1 Mbps for initial load) • Server: Stable internet connection (for cloud hosting or remote access)	Optimized for environments with unstable connectivity; core assets are cached for offline map viewing, though AI features require initial online load.

Software requirements define the technical ecosystem across development and runtime environments. On the frontend, the system uses React 18 with Vite for fast development and optimized builds, TailwindCSS for responsive styling, Leaflet.js for interactive mapping, and Axios for API communication. The backend is implemented in Python 3.10+ using FastAPI, leveraging Pydantic for data validation and Uvicorn as the ASGI server. The database layer employs PostgreSQL 14+ with PostGIS 3.3+ to support geospatial operations, interfaced via SQLAlchemy and GeoAlchemy2. AI models (e.g., K-Means, Random Forest) are developed in scikit-learn 1.3+, with data processing handled by Pandas and NumPy, and model persistence managed via Joblib. The entire stack is open-source, cross-platform, and containerizable (e.g., via Docker), facilitating future deployment without proprietary dependencies.

Table 2 Software Requirements

Component	Technology/Tool	Purpose
Frontend	React + Vite	Dynamic, responsive UI with fast hot-reloading
	Leaflet.js + GeoJSON	Interactive map visualization of zoning and business locations
	Axios, React Router	API communication and client-side navigation
	TailwindCSS	Responsive, modern styling
Backend	FastAPI (Python)	High-performance RESTful API with automatic OpenAPI docs
	Pydantic	Data validation and serialization
Database	PostgreSQL + PostGIS	Storage and querying of geospatial and relational data
	GeoAlchemy2, SQLAlchemy	ORM for spatial data integration
AI/ML Environment	Scikit-learn, Pandas, NumPy	Data preprocessing, feature engineering, and model training
Deployment	Vercel/Render/Supabase/Neon	Scalable, modular cloud hosting with free-tier support

User requirements form the foundation of the system's functional design and are derived from dual-user personas: LGU officials (e.g., barangay captains, business permit officers) and MSME owners (e.g., sari-sari store operators, street vendors). For LGUs, the system must provide zoning compliance validation, and business cluster visualization through an intuitive dashboard. For MSMEs, it must deliver location-specific business recommendations, competitor density maps, and plain-language guidance on permit requirements. Crucially, both interfaces must operate in Filipino or English, require minimal training, avoid technical jargon, and function smoothly on mobile screens—reflecting the limited digital literacy and device preferences of target users. These requirements directly informed the choice of a responsive, role-based UI and the integration of explainable AI outputs (e.g., viability scores with clear reasoning).

Together, these hardware, software, and user requirements ensure that the software architecture is not merely a technical blueprint but a contextually grounded, human-centered framework—balancing computational capability with real-world accessibility in the Philippine local development setting.

The **Database Design** of the AI Business Zoning Guide is centered on a relational, geospatially enabled schema implemented in PostgreSQL 14 with the PostGIS 3.3 extension, chosen for its robust support of spatial data types, indexing, and SQL-based geospatial operations. The schema is normalized to reduce redundancy while optimized for read-heavy analytical queries typical in decision support contexts. It comprises five core entity tables—users, businesses, zones, grievances, and recommendations—each structured to support the dual-user functionality of the system.

RESULTS AND DISCUSSIONS

System Implementation and Core Features

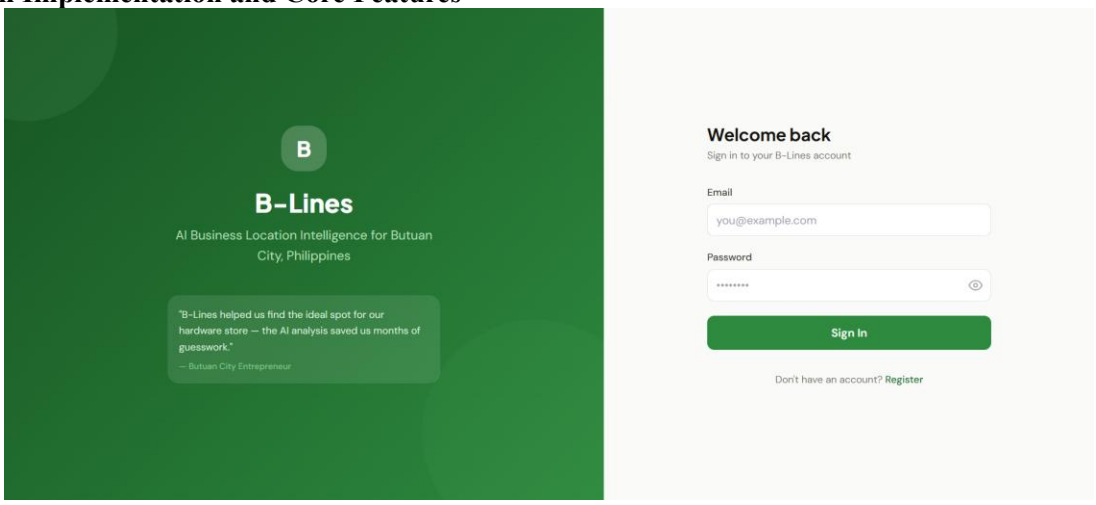

Figure 2 Web App's Landing Page

Figure 2 is the web app's landing page where the user can log in. If the user don't have an account, they can create an account by clicking the word "Register" below the sign in button. The admin user can also log in this page with account given by the super admin that will manage the application.

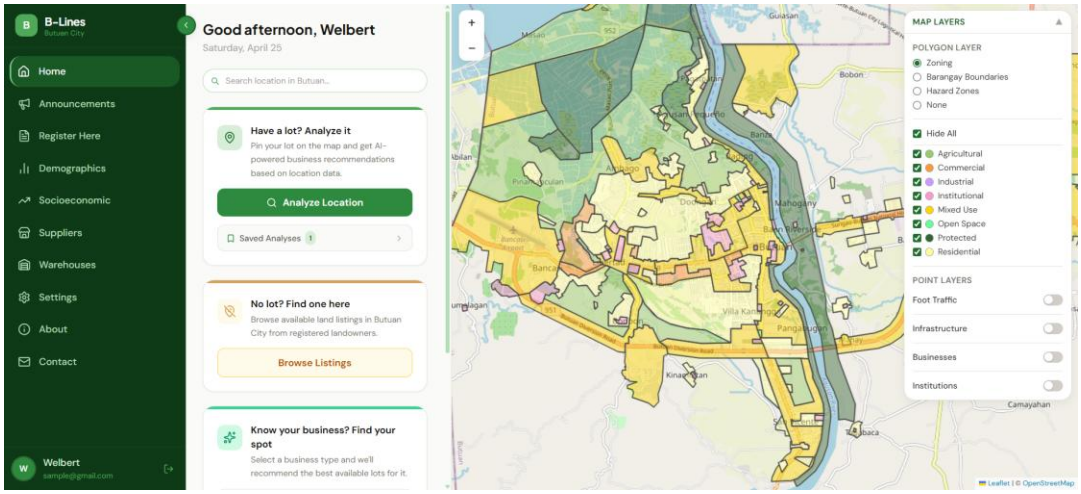

Figure 3 End-User's Main Interface

Figure 3 is the main interface features all the core feature of the web application. On the right side bar is the map layers where you can see the zoning division, barangay boundaries and hazard zones in the interactive map. You can also see the foot traffic, infrastructure, active businesses and institutions in the map by toggling it on.

The white part of the left side bar is where AI comes in. This feature is to recommend type of business or business points to start entrepreneurship journey. Users can ask to analyze chosen place for what business to build, look for available places or to ask where is the good spot to start this kind of business.

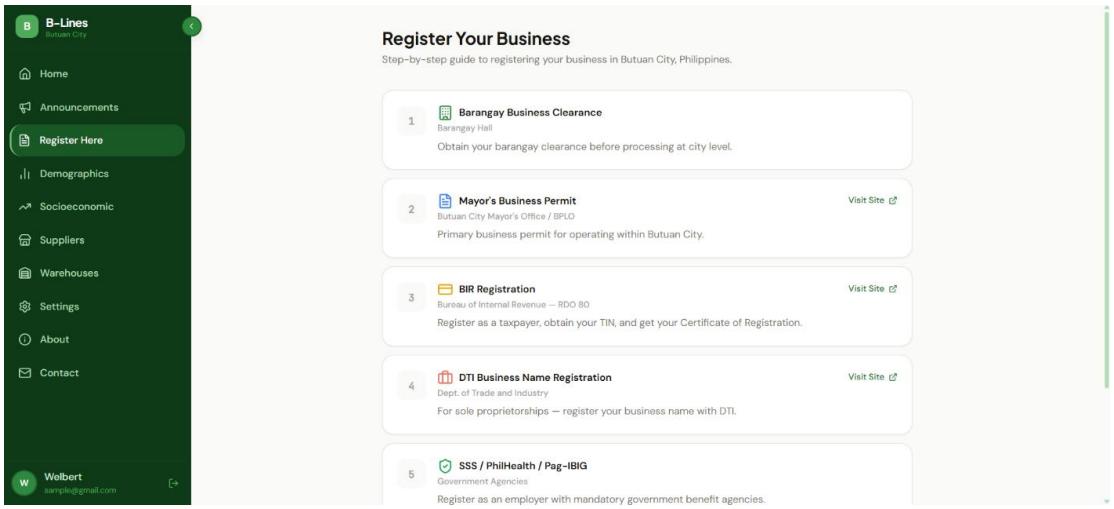

Figure 4 Registration Page Guide

Figure 4 is one of the main feature of the app. User can access this by clicking “Register Here” in the left side bar. This feature is to help and guide the entrepreneurs on their registration for their businesses. It will make registration faster by guiding them to the city’s and nationals’ legal compliances.

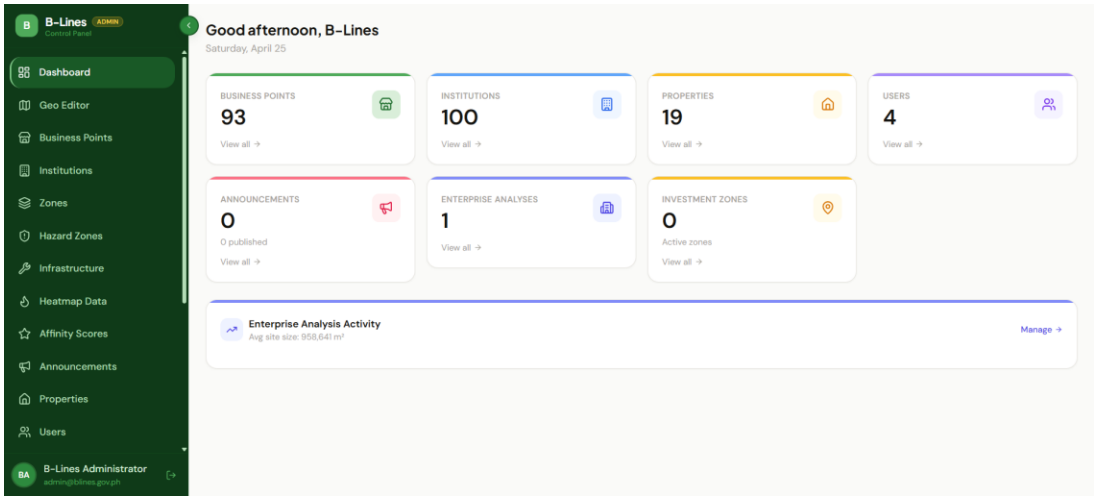

Figure 5 Admin’s Main Interface

Figure 5 is the main interface of Admin where the city LGU has access to. Upon accessing the admin page, admin user will be greeted by the statistics page of all the features of the app; these are the business points, institutions, properties, users, announcements, enterprise analyses and investment zones. In the left side bar is where admin can manage the different features of the app that will also reflect on the msme’s user page. Admin can edit information like zones and business points by adding, deleting or simply edit the data. This page is where a lot of things happens so it should be only access by few people, mainly the LGU that is assigned to it.

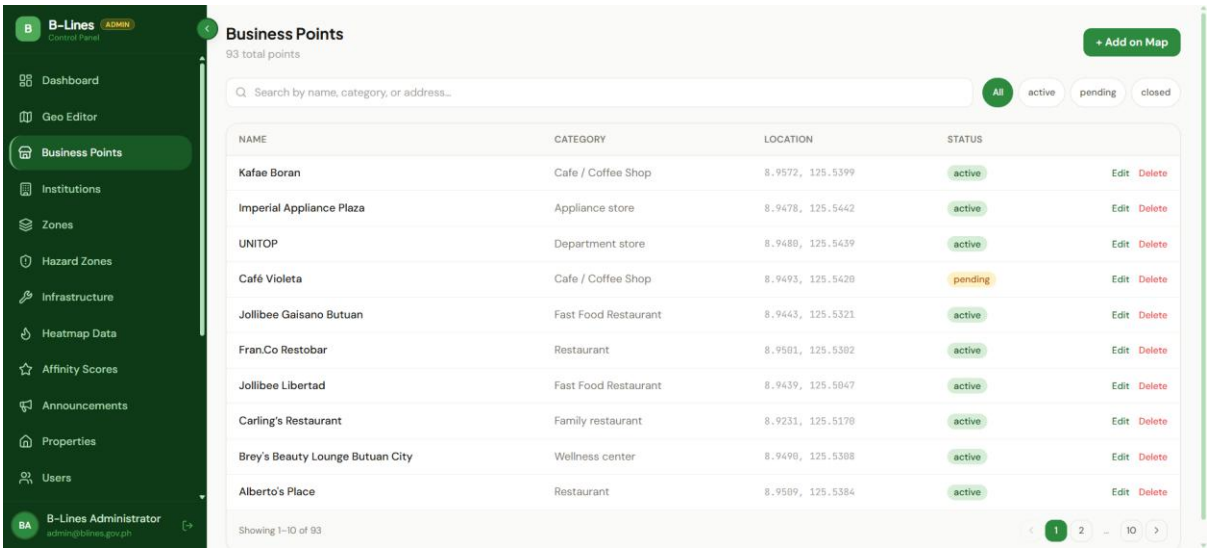

Figure 6 Business Points Page

Figure 6 is one of the features of the admin page where admin user can manage businesses. Admin can edit active businesses like adding or deleting. Admin user can also confirm pending requests that comes from the msme's side of the web app. Click "Add on Map" on the right top corner of the page and the interface will be redirected to the interactive map which is part of the "Geo Editor". The geo editor is where admin users can edit layers of the map. It is where admin can click parts of the map to add new business, delete business spots or manage zoning allocations of the city and more.

CONCLUSIONS

This study addressed the gap in localized, dual-user decision support tools for Philippine LGUs and MSMEs by designing and developing the B-Lines: AI Business Zoning Guide—a frugal, web-based AI-powered Decision Support System. Grounded in the Technology Acceptance Model and Institutional Theory, the system integrates real-world business data from Google Maps, synthetic but regulation-compliant zoning layers (including agricultural, commercial, residential, industrial, and restricted land uses), and lightweight machine learning models to deliver role-specific insights. Built using an open-source stack (React, FastAPI, PostgreSQL/PostGIS), the prototype features interactive zoning maps, real-time compliance validation, business viability scoring, and competitor density analysis. Preliminary validation through expert interviews and a TAM-aligned questionnaire confirmed the system's functional accuracy, contextual relevance, and potential usability—demonstrating that a technically sound, institutionally aware, and user-centered AI-DSS can be developed without large-scale resources or complex infrastructure.

The successful implementation of B-Lines proves that AI for local governance need not be high-cost or high-complexity. By embedding legal zoning frameworks and MSME operational realities into a single, responsive interface, the system bridges a critical information asymmetry between regulators and micro-entrepreneurs. It transforms fragmented public data into coordinated, actionable intelligence—empowering LGUs to enforce regulations more efficiently and enabling MSMEs to make informed location decisions with greater confidence. While this research focuses solely on system construction, the prototype establishes a replicable model for frugal innovation in public-sector AI, one that prioritizes accessibility, transparency, and institutional legitimacy over technological novelty.

RECOMMENDATIONS

Based on the development experience and expert feedback, the following recommendations are proposed:

For System Enhancement:

1. Improve offline functionality.
2. Add support for Filipino, Cebuano, and other regional languages.
3. Improvement for AI and Interactive Zoning Maps (satellite imagery/terrain mode)
4. Integration of hardware like Drones for real-time aerial view

For LGU Adoption

1. Integrate B-Lines as a pre-screening tool in the business permit application process.
2. Use grievance and clustering insights for proactive urban planning and enforcement.

For Policy and Research

1. National agencies (DTI, DILG, DICT) should promote standardized open zoning and business data formats to enable interoperability.
2. Future studies should conduct a full pilot deployment to evaluate impact on decision quality, processing time, and user trust using rigorous mixed-methods approaches.
3. Explore Explainable AI techniques to further enhance user understanding of recommendation logic.

In sum, B-Lines is more than a prototype—it is a step toward equitable, data-driven local development where technology serves the many, not just the few.

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