IREASE: An INK Removal Device

Nichol Isidore A. Lupian; Rica Jane A. Amparo; Mil Ariel C. Lamban Jr; Eirah Jen B. Langi; Kent Dhanty A. Lupiba;Kent Dhanty A. Lupiba; Ma. Gina L. Navacilla; Jascel Mae B. Padayao; Jenneth Mae V. Rosas

Science, Technology, Engineering, and Mathematics, San Agustin National High School

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ABSTRACT

This study aimed to develop and evaluate the performance of the Ink Removal and Eradication System (IREASE) device to reduce paper waste and promote paper reuse at San Agustin National High School. The system integrates chemical ink removal using acetone and sodium hypochlorite with a semi-automated process consisting of solvent application, mechanical eradication using rollers, and automated drying to remove ink from printed paper. Using a quantitative research and development (R&D) design with an experimental comparative approach, the device was developed and its performance was compared with a traditional ink removal method. Data on the percentage of ink removed and removal response time were gathered through observation, documentation, and photographic analysis.

Results showed that when acetone was used, the IREASE device achieved 77.60% ink removal with a response time of 01:30.00, compared to 50.08% and 01:58.08 for the traditional method. Similarly, using sodium hypochlorite, the IREASE device obtained 74.54% ink removal with a response time of 02:00.00, while the traditional method achieved only 51.16% with 02:27.70.

Statistical analysis confirmed significant differences between the two methods, indicating that the IREASE device is more effective and faster than the traditional ink removal method. The findings suggest that the IREASE device has strong potential for application in educational institutions to support sustainable paper reuse practices.

Keywords: IREASE device, ink removal, paper reuse, acetone, sodium hypochlorite, semi-automated system

INTRODUCTION

Rationale

In today's environmentally conscious world, paper recycling has gained significant momentum, fueled by both strong international markets and growing domestic demand. Recycled fibers now serve as an essential alternative to virgin pulp in the global paper industry, with recovery rates steadily rising each year.

Recent advancements in recycling technologies, particularly in pulping, flotation deinking, and cleaning/screening, have greatly enhanced the quality of paper produced from secondary fibers, making it comparable to that made from virgin materials.

According to Abushammala (2023), the pulp and paper industry (PPI) is a major contributor to the global economy, but it also poses a challenge for waste disposal, as it generates large amounts of several waste streams. Among these, paper rejects are generated during the papermaking process and could account for up to 25% of the produced paper.

Moreover, hundreds of millions of tons of paper are produced annually that end up in landfills if not burned or recycled. Furthermore, the PPI significantly contributes to climate change and global warming in the form of deforestation and water and air pollution.

Based on an interview with the school staff of San Agustin National High School, a large amount of single-use paper from the office is being disposed of in the Materials Recovery Facility (MRF).

Although the office shreds their paper monthly and the MRF manages waste, the excessive volume of discarded paper still adds to environmental impact and resource consumption.

This issue shows the need for solutions that reduce paper waste, such as reusing sheets, shifting to digital processes, or applying technologies that allow paper to be cleaned and reused, helping the school save resources and promote sustainability.

Ink removal from printed paper has been explored in various studies, primarily through the use of chemical solvents such as acetone, isopropyl alcohol, and other bleaching agents.

These chemicals are known to break down or dissolve ink particles, especially those from inkjet printers.

According to Sumayli et al. (2025), manual ink removal techniques, like rubbing, soaking, or wiping, have been practiced in small-scale or household settings, but they often result in damaged paper quality, chemical exposure risks, or inconsistent results.

Most of the existing solutions focus only on the chemical process without integrating any form of mechanized or system-based assistance.

However, there remains a significant gap in the development of a functional and semi-automated system that incorporates these chemical agents to efficiently remove ink while preserving the paper's reusability.

To date, very few studies have explored combining chemical ink removal with a mechanical or Arduino-based process, especially intending to make it accessible for educational or community-level recycling.

This study aims to evaluate the effectiveness and acceptability of an IREASE device that utilizes agents such as acetone, sodium hypochlorite (zonrox), and a systematic eradication process to remove ink from printed paper.

Specifically, the study seeks to determine the effectiveness of acetone, sodium hypochlorite, and systematic eradication as chemical solvents for ink removal, and to design and construct a systematic mechanism that integrates these solvents into a functional ink eradication process.

The increasing demand for efficient and precise cleaning methods in various institutional and industrial settings underscores the importance of exploring innovative solutions for ink removal.

The development of automated systems that integrate microcontroller technology offers opportunities to address these challenges by improving consistency, reducing waste, and enhancing safety measures.

By examining the use of acetone and sodium hypochlorite in a controlled, automated process, this study aligns with broader efforts to modernize maintenance practices, promote operational efficiency, and encourage the adoption of practical, technology-driven solutions.

Theoretical Background

Sustainable ink removal has become increasingly important in recycling and waste management as conventional chemical methods pose environmental and technical drawbacks.

The following theoretical background reviews these developments, emphasizing specific chemical agents role in advancing both environmental sustainability and practical deinking performance.

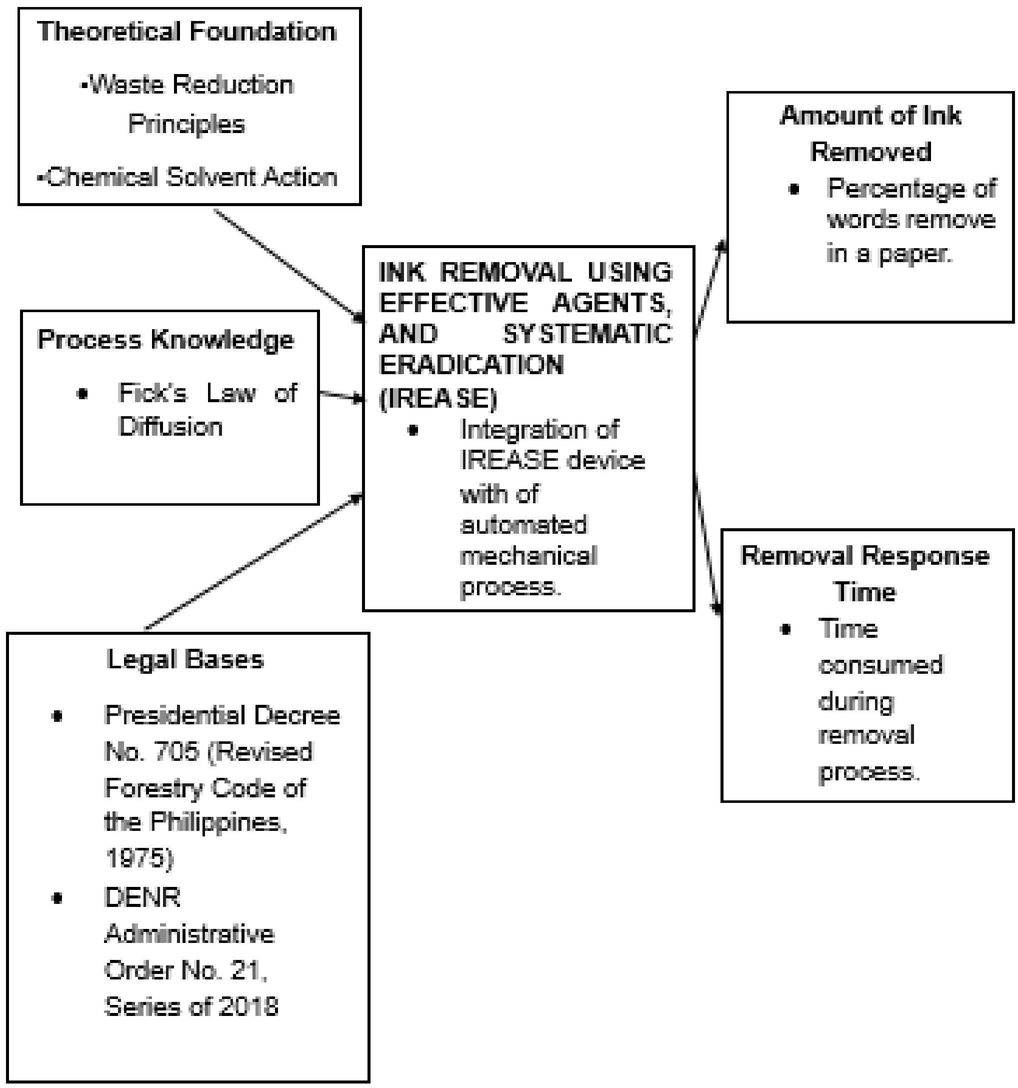

Figure 1. Conceptual Framework of the Study

According to Amir et al. (2025), the Waste Reduction Principles tackle about the 3R-based Zero Waste approach aims to minimize household solid waste through the principles of Reduce, Reuse, and Recycle. This study examines the relationship between household environmental knowledge, personal attitude, subjective norms, and perceived behavioral control as key behavioral predictors. A structured survey was conducted among 1,200 urban households across 12 Indonesian cities. Data were analyzed using Pearson correlation and multiple regression analysis.

Based on the study by Guo et al. (2023) showed that Chemical Solvents Action remove ink by breaking the forces that hold it to surfaces, and that controlling the chemical conditions improves effectiveness. It explains how the chemical solvent action theory removes the ink pigments from the paper. The IREASE device applies this principle by using precise, Arduino-controlled chemical and mechanical action to efficiently remove ink from paper while keeping the process safe and eco-friendly.

The Arduino-based ink removal device using acetone and sodium hypochlorite integrates the Waste Reduction Principles and the Chemical Solvent Action Theory. Waste Reduction Principles ensure minimal solvent use, optimized process efficiency, and possible solvent reuse to reduce environmental impact. Meanwhile, the Chemical Solvent Action Theory explains how acetone and sodium hypochlorite dissolve ink by breaking pigment–binder bonds through solubility and surface interactions. By combining these, the system can precisely control solvent application and contact time, achieving effective ink removal while remaining sustainable and cost-efficient.

Presidential Decree No. 705 (Revised Forestry Code of the Philippines, 1975) emphasizes sustainable forest management and environmental protection in the Philippines. According to Domingo and Manejar (2019), the study explains how this decree shaped forestry policies by strengthening conservation, regulation, and accountability in resource use. In relation to ink removal using acetone, sodium hypochlorite, and systematic eradication, the decree's principles remind us that improper handling and disposal of chemicals can contribute to environmental degradation similar to unsustainable forest exploitation. Thus, applying systematic and responsible chemical management in experiments aligns with the law's goal of ensuring long-term ecological sustainability.

The Department of Environment and Natural Resources Administrative Order No. 21, Series of 2018, provides stricter guidelines on hazardous waste management to safeguard public health and the environment. According to Ditan (2023), the Philippines continues to face challenges in hazardous waste handling, such as improper storage, disposal, and a lack of enforcement, highlighting the need for compliance with existing regulations. In the context of ink removal experiments, the safe and systematic use of sodium hypochlorite and acetone reflects the intent of Department Administrative Orders (DAO) 21 by ensuring chemical wastes are managed responsibly. This prevents risks to both people and ecosystems, demonstrating how even small-scale laboratory activities should adopt practices consistent with national environmental policies.

Fick's first law of diffusion relates the diffusive flux to the gradient of the concentration. It postulates that the flux goes from regions of high concentration to regions of low concentration, with a magnitude that is proportional to the concentration gradient (spatial derivative), or in simplistic terms, the concept that a solute will move from a region of high concentration to a region of low concentration across a concentration gradient.

This law relates to this because it explains how acetone and alcohol molecules move from the solvent into the ink layer over time. According to the law, the rate of diffusion depends on the concentration gradient—the greater the difference between solvent concentration at the ink surface and within the ink layer, the faster the solvent penetrates and dissolves the ink pigments and binders. In this study, controlling factors such as solvent amount, contact time, and even slight agitation can maximize this diffusion process. This means the law helps the study to understand and optimize how quickly and effectively the solvent interacts with and removes the ink, leading to more efficient and consistent results.

The increasing amount of printed paper waste has created a need for simple and effective ways to remove ink so paper can be reused. Many existing ink removal methods use strong chemicals and complicated machines that may harm the environment. Recent studies show that combining mild chemical agents, mechanical action, and basic automation can improve ink removal while making the process safer and more efficient. Technologies such as Arduino-based systems allow better control of ink removal steps like chemical application, scrubbing, and drying. In line with these studies, this review of related literature discusses previous research that supports the design and importance of the IREASE device.

Recent studies have explored environmentally and alternative ink removal methods and techniques. Based on the study by Sumayli et al. (2025), investigated the potential of a specific fungal species, emericella quadrilineata (Aspergillus quadrilineatus), for deinking process as a biological agent for removing ink pigments from waste paper. The study aimed to provide an eco-friendly and sustainable to ink removal in paper recycling process. Moreover, according to Priyanti et al (2024), a corona discharge plasma was effective in de-inking, achieving the highest removal efficiency for blue ink (approximately 64%). Environmentally sustainable deinking technologies have gained increasing attention due to the environment disadvantage of conventional chemical-based recycling process. The specific plasma produced reactive oxygen and nitrogen species that interacted with the ink, weakening their molecular structure, reducing their adhesion to paper fibers, and dissolving the ink pigments.

In the other hand, enzymatic de-inking has been widely studied and investigated as an eco-friendly alternative to conventional chemical de-inking process in paper recycling. Gea et al (2020) investigated the combining of cellulase and laccase enzyme in the de-inking of newspaper pulps. Their results showed that a cellulase-to-laccase ratio produced the most favorable outcomes. This combination is significantly increased the crystallinity

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index and improved the thermal stability of the paper pulp, which means it needs to have an enhanced fiber structure. However, according to Priyanti et al. (2024), plasma deinking has demonstrated effectiveness across different ink colors, although variation in deink ability have been observed depending on the ink composition and the plasma treatment parameters such as voltage, exposure time, and tge gas type utilizes during deinking process. The findings indicated that the plasma deinking represents a viable and eco-friendly alternative to conventional deinking methods.

These studies are relevant to the development of the IREASE device as they provide a scientific support for pursuing environmentally sustainable alternatives to conventional chemical-based deinking process. These studies demonstrate that there is an effective way to remove ink pigments while minimizing environmental impact. Although the IREASE device does not employ fungal, enzyme based, or plasma treatment technologies, the theory and the principle identified in these studies, such as controlled ink to fiber interaction, the reduction of ink adhesion, and optimization of treatment parameters is the basis for the generating a sustainable and efficient solution. By integrating controlled processing and minimizing chemical dependency, the IREASE device aligns with the eco-friendly objectives and efficiency goals highlighted in these prior studies, reinforcing its potential as a sustainable solution for ink removal from paper.

Milbrandt et al. (2023) conducted a physical and statistical evaluation of paper and cardboard waste in the United States and discovered that around 110 million tons were managed locally in 2019. In the total of, over 56% was landfilled, 6% was burned, and only 38% was recycled. The study shows that discarded paper waste could result in an economic loss of $4 billion, along with considerable losses. These findings emphasize the limitations of existing paper waste disposal practices and the need for plans that lessen landfilling and help improve recovery.

Yang et al. (2020) inspect the conservation of waste paper recycling in Beijing using GIS and value chain methods. Their results found that the informal waste sector recorded for over 80% of waste paper disposal within year 2015 and 2018, while the amount of recycling facilities decreased and moved farther from urban areas. Despite that the system mainly consist sustainable structure study showed that rising prices could seriously damage recycling efforts. In the same way, Srivastava et al. (2025) reported that paper remains the largest part of municipal solid waste in the United States. Their comparison of EPA data and Waste Characterization Studies found significant discrepancy in disposal evaluation, confirming the importance of accurate data for effective policy making and waste management. Both studies shows the ongoing problem of paper waste and the limitation of current recycling solutions.

This study on the IREASE device presents a different approach of handling paper waste by allowing the reuse of paper through automated ink removal. Instead of relying only on recycling or disposal systems, the IREASE device offers an effective method to prolong the life of paper materials. This supports the demand for innovative and environmentally friendly waste management techniques, as the device lessen paper disposal, reduce resource loss, and supports environmental sustainability by converting used paper into reusable material.

The environmental importance of recycling waste paper has encouraged intensive research into chemical deinking methods that can restore cellulose fibers without compromising their strength. A comprehensive assessment of paper purification techniques has revealed that the removal of synthetic dyes and industrial pigments requires a strategic combination of chemical agents. According to Yelobay et al. (2025), the integration of surfactants such as sodium dodecyl sulfate (SDS) with oxidizing agents like sodium hypochlorite significantly enhances the optical quality of recycled paper. Their research highlights that while surfactants aid in spreading contaminants, the oxidative power of the chemical treatment is what ultimately restores the paper's whiteness, making it viable for high-grade reuse.

In a different but scientifically relevant context, the chemical properties of specific solvents are studied for their ability to dissolve complex organic layers and surface debris. A study focused on the effectiveness of medical cleaning agents investigated how certain solutions interact with organic "smear layers"—a mixture of biological matter and debris. According to Mikheikina et al. (2024), sodium hypochlorite remains the premier choice for organic dissolution due to its potent proteolytic activity, which allows it to break down stubborn surface contaminants effectively. The study emphasizes, however, that the success of the process is highly contingent on the concentration and the specific delivery method, suggesting that a systematic approach is necessary to achieve complete surface cleaning.

These scientific perspectives provide a strong technical framework for our development of the IREASE: An Ink Removal Device. The chemical deinking principles established in the study according to Yelubay et al. (2025) validate our use of sodium hypochlorite as a primary solvent for neutralizing ink pigments on printed paper. Furthermore, the precision and dissolution mechanisms detailed according to Mikheikina et al. (2024) directly inform the mechanical design of our device, specifically the need for the Arduino-controlled pump and rollers to regulate the application of the solvent. By bridging the gap between industrial paper chemistry and precise organic dissolution, our study offers a practical, semi-automated solution that maximizes paper reusability through a synergy of chemical action and mechanical control.

According to Chung et al. (2022), sodium hypochlorite, commonly known as bleach, poses a significant health risk when mishandled or mixed with other chemicals. The reason for this is that sodium hypochlorite may cause burns, respiratory issues, and gastric issues, as well as toxic tissue damage when mishandled. Another study, this time by Ki et al. (2024), which appeared in the journal Applied Sciences, illustrates how employees who use chemicals for cleaning purposes tend to risk health hazards, especially when hypochlorite is mixed with acids commonly used in cleaning agents because it may form toxic chlorine gas. This serves as an example of how health hazards may be quite prevalent when preventive steps are overlooked. Moreover, the review by Singh et al. (2022) illustrated that the wastewater emitted from paper and pulp mills comprises organic along with inorganic compounds which are toxic to aquatic life as well as human health. This paper showed that such wastewater shows endocrine disruption, neurotoxicity, and phytotoxicity, thereby emphasizing that wastewater management through industries is necessary for the proper upkeep of the environment to make it free from pollution. Similarly, Ramadhan & Masjud (2024) mentioned that unmanaged waste disposal brings adverse effects on air, water, as well as soil quality, which might exert threatening effects on human health and the environment. The process of using chemical solvents to remove ink from the surface is also exhibited by the IREASE device since it is also essential to this study since this article is about how improper handling of certain chemicals, like sodium hypochlorite, is harmful to both human health and the environment. This is because it is known that the use of the Arduino system reduces direct interaction with chemicals, which is in line with the aspect of proper ventilation and handling. The article examines automation and waste as means of mitigating harm to the environment because it is intended that with IREASE, there is an incentive to reuse paper, reduce any amount of solid wastes that are disposed of in the educational setting, and also an automated process to remove ink.

Recent studies emphasizes the effectiveness of Arduino microcontroller systems in automation to be significant owing to their low cost, flexibility, and ability to connect with sensors and wireless technology. Yadav (2025) proposed an automation system for industries using both sensors and Bluetooth technology for better efficiency and security. In the field of home automation, Ajagbe et al. (2024) have proposed a home automation system using feedback from sensors implemented by smartphones. In transport safety, Mulyani et al.(2025) presented an auto barricade for railways made from the Arduino controller. This is aimed at preventing incidents effectively and efficiently. All the literature discussed above highlights the vast potential for Arduino systems in the field of automation with even more scope for advancement through IoT and cloud technology.

Recent research has also pointed out the relevant use of the Arduino automation system. Yadav (2025) have demonstrated the use of the Arduino automation system to control the sensors and actuators of industry processes. There is conceptual relevance here to how the automation of the discharge of chemicals and the use of mechanical parts is processed. Ajagbe et al. (2024) argued that automation and application of technology within the house through the Arduino technology is relevant.

There is only partial relevance at this point for the conceptual framework to understand the systems integration and monitoring. Mulyani et al. (2025) have also implemented the use of the Arduino automation system for transportation safety. There is relevant use here for the activation process using the conceptual framework.

The above experiments and projects essentially validate the use of Arduino to develop a semi-automatic device for removing ink because they show the functionality and capability of the microcontroller to handle sensor and actuator control as well as mechanically control edactions, which play an essential role in chemical and/or mechanical processes.

The reviewed literature highlights the importance of developing safe, efficient, and environmentally friendly methods for ink removal from paper. Studies on paper waste management, chemical agents, and alternative deinking techniques emphasize minimizing environmental impact while improving paper quality and reuse. Research on automation and Arduino-controlled systems demonstrates how technology can provide precise control over chemical application and mechanical processes, reducing human exposure to hazardous materials. These findings collectively support the development of the IREASE device, which integrates controlled chemical treatment, mechanical eradication, and automation to provide a sustainable, semi-automated solution for reusing printed paper and addressing the limitations of conventional deinking methods

Statement of the Problems

This study aimed to develop and assess the performance of the IREASE

device in removing ink applied to paper sheets.

Specifically, this study sought to answer the following questions:

What is the profile of the IREASE device in terms of :

- circuit design;
- logic flow; and
- physical and mechanical setup?

How does the performance of the IREASE device and traditional ink remover compare in terms of:

- removal percentage; and
- removal response time?

What recommendations can be drawn from the findings of the study?

Hypothesis

There is no significant difference in the performance between the IREASE device and traditional ink removal procedure.

Significance of the Study

The results of this study aimed to provide valuable information to the following entities**:**

Students. This study may help students become more aware of ecofriendly practices by showing how printed paper can be reused instead of being discarded. It also promotes creativity and innovation in solving everyday environmental problems.

School Staff. This study may benefit from adopting the device as a cost saving method for reducing paper waste. It may provide a practical solution that can be integrated into school operations, especially in areas with limited resources.

Innovators. This study may give insights for innovators to work on practical, cost-effective solutions that promote sustainability. It gives a demonstration of simple solutions being effective for environmental problems.

Environmentalists. This study may contribute to environmentalists by encouraging waste reduction and the use of resources in a way that is environmentally sustainable.

Future Researcher. This study may give insights to future researchers and serve as a springboard for further development and assessment of work-related studies.

Scope and Limitations

This study aimed to evaluate the effectiveness of the IREASE device in removing ink from used printed paper. This study focused on measuring the device's percentage of ink removed and removal response time. The study was conducted at San Agustin National High School, San Agustin, Sagbayan, Bohol because of its large amount of paper waste and available resources for the IREASE device.

The study used short bond paper with ballpoint and inkjet inks as samples, with twenty-five samples for the controlled group. The IREASE device was used to ensure consistent results. The research also covered the device's circuit design, physical and mechanical setup, and logic flow, with a focus on the use of sodium hypochlorite and acetone as the primary chemicals for ink removal.

This study was limited to the specific materials, environment, and conditions used in testing. The results may not be the same in other places with different temperatures and humidity. The device is designed only for short bond paper and two ink types, ballpoints and inkjet, and does not include other kinds of ink or paper, such as gel pens, permanent markers, glossy, or recycled paper.

The data focused only on the device's technical performance and not on human use or other chemical solutions. Therefore, researchers generalized the results only within the same testing setup and materials used in this study. Further studies are encouraged to test the IREASE device in other conditions, with other inks and papers, to expand its application and reliability.

Despite these limitations, this study provided useful information about the effectiveness of the IREASE device in removing ink from paper using sodium hypochlorite and acetone. It helped to show how the device can support recycling and reduce paper waste in schools. The results may serve as a guide for future researchers who want to improve ink removal devices, test other chemicals, or use the device in different environments for wider applications.

RESEARCH METHODOLOGY

Research Design

This study employed a quantitative research approach, specifically adopting a research and development (R&D) design with an experimental comparative approach that evaluated the performance of the Ink Removal using Effective Agents and a Systematic Eradication (IREASE) device. Quantitative research is appropriate for obtaining objective, measurable data that can be statistically analyzed to evaluate device functionality (Ishtiaq, 2019).

This study involved quantifiable variables, such as the removal percentage and the removal response time, that was statistically analyzed to assess the device’s performance compared to traditional ink removal methods.

The research and development (R&D) design supports the goal of creating and improving a technological innovation that addresses a real-world problem— excessive paper waste in schools. As stated by Richey and Klein (2014), the R&D design focuses on the systematic process of designing, developing, testing, and refining products or systems to ensure both functionality and educational or practical value. In this study, the R&D phase involved the design, construction, and optimization of the IREASE device while observing essential safety protocols throughout the development process.

Since this study involved chemical solvents and mechanical components, the researchers were required to use personal protective equipment (PPE), proper fume ventilation, secure storage of chemicals, and strict avoidance of open flames or ignition sources.

Additionally, the experimental-comparative approach was employed to test and compare the performance of the IREASE device with the traditional manual ink removal process.

According to Campbell and Stanley (1963), this approach allowed the researchers to determine whether statistically significant differences existed between treatments under controlled conditions.

The study compared both methods based on two key performance indicators: (1) the removal percentage and (2) the removal response time. This approach ensured that the evaluation is objective, data-driven, and aligned with the study's hypothesis.

Problem Context and Design Rationale

Educational institutions, like school, generate a large volumes of single-use paper through daily administrative and academic activities, much of which is discarded after minimal use (Saglam & Aydin, 2024).

At San Agustin National High School, interviews with school staff revealed that a large amount of printed paper from offices and academic requirements is routinely shredded and disposed of through the Materials Recovery Facility, contributing to resource depletion and environmental burden.

While recycling initiatives exist, these practices do not fully address the loss of usable paper fibers nor the costs associated with continuous paper consumption.

Existing ink removal methods are largely manual, inconsistent, and potentially harmful to both users and paper quality due to uncontrolled chemical exposure.

Moreover, most available deinking solutions focus solely on chemical treatment without integrating mechanical or automated processes, creating a gap for a safe, efficient, and school-appropriate technology that enables paper reuse rather than disposal.

The IREASE device was designed to address this gap by integrating chemical ink removal with a semi-automated mechanical system that prioritizes efficiency, safety, and sustainability.

Acetone and sodium hypochlorite were selected as effective ink-removal agents based on their proven ability to dissolve or oxidize ink pigments when applied in controlled conditions.

To overcome the limitations of purely manual methods, the device incorporates an Arduino-based control system that regulates solvent application, mechanical eradication through rollers or brushes, and automated drying. This systematic design ensures consistent ink removal while minimizing paper damage, chemical waste, and user exposure.

Grounded in waste reduction principles and diffusion theory, the IREASE device provides a practical, low-cost solution tailored for school environments, supporting sustainable paper reuse and reducing dependence on virgin paper resources.

Development of Innovation

This study followed a structured step-by-step approach composed of five key stages: product development, performance testing, data collection, data analysis, and statistical treatment. These stages are crucial in determining the effectiveness of the IREASE device in removing the ink from the paper.

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But before that, the researchers sought approval from the school principal to allow the study to be conducted within the school premises. Once approved, the researchers prepared the IREASE device and set up a controlled testing area.

To formally begin the research process, the researchers followed the flow of the procedure, which served as the basis for developing the IREASE device. The research process started with product development.

This stage involved generating and collaborating on ideas for the desired structure of the machine. After finalizing the design, the necessary materials were gathered, such as steel bar, steel plates, and the mechanical machines to use in developing the product.

Next, the researchers constructed the physical structure by cutting the steel bars and steel plates to form the desired design and length, and welding the foundational framework of the IREASE device.

Performance Evaluation Design

The next stage involved testing the IREASE device to evaluate its effectiveness. Once the device was developed and initialized, the machine underwent testing and evaluation of its effectiveness.

The testing of the study was conducted at San Agustin National High School and the testing area will be clearly labeled as "Prototype Testing – Restricted Access" to ensure safety and controlled access.

This performance testing was applied on the rejected paper samples with different types of ink, including ballpoint ink and printed text from an inkjet printer to represent dye- or pigment based inks commonly used in offices and schools.

In this stage, the paper is inserted into the machine, then the device applies a specific solvent to remove the ink, whether it is printed or written on the paper.

If the paper is inserted, the device proceeds to the application of solvent, followed by the mechanical eradication stage, where rollers and brushes lift the dissolved ink. After this, the paper is dried using the automated air system. Once the first attempt is done, the paper goes for another one to ensure that 100% of the ink is removed.

After the three attempts are completed, the paper emerges from the machine, and the reattempt counter ensures that the ink from the paper is completely removed, allowing it to be used as brand-new bond paper.

All solvent residues from the ink removal process will be collected in sealed containers and disposed of according to the school's hazardous-waste procedures to minimize environmental hazards.

Each sample was standardized on short bond paper, with ink applied in structured patterns such as lines and paragraphs to represent varying ink densities.

This method accurately ensured the device's effectiveness by using both faint and dense ink, and a high-quality image was taken of each sample before and after treatment to document the original and the final ink coverage. The effectiveness of ink removal was evaluated based on removal percentage and removal response time.

To ensure reliable results, each sample was tested thrice, following the test-retest reliability principle, which confirms that measurements are consistent and not due to random variation. The duration of testing was two weeks, with samples processed under consistent conditions each day.

After completing the testing, the data collected was organized and analyzed to measure the overall effectiveness of the IREASE device based on the specific criteria.

All documentation was stored ethically in password-protected folders accessible only to the researchers and the adviser, and data will be deleted after one year to maintain confidentiality and privacy.

Data Collection Procedure

Before conducting the actual data analysis, all instruments and procedures were carefully standardized to ensure the reliability and accuracy of the gathered results.

The process involved verifying the consistency of solvent release from the dispenser, maintaining uniform lighting and imaging conditions for the captured samples, and confirming the precision of time measurements recorded by the device.

Through this standardization, the researchers were able to obtain valid and comparable measurements for both the percentage of ink removed and the corresponding response time of the device.

After ensuring consistency in all experimental conditions, the procedure was carried out on multiple paper samples to gather accurate and comparable data. Each sample was treated with a controlled amount of solvent using the IREASE device, following uniform operational parameters.

Visual documentation was taken before and after every process, allowing precise evaluation of the ink removal effectiveness through image-based analysis. The duration of each process was also monitored to determine the time efficiency of the machine.

All results were systematically recorded and reviewed to confirm that the outcomes reflected stable and dependable performance across different tests.

In addition, risk-management and emergency protocols were observed throughout the data-gathering process. This included having a spill-response guideline for solvent leaks, a first-aid plan for chemical exposure or accidental contact, and ensuring that testing was supervised by an adult at all times.

These measures were implemented to maintain safety during the handling of chemical solvents and operation of the IREASE device, ensuring that the data collection process remained controlled and hazard-free. **Data Analysis**

The data gathered from the performance tests of the IREASE device was analyzed using weighted mean and a paired t-test to determine its effectiveness compared to the traditional ink removal method. Data obtained from the performance tests is analyzed using the weighted mean, and paired t-test as the main statistical tools.

The weighted mean determines the average performance of the IREASE device in terms of percentage of ink removed and removal response time, providing accurate results when data have varying weights (Levine et al., 2020).

The paired t-test assesses whether there is a significant difference between the IREASE device and the traditional ink removal method, ensuring an objective evaluation of the device's overall effectiveness (Nandiyanto and Hofifah, 2023).

The weighted mean is used to find the average score of the device's performance in terms of the percentage of ink removed and removal response time:

Where:

$$\bar{x} = \frac{\sum x}{n}$$

$\bar{x}$ - Mean

$\sum$ - Summation of all observed values from the trials

n - Total number of samples tested

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x - Observed value from each sample tested

Lastly, the paired t-test determine if there is a significant difference between the IREASE device and the traditional method:

where:

$$t = \frac{\bar{d}}{S_d \,/\, \sqrt{n}}$$

t= t-value,

$\bar{d}$= mean of the differences,

S_d= standard deviation of the differences,

n= number of paired observations.

statistical tools ensured that the data were analyzed objectively, aligning with the study's hypothesis and supporting the comparison of both ink removal methods.

To interpret the weighted mean for the percentage of ink removed, the following descriptive scale was used:

Score	Description	Percent Ink Removed
5	Complete removal	81-100%
4	Near complete	61-80%
3	Significant removal	41-60%
2	Moderate removal	21-40%
1	Slight removal	0-20%

To interpret the weighted mean for the removal response time, the following descriptive scale was used:

Score	Description	Removal Response Time
5	Very fast response	0-60 seconds
4	Fast response	61-120 seconds
3	Moderate response	121-180 seconds
2	Slow response	181-240 seconds
1	Very slow response	241-300 seconds

Ethical and Technical Considerations

The researchers observed proper ethical standards throughout the study. Although no human respondents are involved, strict safety measures were followed during experimentation. Personal protective equipment (PPE) was worn when handling chemicals and operating electronic components to prevent accidents.

Proper disposal of chemical residues was practiced to avoid environmental harm, and all procedures will be performed in safe, dry areas. The device was tested in well-ventilated areas or near an exhaust fan, and masks are advised to ensure air quality management and prevent inhalation of solvent vapors. Testing was also supervised by an adult at all times.

The researchers uphold honesty in collecting and reporting data, acknowledge all sources used, and follow the ethical guidelines set by the school to ensure that the study is conducted responsibly and safely.

In addition, the study aligns with the Belmont principles for non-human research: beneficence by minimizing harm, justice by safe facility use, and respect for persons by ensuring the safety of all individuals in the testing vicinity.

IREASE Device

Refers to the ink removal using effective agents and systematic eradication device developed in this study.

Circuit Design

The electrical layout of the IREASE device connects components such as motors, and controllers to ensure proper system operation

Physical and Mechanical Setup

The overall structure and assembly of the IREASE device, including it's framework, moving parts, and mechanisms responsible for the ink removal process.

Logic Flow

The programmed sequence or operational sequence or operational process that controls how the IREASE device perform ink removal, form solvent application to mechanical action and drying.

Percentage of Ink Removed

The measurable proportion of ink successfully eliminated from the paper surface after treatment.

Removal Response Time

The duration required for the IREASE device to complete the ink removal process, from activation to a clean paper output.

Performance

Refers to the overall effectiveness of the IREASE device in removing ink, evaluated through the percentage of ink removed and removal response time

Traditional Ink Removal Method

Refers to the manual or conventional process of removing ink using hand-applied solvents and scrubbing, used in this study as the basis for comparison with the IREASE devic

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Presentation, Analysis, And Interpretation of Data

This chapter deals with the presentation, analysis, and interpretation of data derived from the study. The findings discussed in this chapter are divided into two sections. The first section presents the profile of the IREASE device in terms of circuit design, logic flow, and physical and mechanical setup. The second section presents the comparative performance of the IREASE device and the traditional ink removal method in terms of percentage of ink removed and removal response time.

Circuit Design of the Irease Device

The circuit design shown in Figure 2 below utilized two Arduino microcontrollers powered by a single battery through a power jack and a master switch. One Arduino controlled two NEMA 12 stepper motors and a water pump, which required higher current and load handling.

The second Arduino was assigned to control small stepper motors with lower power requirements. Separating the control systems reduced electrical interference and improved stability. Using a shared battery simplified power distribution while maintaining independent control of each subsystem.

Additionally, the front view of the device the main switch, an LED light, and four push buttons. Once the main switch is activated, the LED light will on signifying that the device is on and ready for eradication process.

The 2 Arduino Uno RS serves as the microcontroller, connected to a driver for a NEMA 17 stepper motor. The stepper is programed to turn when the button is pushed.

Another the same circuit for BYJ45 stepper motor but the other ports is connected to a peristaltic water pump. The one pump is set to spray the acetone for 1 minutes and 30 seconds, while the other water pump is set for 2 minutes. The electric heating mechanisms is activated once the user push the button for NEMA 17 stepper but it is delay for 30 seconds.

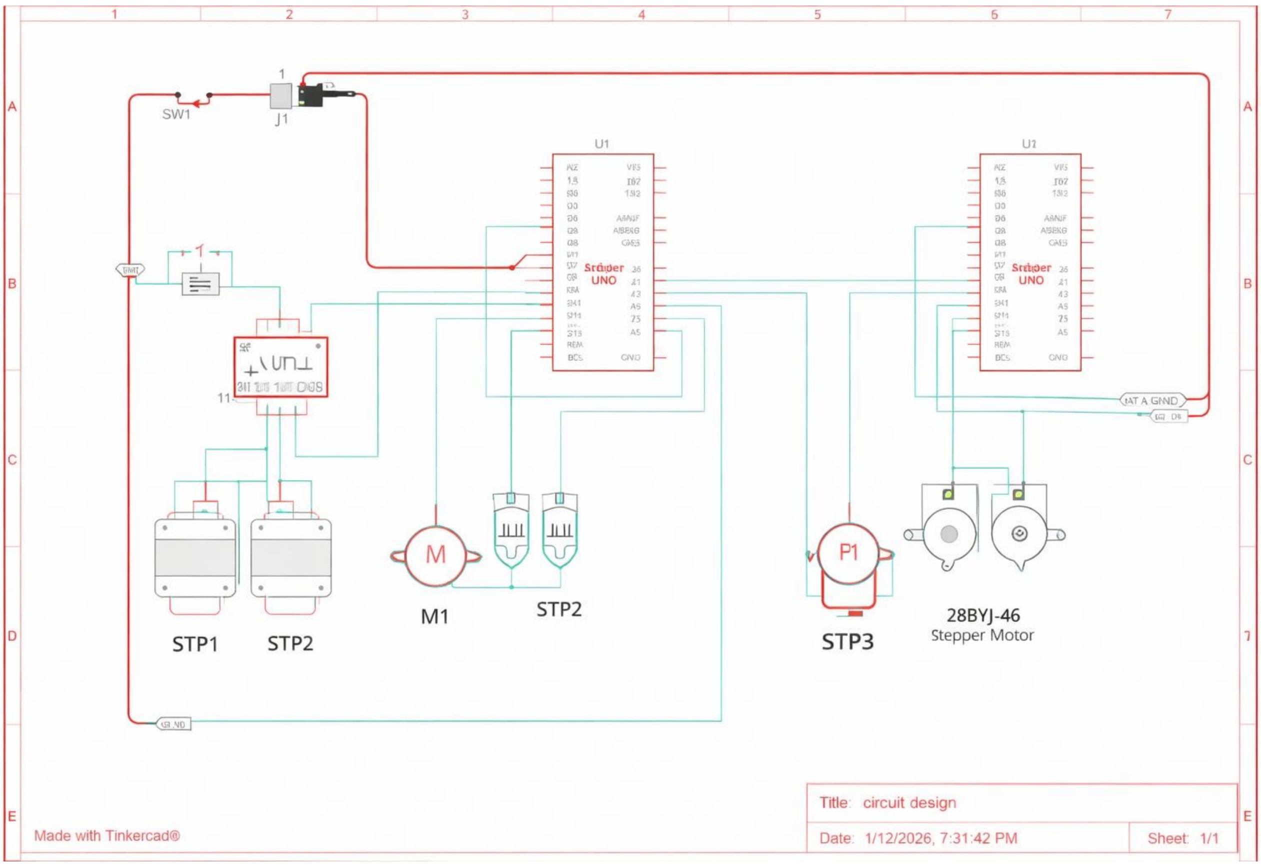

Figure 2. Circuit Design of IREASE Device

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The Logic Flow of the Irease Devic

Figure 3 presents the logic flow of the IREASE device. The process begins with the preparation of materials and system components necessary for the operation of the device. Once prepared, the IREASE system is developed and initialized to ensure proper functionality. After system readiness, the paper to be treated is inserted into the IREASE device for processing.

Upon insertion, a solvent is applied to the paper to dissolve the ink present on its surface. This step is followed by the mechanical eradication stage, where rollers and brushes remove the dissolved ink from the paper. After ink removal, the paper undergoes a drying process to eliminate residual solvent and moisture. Once dried, the clean paper is collected, marking the completion of the ink eradication process. This logical sequence ensures that the paper is systematically treated from preparation to final output, resulting in clean and reusable paper after passing through the IREASE device.

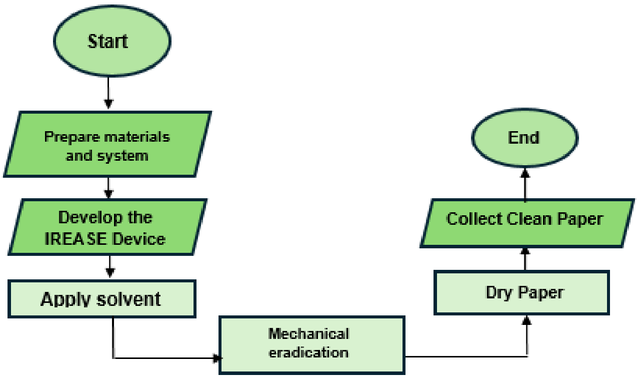

Figure 3. Logic Flow of the IREASE Device

Figure 3. Logic Flow of the IREASE Device

Physical and Mechanical Setup of the Irease Device

Figure 4 below shows the physical and mechanical etup of the IREASE device, which consists of paper feed mechanisms that align and guide the paper into the systematic procedure. The Arduino-based dispensing unit applied a measured mixture of acetone and sodium hypochlorite, and the mechanical eradication unit, equipped with rollers or brushes, lifted the dissolved ink from the paper. The device also utilizes an automated air flow system to dry the wet paper soaked with sodium hypochlorite, while waste collection containers store the used chemicals during the eradication process.

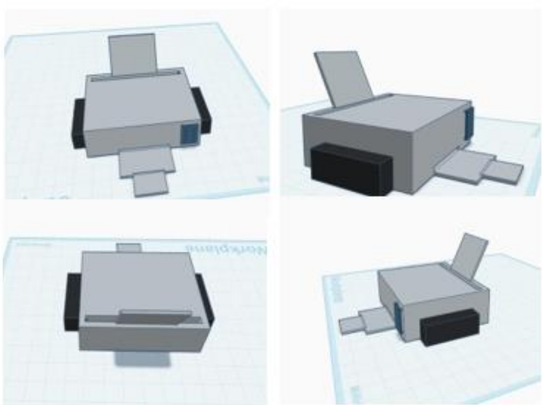

Figure 4. Physical and Mechanical Setup of IREASE System

After constructing the physical structure, the next step is the installation of the mechanical setup. The device is divided into three sections: chemical application, mechanical removal, and control system. Sodium hypochlorite and acetone are used in the chemical application section to loosen and dissolve the ink pigments efficiently. The mechanical removal section consists of a motorized brush and drying unit to finalize the ink removal process. As the main control system, the Arduino Uno microcontroller is utilized for its reliability and precision in managing automated operations. Moreover, the Arduino-based control system is programmed to coordinate the step-by-step sequence of actions. The circuit and program are tested on Tinker CAD, shown in Figure 2, before building the system to verify correct wiring, operation order, and indicator operations. LEDs served as the signal that the system is in operational status and the completion of each step.

By construction of the physical mechanical setup of the IREASE device, the Table 1 below presents the materials and specifications used in the fabrication of the IREASE device. The structural components include a printer box housing with 28 cm x 48 cm x 64 cm dimensions, plain bars and angle bars measuring 182.88 cm, a plain sheet with dimensions of 4 × 8 feet, and various assembly materials such as rivets, drill bits, cutting discs, spray nozzles, rollers, roller brushes, and black paint (Black B-620, 1 L). Chemical materials used in the system consist of 500 mL of acetone and 500 mL of sodium hypochlorite, which are essential for the ink eradication process.

In terms of electronic components, the device is powered and controlled by an Arduino-based system. This includes one Arduino Uno R3 and one Arduino kit, two NEMA 17 stepper motors with corresponding L298 drivers, one MG996R servo motor, and an AC/DC adaptor. Additional electrical materials such as jumper wires, soldering lead, and a 9V battery (6F22) support circuit connections and power distribution. These materials collectively enable the IREASE device to perform its mechanical movement, control operations, and ink eradication functions effectively.

Table 1. Materials and Specifications of the IREASE device

Materials	**Specification**
Printer Box	
Dimensions	28 cm x 48 cm x 64 cm
Other Materials	
Acetone	500 mL
Sodium Hypochlorite	500 mL
Plain Bar	182.88 cm
Plain Sheet	4x8 ft
Angle Bar	182.88 cm
Spray Nozzle	2x
Roller (Big)	1x
Roller Brush	4x
Paint Black (Black B-620)	1x, 1L
Electronic Components	**Quantity**
Arduino Kit	1x
Arduino Uno R3	1x
Nema 17 (Stepper)	2x
Driver (L298)	2x

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

Battery (Battery 6F22, 9V)	2x
Male to Female Jumper Wire	40x
Servo Motor MG996 R	1x
AC/DC Adaptor	1x
Wire C2105A.93.03	10 meters

The Comparative Performance of the Irease Device

This section presents a statistical analysis of the performance of the IREASE Device compared to the traditional ink remover. The analysis is based on the result of the computed p-values from the two-sample t-test, that evaluates the significant differences of the performance of the two group in terms of removal percentage and removal response time.

Table 2 shows the statistical analysis of the performance of the IREASE device and the traditional ink removal using the acetone removing solvent. For the variable removal percentage, the accumulated p-value is 5.97017E-08, which is far below the critical p-value of 0.05. This leads to the rejection of the null hypothesis. With this, this confirms that the difference in ink removal performance between the IREASE device and the traditional ink removal method is statistically significant.

Table 2. Comparative Performance Results (Acetone)

Variables	Group	Mean Score	P-value	Critical p-value	Decision
Removal Percentage	IREASE Device	4.2	5.97017E-08	0.05	Reject the null hypothesis
	Traditional Ink Remover	2.88			
Removal Response Time	IREASE Device	4	0.000221093	0.05	Reject the null hypothesis
	Traditional Ink Remover	3.56			
Overall	IREASE Device	4.1	1.26634E-11	0.05	Reject the null hypothesis
	Traditional Ink Remover	3.28			

The superior performance of the IREASE device is further explained by the automation and control theory by Yadav (2025) and Ajagbe et al. (2024), who showed that Arduino-based systems provide precise control over fluid delivery and mechanical motion. In the IREASE device, acetone is dispensed in a regulated and uniform manner while the rollers maintain consistent contract with the paper surface. This controlled application maximizes acetone's solvent action, ensuring deeper and more even penetration into the ink layer compared with the traditional manual method. Overall, the extremely low p-value confirms that the IREASE device has higher ink removal performance as the result of combining acetone's chemical dissolving ability with automated and controlled application, validating the theoretical foundation of the device as an efficient tool for ink removal and paper use.

For the variable removal response time, between the IREASE device and the traditional ink remover, the accumulated p-value is 0.000221093, which is far below the 0.05 critical p-value. The computed p-value of 0.05 leads to the rejection of the null hypothesis, indicating a significant difference in performance between the two methods. Based on the automation and control capabilities of Arduino-based systems, Mulyani et al. (2025) demonstrated that Arduino-controlled automation can efficiently handle complex mechanical processes, reducing manual intervention and improving operational speed. In the IREASE device, the automated control of solvent delivery and roller movement ensures consistent application and mechanical action, minimizing delays caused by manual handling in traditional ink removal. So, the significant difference in removal response time demonstrates that the IREASE device's integration of automated control and precise mechanical action enables faster and more consistent ink removal than manual methods.

Lastly, overall performance comparison between the IREASE device and the traditional ink remove obtained a p-value of 1.26634E-11, which leads to the rejection of the null hypothesis since the p-value is below the critical p-value 0.05. This indicates a statistically significant difference in overall performance between the two methods. This result shows that the IREASE device consistently outperforms the traditional ink removal method by providing more effective, controlled, and uniform ink removal, confirming its reliability and efficiency as a semi-automated solution for ink remover.

The concept of optimized treatment processes, as highlighted by Gea et al. (2020) in enzyme-assisted deinking, supports the idea that precise coordination of chemical and mechanical factors enhances ink removal efficiency. By controlling the interaction between acetone and the ink layer, the IREASE device maximizes ink detachment and ensures thorough removal, outperforming the traditional manual method. Overall, the statistically significant result confirms that the integration of controlled chemical application and mechanical automation enables the IREASE device to achieve superior overall performance, validating its effectiveness as a semi-automated solution for ink remover method using acetone as the removing solvent agent.

Table 3 below shows the statistical analysis of the performance of the IREASE device and the traditional ink remover using sodium hypochlorite as the removing solvent. For the variable removal percentage, the accumulated p-value is 1.69153×10^{-5}, which is far below the critical p-value of 0.05. This leads to the rejection of the null hypothesis, confirming that the difference in ink removal performance between the IREASE device and the traditional method is statistically significant.

Table 3. Comparative Performance Results (Sodium Hypochlorite**)**

Variables	Group	Mean Score	P-value	Critical p-value	Decision
Removal Percentage	IREASE Device	4.32	1.69153E-05	0.05	Reject the null hypothesis
	Traditional Ink Remover	2.96			
Removal Response Time	IREASE Device	4	4.3217E-19	0.05	Reject the null hypothesis
	Traditional Ink Remover	2.96			
Overall	IREASE Device	4.16	3.34975E-12	0.05	Reject the null hypothesis
	Traditional Ink Remover	2.96			

According to Yelubay et al. (2025), the combination of surfactants and oxidizing agents, such as sodium hypochlorite, enhances the detachment of ink pigments from paper fibers. Furthermore, Mikheikina et al. (2024) highlighted that the effectiveness of chemical cleaning depends on controlled application and exposure. The IREASE device applies sodium hypochlorite in a regulated and uniform manner using its Arduino-controlled rollers and pumps, ensuring consistent solvent contact and mechanical action, which maximizes ink dissolution and removal compared with the traditional manual method.

For the variable removal response time, between the IREASE device and the traditional ink remover, the accumulated p-value is 4.3217E-19, which is far below the 0.05 critical p-value. This leads to the rejection of the null hypothesis, indicating a significant difference in performance between the two methods after using sodium hypochlorite as ink remover solvent agent. Mulyani et al. (2025) demonstrated that Arduino-based automation systems can efficiently control mechanical processes and reduce delays caused by manual operation. In the IREASE device, the coordinated control of solvent delivery and roller motion minimizes variability and allows the chemical and mechanical steps to be executed simultaneously, resulting in faster and more consistent ink removal.

Lastly, overall performance comparison between the IREASE device and the traditional ink remove obtained a p-value of 3.34975E-12, which leads to the rejection of the null hypothesis. This indicates a statistically significant difference in overall performance between the two methods using the sodium hypochlorite as the ink remover agent. This result shows that the IREASE device consistently outperforms the traditional ink removal method by providing more effective, controlled, and uniform ink removal, confirming its reliability and efficiency as a semi-automated solution for ink remover.

Overall, the statistically significant results confirm that the integration of controlled chemical application and automated mechanical control enables the IREASE device to achieve superior performance compared with the traditional ink remover, validating its effectiveness as a semi-automated solution for sustainable paper reuse.

This chapter presents the summary of the study and its findings, the conclusions drawn, and the recommendations derived from these findings.

Summary

The main purpose of the study is to develop and assess the performance of the IREASE device in removing ink applied to paper sheets.

Answer were sought to the following questions:

1. What is the profile of the IREASE device in terms of:
    - 1.1 circuit design;
    - 1.2 logic flow; and
    - 1.3 physical and mechanical setup?
2. How does the performance of the IREASE device compare with the traditional ink removal in terms of:
    - 2.1 removal percentage; and
    - 2.2 removal response time?
3. What recommendations can be drawn from the findings of the study?

FINDINGS

The analysis of the data yielded the following findings:

Profile of the IREASE device

Circuit Design

The IREASE device uses a dual-Arduino control system powered by a single battery through a power jack and master switch. One Arduino controls the high-load components, including the NEMA 17 stepper motors and water pumps, while the second Arduino controls the smaller stepper motors. This separation improves electrical stability and prevents signal interference. The front panel includes a main switch, LED indicator, and four push buttons that allow the user to control the sequence of operations. The system also integrates time-controlled spraying of acetone and water and a delayed heating mechanism, which allows the ink to dissolve properly before mechanical removal begins. This design ensures safe, stable, and coordinated operation of all electrical and mechanical components.

Logic Flow

The logic flow of the IREASE device follows a clear and systematic sequence. The process starts with system initialization and preparation of materials. Once the paper is inserted, the device applies a solvent to dissolve the ink. This is followed by mechanical eradication using rollers and brushes to remove the dissolved ink. Afterward, the paper passes through a drying stage to remove excess solvent and moisture. Finally, the clean and reusable paper is collected. This step-by-step logic ensures that ink removal is performed in an organized, controlled, and efficient manner.

Physical and Mechanical Setup

The physical and mechanical setup of the IREASE device consists of three main sections: chemical application, mechanical removal, and control system. The chemical application unit dispenses acetone and sodium hypochlorite in controlled amounts to loosen and dissolve ink. The mechanical section includes motorized rollers and brushes that lift and remove the ink from the paper surface, while an automated air-drying system dries the paper after treatment. The Arduino-based control system coordinates all movements, chemical dispensing, and timing. The materials used, including the frame, rollers, electronic components, and chemical supplies, allow the device to perform its ink eradication process effectively and consistently.

Performance of the IREASE Device Compare with the Traditional Ink Removal

Removal Percentage

The results show that the IREASE device achieved a significantly higher removal percentage than the traditional ink remover when acetone was used as the solvent. The computed p-value, 5.97017×10^{-8}, is far below the 0.05 critical value, leading to the rejection of the null hypothesis. This indicates a statistically significant difference between the two methods. The high mean score of the IREASE device, 4.2, 77.60 in percentage compared with the traditional method, 2.88, 50**.08** in percentage, confirms that the automated and controlled application of acetone in the IREASE device allows more effective and uniform ink removal.

Similarly, when sodium hypochlorite was used as the removing solvent, the IREASE device again showed superior performance. The p-value of 1.69153×10^{-5} is also far below 0.05, resulting in the rejection of the null hypothesis. The higher mean score of the IREASE device with 4.32 score, 74.54 in percentage, compared with the traditional ink remover with 2.96 score, 48.83 in percentage, indicates that the device removes a greater amount of ink. This demonstrates that the regulated delivery of sodium hypochlorite and synchronized mechanical action in the IREASE device leads to more efficient ink detachment from the paper.

Removal Response Time

For acetone, the IREASE device obtained a mean removal response time of 4, while the traditional ink remover recorded 3.56. The accumulated p-value of 0.000221093, which is below the 0.05 critical value, leads to the rejection of the null hypothesis. This indicates a statistically significant difference in removal response time between the two methods. This shows that the IREASE device removes ink faster due to its automated control of solvent application, roller movement, and heating.

When sodium hypochlorite was used, the IREASE device achieved a mean removal response time of 4, while the traditional ink remover recorded 2.96. The accumulated p-value of 4.3217E-19, which is below the 0.05 critical value, also leads to the rejection of the null hypothesis. This confirms that there is a statistically significant difference in response time between the two methods. The synchronized control of solvent delivery and mechanical eradication in the IREASE device allows the ink removal process to be completed more quickly and consistently than the traditional manual method.

CONCLUSION

Based on the aforementioned findings, the null hypothesis stating that there is no significant difference between the IREASE device and the traditional ink removal method is rejected. The results showed that the IREASE device achieved higher ink removal efficiency and shorter response time than the traditional method, with the difference found to be statistically significant. Therefore, it can be concluded that the IREASE device is more effective and efficient than the traditional ink removal method in removing ink from paper surfaces. This implies that the IREASE device can serve as a viable alternative for paper reuse and ink removal applications.

RECOMMENDATIONS

Based on the findings and conclusions derived from the study, the researchers present the following recommendations:

1. Enhancement of the device by upgrading its solvent dispensing mechanism, mechanical eradication unit, and drying system to increase efficiency.
2. Future researchers are encouraged to test the device using additional types of ink and paper to further assess its applicability and improve its performance.
3. Safety protocols should be strictly observed during operation, ensuring proper ventilation, chemical handling, and disposal in accordance with environmental standards.
4. Future researchers are encouraged to use a strong and chemical-resistant container to prevent damage from acetone and sodium hypochlorite.

LIST OF ABBREVIATIONS

ABBREVIATION	DEFINITION
DENR	Department of Environment and Natural Resources
IREASE	Ink Removal using Effective Agents and Systematic Eradication
MRF	Materials Recovery Facility
PPE	Personal Protective Equipment
PPI	Pulp and Paper Industry
PVA	Polyvinyl Alcohol
R&D	Research and Development

ACKNOWLEDGEMENT

Deepest and foremost, praises and thanks to the God, the Almighty, for his showers of blessings throughout the research work to be done carefully.

The researchers would like to express their deep and sincere gratitude to their research supervisor, **Mr. Joselito Y. Bulabos** for giving the opportunity to do research and providing invaluable guidance throughout this research.

The researchers would also like to thanks to their research advisor, **Mrs. Marie Stefanie H. Candawan**, for her continuous support, insightful feedback, and encouragement throughout the research process.

The researchers would also like to thank the panel of examiners, **Mrs. Peregrita J. Datahan, Mr. Fernando B. Enad, Mr. Joselito Y. Bulabos, Mrs. Marie Stefanie H. Candawan, and Mrs. Rhea Marie D. Enad** for the suggestion and inquiries to help improve the present study.

The researchers are thankful for their parents that they had let them spend time with their co-researchers in conducting research at the place where the researchers agreed upon**.**

Furthermore, the researchers would also like to thank Mr. **Nilo C. Lanoy**, our school principal, for the approval of conducting the study. With this approval, the researchers successfully conducted this study.

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APPENDICES

APPENDIX A. Transmittal Letter

Republic of the Philippines
Department of Education
SAN AGUSTIN NATIONAL HIGH SCHOOL

Date: _____________

NILO C. LANOY EdD
School Principal II
School Head

Dr. Lanoy:

We hope this letter finds you well. We, the undersigned Grade 12-STEM students, are writing to formally request permission to conduct a research study as part of our Practical Research 2 class requirement. The study entitled **"IREASE: AN INK REMOVAL DEVICE"** will be conducted under the supervision of our research adviser, **MRS. MARIE STEAFNIE H. CANDAWAN**.

Due to the nature of our topic, we kindly request permission to conduct the study inside the school setting. We believe that a close and practical environment is essential for the accuracy and effectiveness of our data collection.

We assure you that we will strictly adhere to all safety protocols and guidelines provided by the school. Additionally, we are willing to coordinate with school administrators to ensure that our study aligns with the institution's regulations and academic goals.

We appreciate your time and consideration of this request. We look forward to your approval and guidance in facilitating this valuable learning experience.

Thank you very much for your support.

Respectfully Yours,

NICHOL ISIDORE A. LUPIAN
Research Leader

Recommending Approval:

MRS. MARIE STEAFNIE H. CANDAWAN, MSc
Research Adviser

Approved:

MR. NILO C. LANOY, EdD
School Principal II
School Head

Let the SANHS shine!
Purok 2, San Agustin, 6331 Sagbayan, Bohol, Philippines
Telephone No. +63 (920) 500-1182
sanhs.sagbayan 302887@deped.gov.ph www.sanagustinnhs.net

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APPENDIX B. Research Instrument

A.

IREASE DEVICE (ACETONE)				
Sample	% Amount of Ink Before	% Amount of Ink After	% Amount Ink Removed	Time

B.

IREASE DEVICE (SODIUM HYPOCHLORITE)				
Sample	% Amount of Ink Before	% Amount of Ink After	% Amount Ink Removed	Time

C.

TRADITIONAL INK REMOVAL (ACETONE)				
Sample	% Amount of Ink Before	% Amount of Ink After	% Amount Ink Removed	Time

D.

TRADITIONAL INK REMOVAL (SODIUM HYPOCHLORITE)				
Sample	% Amount of Ink Before	% Amount of Ink After	% Amount Ink Removed	Time

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

APPENDIX C. Declaration of Anti-Plagiarism

Republic of the Philippines
Department of Education
Region VII, Central Visayas
Schools Division of Bohol
District of Sagbayan
SAN AGUSTIN NATIONAL HIGH SCHOOL
RESEARCH AND DEVELOPMENT CENTER
Senior High Department
San Agustin, Sagbayan Bohol

DECLARATION OF ANTI-PLAGIARISM
(DepEd Research Management Guidelines)

A. We, Nichol Isidore A. Lupian, Rica Jane A. Amparo, Mil Ariel C. Lamban Jr., Eirah Jen B. Langi, Kent Dhanty A. Lupiba, Ma. Gina L. Navacilla, Jascel Mae B. Padayao, and Jenneth Mae V. Rosas, understand that plagiarism is the act of taking and using another person's ideas and works and passing them on as one's own. This includes explicitly copying the whole work of another person and/or using some parts of such work without proper acknowledgement and referencing thereof.
B. We understand that violation of this declaration and commitment shall be subject to consequences and shall be dealt with accordingly by the Department of Education.
C. We hereby attest to the originality of this report and have cited properly all the references used. We further commit that all deliverables and the final research emanating from this study shall be original content. We shall use appropriate citations in referencing other works from various sources.

Name	Signature
Nichol Isidore A. Lupian	
Rica Jane A. Amparo	
Mil Ariel C. Lamban Jr.	
Eirah Jen B. Langi	
Kent Dhanty A. Lupiba	
Ma. Gina L. Navacilla	
Jascel Mae B. Padayao	
Jenneth Mae V. Rosas	

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

Appendix D. Certificate of Plagiarism Test

turnitin Page 2 of 91 - Integrity Overview Submission ID trn:oid:::1:3458688009

13% Overall Similarity

The combined total of all matches, including overlapping sources, for each database.

Filtered from the Report

- Bibliography
- Quoted Text

Match Groups

- 98 Not Cited or Quoted 12%
  Matches with neither in-text citation nor quotation marks
- 9 Missing Quotations 1%
  Matches that are still very similar to source material
- 0 Missing Citation 0%
  Matches that have quotation marks, but no in-text citation
- 0 Cited and Quoted 0%
  Matches with in-text citation present, but no quotation marks

Top Sources

- 12% Internet sources
- 6% Publications
- 9% Submitted works (Student Papers)

turnitin Page 2 of 91 - Integrity Overview Submission ID trn:oid:::1:3458688009

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

APPENDIX E. Declaration of Absence of Interest

Republic of the Philippines
Department of Education
Region VII, Central Visayas
Schools Division of Bohol
District of Sagbayan
SAN AGUSTIN NATIONAL HIGH SCHOOL
RESEARCH AND DEVELOPMENT CENTER
Senior High Department
San Agustin, Sagbayan Bohol

DECLARATION OF ABSENCE OF INTEREST
(DepEd Research Management Guidelines)

We, Nichol Isidore A. Lupian, Rica Jane A. Amparo, Mil Ariel C. Lamban Jr., Eirah Jen B. Langi, Kent Dhanty A. Lupiba, Ma. Gina L. Navacilla, Jascel Mae B. Padayao, and Jenneth Mae V. Rosas, understand that conflict of interest refers to a situation in which financial or other personal considerations may compromise our judgment in evaluating, conducting, or reporting research.

We hereby declare that we don't have any personal conflict of interest that may arise from the submission of this research report.

We hereby attest to the originality of this report and have cited properly all the references used. We further commit that all deliverables and the final research emanating from this study shall be original content. We shall use appropriate citations in referencing other works from various sources.

Name	**Signature**
Nichol Isidore A. Lupian	
Rica Jane A. Amparo	
Mil Ariel C. Lamban Jr.	
Eirah Jen B. Langi	
Kent Dhanty A. Lupiba	
Ma. Gina L. Navacilla	
Jascel Mae B. Padayao	
Jenneth Mae V. Rosas	

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

APPENDIX F. Computation

IREASE DEVICE (ACETONE)						
Sample	**% Amount of Ink Before**	**% Amount of Ink After**	**% Amount Ink Removed**	**Scale Score**	**Time**	**Scale Score**
1	100%	5.07%	94.93%	5	1:30.00	4
2	100%	4.52%	95.48%	5	1:30.00	4
3	100%	4.29%	95.71%	5	1:30.00	4
4	100%	5.04%	94.96%	5	1:30.00	4
5	100%	4.57%	95.43%	5	1:30.00	4
6	100%	4.77%	95.23%	5	1:30.00	4
7	100%	18.6%	81.4%	5	1:30.00	4
8	100%	19.79%	80.21%	4	1:30.00	4
9	100%	39.29%	60.71%	3	1:30.00	4
10	100%	21.96%	78.04%	4	1:30.00	4
11	100%	20.08%	79.92%	4	1:30.00	4
12	100%	21.54%	78.46%	4	1:30.00	4
13	100%	21.54%	78.46%	4	1:30.00	4
14	100%	19.93%	80.07%	4	1:30.00	4
15	100%	24.1%	75.9%	4	1:30.00	4
16	100%	34.42%	65.58%	4	1:30.00	4
17	100%	35.6%	64.4%	4	1:30.00	4
18	100%	45.63%	54.37%	3	1:30.00	4
19	100%	24.04%	75.96%	4	1:30.00	4
20	100%	31.22%	68.78%	4	1:30.00	4
21	100%	31.14%	68.86%	4	1:30.00	4
22	100%	35.82%	64.18%	4	1:30.00	4
23	100%	26.49%	73.51%	4	1:30.00	4
24	100%	26.89%	73.11%	4	1:30.00	4
25	100%	33.81%	66.19%	4	1:30.00	4
Total Mean	**100%**	**22.40%**	**77.60%**	**4.2**	**01:30.00**	**4**

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

IREASE DEVICE (SODIUM HYPOCHLORITE)						
Sample	**% Amount of Ink Before**	**% Amount of Ink After**	**% Amount Ink Removed**	**Scale Score**	**Time**	**Scale Score**
1	100%	38.94%	61.06%	4	2:00.00	4
2	100%	33.19%	66.81%	4	2:00.00	4
3	100%	21.57%	78.43%	4	2:00.00	4
4	100%	13.43%	86.57%	5	2:00.00	4
5	100%	19.49%	80.51%	4	2:00.00	4
6	100%	27.19%	72.81%	4	2:00.00	4
7	100%	35.1%	64.9%	4	2:00.00	4
8	100%	15.73%	84.27%	5	2:00.00	4
9	100%	36.32%	63.68%	4	2:00.00	4
10	100%	6.31%	93.69%	5	2:00.00	4
11	100%	19.44%	80.56%	4	2:00.00	4
12	100%	16.1%	83.9%	5	2:00.00	4
13	100%	36.06%	63.94%	4	2:00.00	4
14	100%	14.88%	85.12%	5	2:00.00	4
15	100%	18.31%	81.69%	5	2:00.00	4
16	100%	17.04%	82.96%	5	2:00.00	4
17	100%	12.58%	87.42%	5	2:00.00	4
18	100%	58.56%	41.44%	3	2:00.00	4
19	100%	8.89%	91.11%	5	2:00.00	4
20	100%	37.21%	62.79%	4	2:00.00	4
21	100%	43.14%	56.86%	3	2:00.00	4
22	100%	31.48%	68.52%	4	2:00.00	4
23	100%	23.29%	76.71%	4	2:00.00	4
24	100%	33.78%	66.22%	4	2:00.00	4
25	100%	18.36%	81.64%	5	2:00.00	4
Total Mean	**100%**	**25.46%**	**74.54%**	**4.32**	**02:00.00**	**4**

TRADITIONAL INK REMOVAL (ACETONE)						
Sample	**% Amount of Ink Before**	**% Amount of Ink After**	**% Amount Ink Removed**	**Scale Score**	**Time**	**Scale Score**
1	100%	43.74%	56.26%	3	01:55.04	4
2	100%	35.44%	64.66%	4	02:18.05	3
3	100%	48%	52.00%	3	01:49.05	4

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

4	100%	23.48%	76.52%	4	02:00.79	4
5	100%	42.85%	57.15%	3	01:48.77	4
6	100%	51.07%	48.93%	3	01:53.29	4
7	100%	41.49%	58.51%	3	01:51.80	4
8	100%	74.28%	25.72%	2	01:58.74	4
9	100%	47.26%	52.74%	3	02:04.23	3
10	100%	49.25%	50.75%	3	01:48.24	4
11	100%	63.13%	36.87%	2	02:00.10	4
12	100%	27.94%	72.06%	4	01:50.42	4
13	100%	32.78%	67.22%	4	02:06.93	3
14	100%	23.94%	76.06%	4	01:28.40	4
15	100%	51.74%	48.26%	3	01:36.02	4
16	100%	66.47%	33.53%	2	02:27.33	3
17	100%	43.93%	56.07%	3	02:01.58	3
18	100%	61.03%	38.70%	2	02:03.17	3
19	100%	50.36%	49.64%	3	02:10.39	3
20	100%	47.04%	52.60%	3	02:04.32	3
21	100%	39.36%	60.63%	3	02:01.33	3
22	100%	56.34%	43.66%	3	02:07.38	3
23	100%	75.91%	24.09%	2	01:55.20	4
24	100%	68.29%	31.71%	2	01:50.27	4
25	100%	82.25%	17.75%	1	02:01.05	3
Total Mean	**100%**	**49.8948%**	**50.08%**	**2.88**	**01:58.08**	**4.32**

TRADITIONAL INK REMOVAL (SODIUM HYPOCHLORITE)						
Sample	**% Amount of Ink Before**	**% Amount of Ink After**	**% Amount Ink Removed**	**Scale Score**	**Time**	**Scale Score**
1	100%	35.8%	64.2%	4	02:26.09	3
2	100%	36.1%	63.9%	4	02:56.33	3
3	100%	67.57%	32.43%	2	02:03.02	3
4	100%	59.09%	40.91%	2	02:15.42	3
5	100%	49.22%	50.78%	3	02:14.25	3
6	100%	52.59%	47.41%	3	02:28.60	3
7	100%	29.18%	70.82%	4	02:13.80	3
8	100%	36.8%	63.2%	4	02:28.55	3

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

9	100%	61.78%	38.22%	2	02:25.47	3
10	100%	66.71%	33.29%	2	02:43.17	3
11	100%	59.11%	40.89%	2	02:18.77	3
12	100%	68.88%	31.12%	2	02:16.18	3
13	100%	24.98%	75.02%	4	02:05.07	3
14	100%	31.03%	68.7%	4	02:31.84	3
15	100%	28.93%	71.07%	4	02:12.92	3
16	100%	44.82%	55.18%	3	02:14.65	3
17	100%	42.43%	57.57%	3	02:41.32	3
18	100%	26.98%	73.02%	4	02:39.23	3
19	100%	60.05%	39.95%	2	02:36.94	3
20	100%	33.75%	66.25%	4	02:35.32	3
21	100%	22.14%	77.86%	4	02:31.45	3
22	100%	57.83%	42.17%	3	02:40.85	3
23	100%	84.26%	15.74%	1	02:23.03	3
24	100%	73.92%	26.09%	2	03:01.00	2
25	100%	66.71%	33.29%	2	02:33.11	3
Total Mean	**100%**	**48.8264%**	**51.16%**	**2.96**	**02:27.70**	**2.96**

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

APPENDIX G. Ethics Result

18 November 2025

Dear Researchers:

Thank you for submitting your protocol proposal, *"IREASE: An Ink Removal Device"*, for ethical clearance.

We reviewed your application, and there are some points that the Reviewers would like you to address. The following points are the main concerns of the Reviewers regarding your research study. The Reviewers also provide suggestions. Discussion with your adviser is encouraged.

Issue	Possible Solution to be Discussed with your Adviser
Rationale The rationale explains paper waste and ink-removal challenges but does not include an explicit ethical acknowledgment on the safe handling of solvents, environmental impact, and researcher safety.	**SUGGESTION:** *Add a statement that the study will follow safe chemical-handling practices, ensuring minimal exposure to fumes and proper disposal of residues.*
Theoretical Background Engineering and chemical theories are well presented, but ethical engineering principles are absent.	**SUGGESTION:** *Briefly highlight safe engineering practices, responsible design, and proper handling of electronic components as part of ethical engineering.*
Statement of the Problem The SOPs focus on mechanical performance; however, it should clarify that no human participants are part of device testing.	**SUGGESTION:** *Add a line stating that all trials are conducted on paper samples and not on human subjects.*
Scope Technical boundaries are clear but ethical limits (e.g., site restrictions, chemical exposure limits, safe prototype operation) are not.	***SUGGESTION:*** *Add that testing will occur only under supervised, authorized conditions and solvents will be handled in controlled, ventilated areas.*
Research Design The R&D and comparative- experimental design is appropriate, but **safety protocols** are not explicitly documented.	***SUGGESTION:*** *Provide a sub-section listing hazard controls: PPE, fume ventilation, no open flames, solvent storage protocols, and device shutdown procedures.*
Conflict of Interest No conflicts are declared, but the script should clarify that evaluators (if any) are not grading the researchers.	***SUGGESTION:*** *Add that any supervising teacher will not evaluate the study group academically based on results.*
Research	***SUGGESTION:***

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

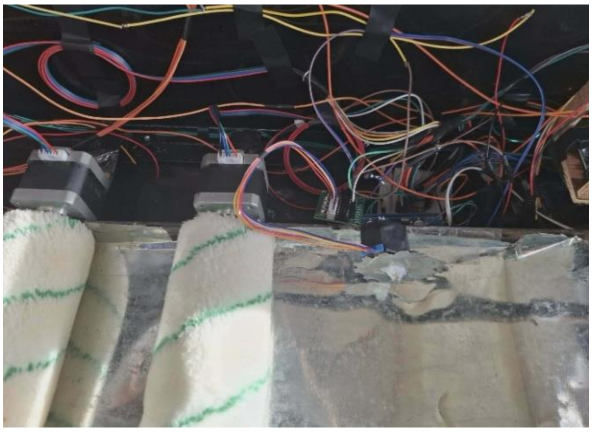
Environment/Participants/Sampling The manuscript mentions a school- based testing area but lacks safety signage and authorization measures. Correctly states that only paper samples are used, but the environmental hazard of solvent residues is not addressed.	*Secure written approval from the principal and clearly label the testing area (“Prototype Testing – Restricted Access”).* *Mention that all solvent waste will be collected in a sealed container and disposed of through the school’s hazardous-waste procedure.*
Recruitment of Participants Not applicable because no human respondents are involved, but this should be clearly reflected in the protocol.	***SUGGESTION*** *Include a statement: “No human participants will be recruited; this study involves paper samples only.”*
Inclusion/Exclusion/Withdrawal Criteria Not applicable, but must still be declared for completeness.	***SUGGESTION*** *Indicate “N/A – non-human research” under these criteria.*
Confidentiality and privacy Although no personal data are collected, operational data and photos of procedures must be stored ethically.	***SUGGESTION:*** Add that all documentation is stored in password- protected folders accessible only to researchers and the adviser; data will be deleted after one year.
Data Gathering The procedure is comprehensive but lacks **risk-management and emergency protocols** for chemical spills, inhalation, or device malfunction.	***SUGGESTION:*** *Add a spill-response guideline, first-aid plan, and a requirement that testing must be supervised by an adult at all times.*
Others The ethical considerations section. Ethical standards are mentioned but remain general. The device uses solvents in a mechanical system; the protocol should specify **air quality management** (ventilation, fume dissipation).	1) Explicitly relate the study to *Belmont principles* for non-human research—Beneficence (minimize harm), Justice (safe facility use), and Respect forPersons (safety of all individuals in testing’s vicinity). 2) Indicate that the device will be tested in a well-ventilated area or near an exhaust fan; mask use is advised.

Sincerely yours,

JOSELITO Y. BULABOS MA
San Agustin NHS-Ethics Review Board

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

APPENDIX H. Design/Features of the System



ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume XI Issue II February 2026

APPENDIX I. Documentation