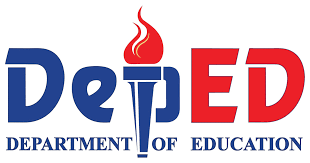
**Kidapawan City Division**

RESEARCH ARTICLE

**PLEMA: Pathogen Locator Evaluation for Mycobacterium Analysis**

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**Abstract**

*Keywords:*

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Roxas St., Kidapawan City

**PLEMA: Pathogen Locator Evaluation for Mycobacterium Analysis**

A Research Study Presented to the Faculty and Staff of

Kidapawan City National High School

Kidapawan City

In Partial Fulfillment of the Requirements for Research IV in

Science, Technology, and Engineering Program

**Members:**

**Oasay, Angela Marie B.**

**Labrado, Jellian Pauline B.**

October 2025

****J **Kidapawan City National High School**

**Science, Technology and Engineering Program**

**Roxas St., Kidapawan City**

**APPROVAL SHEET**

The Investigatory Project entitled, **“PLEMA: Pathogen Locator Evaluation for Mycobacterium Analysis”** prepared and submitted by Oasay, Angela Marie B., Labrado, Jellian Pauline B., in partial fulfillment for the requirements of Science, Technology, and Engineering Program has been examined and is hereby recommended for approval and acceptance.

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**INTRODUCTION**

In Kidapawan City, medical equipment plays a vital role in supporting local healthcare facilities and sustaining the health and livelihoods of many families. However, the city faces major challenges due to the limited availability of modern diagnostic tools and technologies. Many essential diagnostic procedures are still conducted manually, which leads to delays, increases the likelihood of human error, and reduces the overall efficiency of healthcare services. One of the most pressing health concerns in the region is tuberculosis (TB), a life-threatening disease caused by *Mycobacterium tuberculosis* (Mtb), which continues to be a leading cause of death globally, with over one million fatalities recorded each year. In low-resource settings such as Kidapawan, there is an urgent need for accurate, and accessible diagnostic methods to identify TB cases early and initiate timely treatment (Nneoma K. A., et al., 2025). Addressing this need requires innovative solutions that can improve the quality of healthcare services without imposing significant financial or logistical burdens on the system.

This study advocates for the deployment of the PLEMA system (Pathogen Locator Evaluation for Mycobacterium Analysis), an automated robotic platform specifically designed to perform sputum smear microscopy for TB diagnosis. By integrating robotics with AI-powered image analysis, PLEMA is capable of enhancing diagnostic accuracy while significantly reducing manual errors and processing time. The proposed system will be validated using a substantial dataset of sputum samples collected locally in Kidapawan City, ensuring that the technology is tailored to the unique epidemiological and environmental conditions of the country. Additionally, PLEMA will be designed to integrate seamlessly with existing health information systems and function reliably across various laboratory settings, including those in rural or under-resourced areas. A key feature of PLEMA is its user-friendly interface, which allows for rapid adoption by laboratory personnel without disrupting traditional workflows. Ultimately, the implementation of PLEMA represents a transformative step toward modernizing diagnostic practices in Kidapawan City, improving public health infrastructure, and advancing sustainable and scalable healthcare technologies for the broader community.

**STATEMENT OF THE PROBLEM**

The team expects PLEMA for the laboratory. The study aims to develop laboratory equipment that can acquire results automatically. Three sets of trials will be performed to check the functionality of our project. The team will be testing in a laboratory to check the effectiveness of PLEMA when working in the specific kind of field, on how the microscope will obtain the data automatically and accurately. Specially, to answer the following questions:

  1.  How accurate PLEMA will acquire data in:

* Spot Sputum
* Early Morning sputum
* Second Spot Sputum

  2.   Does PLEMA provide a more cost-effective option than existing methods?

  3. What is the data collection and analysis speed of PLEMA?

**Hypothesis**

There is no significant difference between PLEMA and a traditional optical microscope across the three sets and three trials.

**REVIEW OF RELATED LITERATURE**

**Automation of Microscopes**

Automated microscopy has greatly improved TB diagnostics by enhancing accuracy and efficiency. Systems like μ-Scan 2.0 have achieved 95.7% accuracy, 87.7% sensitivity, and 96.0% specificity in sputum smear analysis, showing promise for use in resource-limited settings (Liu et al. 2022). Similarly, an intelligent microscopy scanner integrated with AI image recognition delivered 96.70% accuracy, 91.94% sensitivity, and 97.97% specificity, while saving ~5 person-hours per 100 smears, thereby reducing technician workload (Wang et al. 2024).

Deep learning–based systems have also been found to outperform traditional image-processing methods by abstracting complex features from sputum smear images with minimal human intervention (Melendez et al. 2022). In practice, AI-based high-volume screening systems have rescued missed positive cases, improving sensitivity to 85.7% while maintaining 96.9% specificity, although sample quality remains crucial for consistent outcomes (Chen et al. 2022). Moreover, a meta-analysis confirmed that AI-based automated microscopy tends to have higher pooled sensitivity (0.849) but lower specificity (0.700) than manual microscopy, highlighting a trade-off between detection and false positives (Li et al. 2024).

**Integrating Artificial Intelligence into Healthcare**

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**Artificial Intelligence in Tuberculosis Diagnosis**

AI-based microscopy systems trained on TB sputum smear images using convolutional neural networks (CNNs) outperform traditional image-processing approaches by extracting complex features with higher generalization and reduced need for human intervention (PubMed 2022). This suggests that researchers view AI as not only a tool for automating tedious tasks but also as a method to improve diagnostic quality by identifying patterns invisible to the human eye. In a multicentric clinical trial in India, an AI-powered microscopy system demonstrated 89.25% sensitivity, 92.15% specificity, and 91.53% overall diagnostic accuracy, proving its reliability for clinical use (Gupta et al. 2023). This implies that AI can potentially reduce diagnostic delays and standardize TB detection across laboratories with varying expertise.

**Comparison with Traditional Microscopy**

When compared to manual smear reading, AI-based microscopy achieved up to 95.2% accuracy, 85.7% sensitivity, and 96.9% specificity once poor-quality smears were excluded. The system also recovered 85 previously missed positives (Chen et al. 2022). Researchers interpret this as evidence that AI can act as a safety net for human errors, providing a second layer of verification that enhances both accuracy and reliability in TB diagnostics.

**Clinical Impact and Workflow Efficiency**

Meta-analyses show that AI-based automated microscopy (AI-AM) achieves higher pooled sensitivity (0.849 vs. 0.776) but slightly lower specificity (0.700 vs. 0.983) compared to manual microscopy (Li et al. 2025). This suggests that while AI may increase false positives, it is more effective at minimizing false negatives, making it valuable in high-throughput or early-stage screening where missing a TB case could have severe consequences.

**Limitations and Challenges**

Despite advances, AI-driven sputum smear analysis faces challenges. Limitations include small sample sizes in studies, reduced performance in patient subpopulations such as HIV-positive and pediatric groups, and variability in sample quality (Memon, Bibi, and He 2025). Researchers acknowledge that while AI holds great promise, it is not yet a full replacement for human expertise; rather, it should be viewed as a complementary tool that requires further refinement, validation, and careful integration into existing health systems.

**METHODOLOGY**

**Materials and Methods**

Materials Quantity

Objective lens

(oil immersion) 1 pc

166 mm Tube lens 1 pc

10x widefield eyepiece 1 pc

Condense 1 pc

Field lens 1 pc

LED light source 1 pc

SVBONY SV109 1 pc

MicroSD Card 1 pc

ESP32 Microcontroller 1 pc

Immersion Oi l 30 mL

Glass slide and cover slip 1 set

**Treatments**

Treatment 1 – 5 mL spot sputum

Treatment 2 – 5 mL early-morning sputum

Treatment 3 – 5 mL second spot sputum

Control: Standard Diagnostic Method

**Study Design and Study Area**

**Gathering of Materials**

The majority of materials were bought outside the Philippines—since most of the materials are not found in the local market. Some of the materials are found in the household. The materials used in the experiment include ESP32, digital microscopy (SVBONY SV109), objective lens (100× oil immersion), tube lens/optical tube (160 mm or infinity type), eyepiece, condenser (Abbe condenser with iris diaphragm), LED light source (white and adjustable), stage (automated XY stage with worm gear for push and pull mechanism), chassis (3D printed), processing unit (ESP32), and software/AI model were gathered.

**Microscopy’s Development**

The study will begin with the assembly of the automated sputum smear microscope, where the 100× oil immersion objective lens, 160 mm or infinity tube lens, and Abbe condenser with iris diaphragm are mounted onto the 3D-printed chassis. The abbe condenser will be installed to focus the LED illumination through the condenser, and the SVBONY SV109 digital camera will be mounted in place of the eyepiece and connected to the ESP32 processing unit. All components will be secured using screws, fixed mounts, and alignment tools, with electrical connections checked using a multimeter and soldering tools as necessary. Sputum smears will be prepared on clean microscope slides and stained following standard Ziehl-Neelsen or Auramine-O protocols, then placed on the XY stage and secured with the slide holder. The system will be calibrated by adjusting LED light intensity with the driver circuit. The AI software will capture digital images of the smears and analyze them for the presence of Mycobacterium tuberculosis. To validate the system, a licensed medical technologist will independently examine the same smears using a traditional optical microscope, and results from both methods will be recorded. The data will then be analyzed to compare the automated system’s accuracy, sensitivity, and specificity against the manual method. Safety measures, including the use of gloves and goggles during slide handling, lens cleaning with lens paper, and storage under a dust cover, will be strictly observed throughout the procedure.

**Pilot Testing**

Before formal deployment, pilot testing of PLEMA will be conducted to identify and correct any mechanical, electrical, or software-related issues. All components will be tested thoroughly to ensure the system operates smoothly and safely. Under the supervision of faculty advisors, medical technologists, and technical experts, the pilot test will simulate real-world lab conditions. Emphasis will be placed on validating PLEMA's ability to assist in sputum smear microscopy—the key method used in diagnosing tuberculosis (TB). Feedback gathered during pilot testing will be used to refine the system and prepare it for field implementation.

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