

Technical Evaluation of the Smart Water Jug-Plastic Bottle Disposal System

Arriza Murl L. Azur¹; Kia S. Beraña²; Hannah Mae C. De Lima³;
Jasmine N. Martinez⁴; Ailene M. Milagrosa⁵; Donita Mae M. Panuelos⁶;
Amyiel Enrico D. Rebuena⁷; Camilla Jean B. Salcedo⁸;
Christel Jhana M. Tacadino⁹; John Allen B. Valde¹⁰;
Jessa Mae L. Caletisen¹¹; Xenia S. Baesa Alfelor¹²

^{1,2,3,4,5,6,7,8,9,10}Senior High School, Ocampo National High School, San Francisco, Ocampo, Camarines Sur
^{11,12}Faculty, Department of Education- Ocampo National High School, San Francisco, Ocampo, Camarines Sur

Publication Date: 2026/10/22

Abstract: This study evaluated the technical performance and behavioral impact of the Smart Water Jug–Plastic Bottle Disposal System (SWJ – PBDS) as a strategy at Ocampo National High School – Senior High School (ONHS-SHS). The research addressed the escalating issue of plastic waste, focusing on reducing plastic bottle consumption through innovative smart sensor technology. The study employs a mixed-methods approach, combining descriptive and quasi-experimental designs. The descriptive component details the system’s characteristics via surveys, gathering data on user experiences and operational aspects. The quasi-experimental component assesses the system’s impact on waste management outcomes using a pre-test and post-test survey to compare waste reduction before and after the implementation of the research product. Data were gathered through a waste audit and a five-point Likert Scale survey administered to twenty (20) Grade 12 – Biescas students. The findings revealed that before implementation, 100% of plastic bottles were disposed of in general waste bins due to a lack of specialized infrastructure. Following the installation of the Smart Water jug, the disposal pattern shifted dramatically, with 96.77% of bottles successfully diverted into the automated system. The study concludes that the integration of automated sensors and reward-based incentives is highly effective in modifying disposal habits and enhancing environmental perception. However, the researcher recommends that such technology be paired with continuous environmental education to sustain long-term behavioral changes.

Keywords: Disposal System, Smart Water Jug Plastic Bottle.

How to Cite: Arriza Murl L. Azur; Kia S. Beraña; Hannah Mae C. De Lima; Jasmine N. Martinez; Ailene M. Milagrosa; Donita Mae M. Panuelos; Amyiel Enrico D. Rebuena; Camilla Jean B. Salcedo; Christel Jhana M. Tacadino; John Allen B. Valde; Jessa Mae L. Caletisen; Xenia S. Baesa Alfelor (2026) Technical Evaluation of the Smart Water Jug-Plastic Bottle Disposal System.

International Journal of Innovative Science and Research Technology, 11(10), 1204-1218.

<https://doi.org/10.38124/ijisrt/26oct215>

I. INTRODUCTION

In a world increasingly focused on environmental sustainability, effective waste management has become a critical issue. Driven by population growth and changing lifestyles, the rapid increase in product consumption has resulted in a significant rise in waste production. This threatens human health and also harms environmental quality and economic progress. Furthermore, it exacerbates global problems such as pollution, climate change, and biodiversity loss.

In response to this evolving crisis, many countries and organizations are seeking innovative solutions, including initiatives that help consumers understand the impacts of

waste and the importance of sustainable practices. Advances in technology have also contributed to the development of intelligent waste bins equipped with sensors that optimize waste collection and sorting, thereby increasing efficiency and facilitating waste reduction efforts. The creation of smart waste bins and the implementation of effective waste management programs, which often feature community incentives and local initiatives, exemplify successful waste management strategies.

Nevertheless, despite the advancements, many countries continue to confront significant challenges related to waste disposal each year. These challenges stem from factors such as rapid urbanization, inadequate waste management infrastructure, and limited public awareness

about recycling and waste reduction. As a result, many communities struggle with overflowing pollution and the environmental impacts of improperly discarded waste.

Addressing these persistent challenges requires a multifaceted approach that includes robust government policies, active community engagement, and the adoption of innovative waste management solutions. Countries are increasingly recognizing the importance of these measures by instituting regulations that mandate the placement of recycling bins in public spaces and instituting laws aimed at waste reduction and management. However, the success of these efforts depends not only on the government but also on citizens getting involved.

Improperly managed waste can have severe consequences for ecosystems and public health, leading to the spread of diseases and long-term contamination of land, water, and air. Whether in solid, liquid, or gaseous form, waste can cause irreversible environmental damage, raising global concerns among experts - particularly alarming in a generation that has become increasingly dependent on disposable materials.

If this problem continues to grow, it will have far-reaching consequences, impacting a wide demographic, including both adults and children. Teenagers, in particular, who are navigating the challenges of school life, are at significant risk. This vulnerable group may experience adverse effects on their mental and emotional well-being, as well as their academic performance. Hence, ensuring that effective solutions safeguard the future of these individuals and the community as a whole has become imperative.

According to the Institute for Environmental Research and Education (IERE, 2025), waste is any material or item that is useless, faulty, or without value after it has served its intended purpose, classified into three primary categories based on their physical state: liquid, solid, and gaseous. For instance, plastic bottles fall under the category of solid waste. While these bottles are convenient and widely used, their environmental impact is profound and far-reaching. As a significant source of pollution, plastic waste poses critical challenges to both ecosystems and global health, leading to severe contamination of terrestrial and marine environments.

Currently, with two billion generated each year, the amount of residue growth is estimated to double to at least four billion by 2050 globally (Statista Research Department, 2025). Such exponential growth in waste generation demands urgent and effective waste management strategies. If not addressed properly, this waste surge can be dire, particularly when landfills leak harmful pollutants into the surrounding soil and groundwater. These pollutants can also contribute to the release of dangerous air emissions, resulting in detrimental health effects for nearby communities. Individuals exposed to these hazardous conditions are at an elevated risk of developing serious health problems, including respiratory infections, cardiovascular diseases, stroke, and even lung cancer (World Health Organization, 2024).

In Asia, the region produces approximately 14 million tons of plastic annually, underscoring the critical need to address plastic waste effectively. A significant portion of this plastic ultimately makes its way across oceans from coastal areas, thereby intensifying the global pollution crisis and endangering marine life (Schmaltz et al., 2020). These plastics often break down into microplastics, which pose significant threats to numerous species across diverse ecosystems. Recent estimates indicate that roughly 1,557 species worldwide have inadvertently ingested these tiny particles, which are prevalent in terrestrial and aquatic environments (Lai, 2022). The consumption of microplastics can have harmful consequences on the health of these organisms, particularly affecting their digestive and reproductive systems. This issue extends beyond individual species, raising broader ecological concerns as the accumulation of microplastics within food chains may disrupt entire ecosystems and threaten biodiversity. The lengthy decomposition period of plastics, which can take hundreds to thousands of years to fully break down, depending on their material composition (Chariot Energy, 2024).

Recognizing the critical importance of effective waste management solutions, numerous countries have committed to investing in robust infrastructure. A notable example of success in this area is Germany, which implemented the Deposit Return Scheme (DRS) in January 2003 (TOMRA, 2023). This initiative has resulted in an impressive 98.4% return rate for single-use drink containers, significantly reducing the environmental impact of plastic waste. By incentivizing consumers to return bottles, Germany has established a highly efficient system that prevents millions of plastic containers from being improperly discarded.

In addition to policy measures, innovative scientific advancements are also playing a vital role in enhancing waste management strategies. For instance, in 2016, researchers in Japan discovered a groundbreaking enzyme capable of degrading Polyethylene terephthalate (PET), the most commonly utilized type of plastic (Lewis, 2023). Named PETase, this enzyme can effectively break down PET into its constituent parts, offering a promising solution to the recycling challenges associated with plastic waste.

In the Philippines, the government has undertaken steps to address its escalating waste management crisis. On January 26, 2001, legislation was enacted by the Office of the President aimed at tackling the increasing issue of waste resulting from improper disposal practices. It aims to train Local Governments on effective waste practices. However, despite these legislative efforts, studies indicate that the country continues to face significant challenges related to waste management, including inadequate infrastructure and limited public awareness campaigns (Amaechi, 2022). Accordingly, the need for comprehensive waste management solutions remains high in the Philippines, underscoring the ongoing requirement for improved practices in this essential sector.

The primary objective of this study was to investigate and develop an effective infrastructure aimed at addressing

the pressing challenges associated with waste disposal management. A key focus was placed on strategies to minimize the consumption of plastic bottles, which significantly contribute to environmental pollution. The researchers developed and evaluated an innovative smart sensor technology to monitor and help manage waste. This approach provided valuable insights and solutions to the escalating waste management crisis currently facing the Philippines, ultimately promoting sustainable practices and reducing the ecological footprint of plastic waste.

II. LITERATURE REVIEW

All the literature and studies that are gathered are for the researcher to get a deeper understanding and to have an idea regarding the efficacy of smart waste systems in waste management and their features from the content of the related literature and related studies. It is shown that the current studies are focused on the way innovative strategies of waste management, the outcomes, and the features of the smart system.

According to Alourani Abdullah (2025), a smart waste disposal system uses technology like sensors, artificial intelligence, and the Internet of Things (IoT) to automatically detect, sort, and monitor waste. These systems help in proper recycling, especially for plastic bottles, by identifying materials accurately (Alourani et al., 2025). The idea started with the first automated waste collection system in Sweden in 1961, which inspired today's eco-friendly waste management tools.

As a result of the increasing digital integration and advanced computerization, the innovative solution for plastic waste, including the use of Reverse Vending Machine become a swift transition of plastic waste disposal systems worldwide. In European nations such as Germany and Norway, the implementation of using RVM as a waste disposal system achieves a recycling rate of over 90% for beverage containers. Moreover, a study by the Ellen MacArthur Foundation says that RVM schemes are found crucial for creating a circular economy for plastics as they lower pollution and conserve resources.

In the Philippines, the use of the RVM machine as a way of waste disposal has gained traction as a means of incentivizing recycling and promoting waste disposal. The SM Cares has launched the Eco Vendo Reverse Vending Machine, offering a trade-in plastic bottle for a coupon. This initiative is inspired by countries like Japan, India, and the United States. Active participation allows individuals to support responsible waste management and a sustainable future (Rosales, 2023).

According to GMA Integrated News (2024), the Philippines' adoption of smart waste management technologies has become a promising approach to addressing urban waste challenges and improving efficiency in waste collection and disposal. Notable innovations include projects developed by local students and communities, such as those in Baguio City, where solar-powered smart bins equipped

with real-time capacity monitoring and notification systems have been implemented. These smart bins help waste collectors respond promptly to bin fullness, thereby reducing overflow and unsightly waste accumulation.

Moreover, the introduction of mobile applications and wireless internet-connected systems has enhanced operational efficiency by enabling real-time recording and reporting of waste collection activities. These technologies facilitate better coordination between residents, waste collectors, and local governments, promoting cleaner environments and more effective resource management.

The integration of incentives in these smart waste systems further encourages community participation. Examples include the use of reward-based applications and blockchain technology to track waste amounts and distribute instant rewards, empowering informal waste collectors and fostering greater environmental responsibility.

Therefore, the implementation of smart waste system applications in the Philippines demonstrates the potential of leveraging technology and incentives to transform waste management practices, reduce environmental impact, and promote sustainable urban living.

According to Singson (2022), published a journal article on solid waste management in the Philippines as a means of mitigating the adverse effects of climate change. According to the study, waste segregation is important in terms of recycling and ensuring that all trash is not thrown together. Effective waste segregation and disposal are necessary in order to save the environment since inadequate disposal may result in contamination and pollution of the water, land, and air.

The implementation of smart waste system applications in the Philippines demonstrates the potential of leveraging technology and incentives to transform waste management practices, reduce environmental impact, and promote sustainable urban living.

According to Sampulna (2022), the main problem with waste management in the Philippines is poor segregation of waste at the local level. Proper enforcement of waste management policies through laws by the Local Government Units (LGUs) is essential. The Department of Environment and Natural Resources (DENR) has closed down all open dumpsites and mandates LGUs to create sanitary landfills. Yet, there remains a lack of awareness of waste segregation for households. Proper separation of biodegradable, recyclable, residual, household hazardous, and household healthcare wastes is necessary. The public is encouraged to use color-coded bins or labels. The DENR offers the Basura Buster app to help young people learn about waste management.

Verzosa 2024) carried out a study in coastal barangays in the Philippines and found moderate awareness and practices among communities but pointed out legal knowledge gaps and segregation of waste behaviors, which

are important for sustainable waste management.

In 2023, Mohamed et al. designed and thoroughly tested a prototype smart recycling machine for plastic bottles that utilized Internet of Things (IoT) technology. The system incorporated advanced sensors and cameras to enable real-time tracking of the recycling process and the amount of collected materials. A key feature was its built-in reward system, aimed at motivating users to participate actively in the recycling initiative. Evaluation results revealed major improvements: increased waste collection efficiency compared to conventional methods, enhanced real-time monitoring for continuous performance optimization and quick problem detection, and significantly higher user participation thanks to the reward mechanism. These findings indicate that IoT-based smart recycling machines have strong potential to advance waste management and encourage eco-friendly practices.

In 2024, Gito and colleagues introduced an innovative, internet-connected recycling system that offered users tangible rewards for returning plastic bottles. Featuring a simple, user-friendly design combined with online incentive programs and effective bottle-sorting mechanisms, the system made recycling both convenient and engaging. The study's outcomes were impressive—this tech-driven, reward-based approach not only reduced plastic waste accumulation but also greatly boosted public involvement in recycling efforts. This demonstrates how technology can play a transformative role in addressing environmental issues.

In 2025, Manjares, Mindiola, and Rey presented an innovative approach to waste management through the development of an Arduino Uno-based Automatic Color Segregator. This system aims to improve the efficiency of waste sorting while encouraging responsible disposal practices. It incorporates color sensors linked to an Arduino microcontroller, enabling the automatic detection and separation of waste by color classification, with categories such as plastic, paper, and metal. The Arduino Uno functions as the central processing unit, managing the sensors and actuators that direct waste into their designated compartments. Testing of the prototype showed generally reliable performance, although minor detection inaccuracies were observed, indicating potential for refinement. By automating the segregation process, the system reduces manual labor, minimizes health risks for sanitation workers, and promotes environmental awareness through more effective recycling and waste reduction. Furthermore, its programmable sensors allow customization for the specific waste management requirements of various communities in the Philippines. This work reflects a broader trend in leveraging IoT and microcontroller technologies, such as the Arduino Uno, to create cost-effective, scalable, and efficient smart waste disposal systems that address both environmental concerns and operational inefficiencies.

In a recent study, Khan et al. (2023) explored the impact of interactive waste disposal systems on consumer behavior and recycling rates. Their research indicated that systems incorporating interactive features, such as feedback

mechanisms and real-time data reporting, significantly enhance user participation in recycling initiatives. The study's results suggest that the Smart Water Jug could be designed to incorporate features that engage users and promote responsible disposal of plastic bottles, potentially leading to improved effectiveness in waste management. The high initial cost is a significant barrier to the widespread adoption of smart water jug plastic bottle disposal systems. The advanced features, such as sensors for hydration tracking, Wi-Fi or Bluetooth connectivity, and potentially even self-cleaning technology, all contribute to a higher production cost. This premium pricing can deter many consumers, especially when compared to the low cost of traditional, non-smart alternatives. The expense can make it difficult for these systems to achieve market penetration, as cost-conscious buyers may prioritize affordability over the technological advancements and long-term benefits they offer.

Policy issues present a complex challenge for the development and implementation of smart disposal systems. While some policies, like "Extended Producer Responsibility" (EPR) schemes and deposit-refund systems, are designed to encourage recycling, they may not specifically account for the unique features of smart disposal units. The integration of technology in these systems raises concerns about data privacy and security, which may require new regulations to protect consumer information. Additionally, the effectiveness of existing local ordinances on plastic waste management, which vary from place to place, may not be fully assessed or aligned with the capabilities of these new smart technologies.

III. MATERIALS AND METHODS

This study employed a mixed-methods approach, utilizing both descriptive and quasi-experimental research designs to evaluate the technical effectiveness of the SWJ – PBDS at ONHS - SHS. The descriptive component focused on detailing the characteristics of the disposal system in terms of its design and usage, gathering comprehensive data on user experiences and operational aspects through surveys. Quantitative data were collected to measure the frequency of use, providing a foundational understanding of how the system functioned in a real-world setting and identifying patterns for improvement.

The quasi-experimental component assessed the impact of the SWJ - PBDS on waste management outcomes. A pre-test and post-test design was implemented to compare waste reduction before and after the system's installation. Quantitative data, including the volume of plastic bottle waste collected, were analyzed using statistical tests to determine the significance of any observed changes. This combined approach allowed for a thorough evaluation of the system's effectiveness in reducing waste and fostering environmental responsibility among Grade 12 - Biescas students at Ocampo National High School.

➤ *System Architectural Design*

The Smart Water Jug - Plastic Bottle Disposal System is constructed using a vending machine-style layout, designed

to provide a centralized and durable housing for the disposal process. This structured layout serves as the physical

framework of the study, ensuring a stable and user-friendly unit.

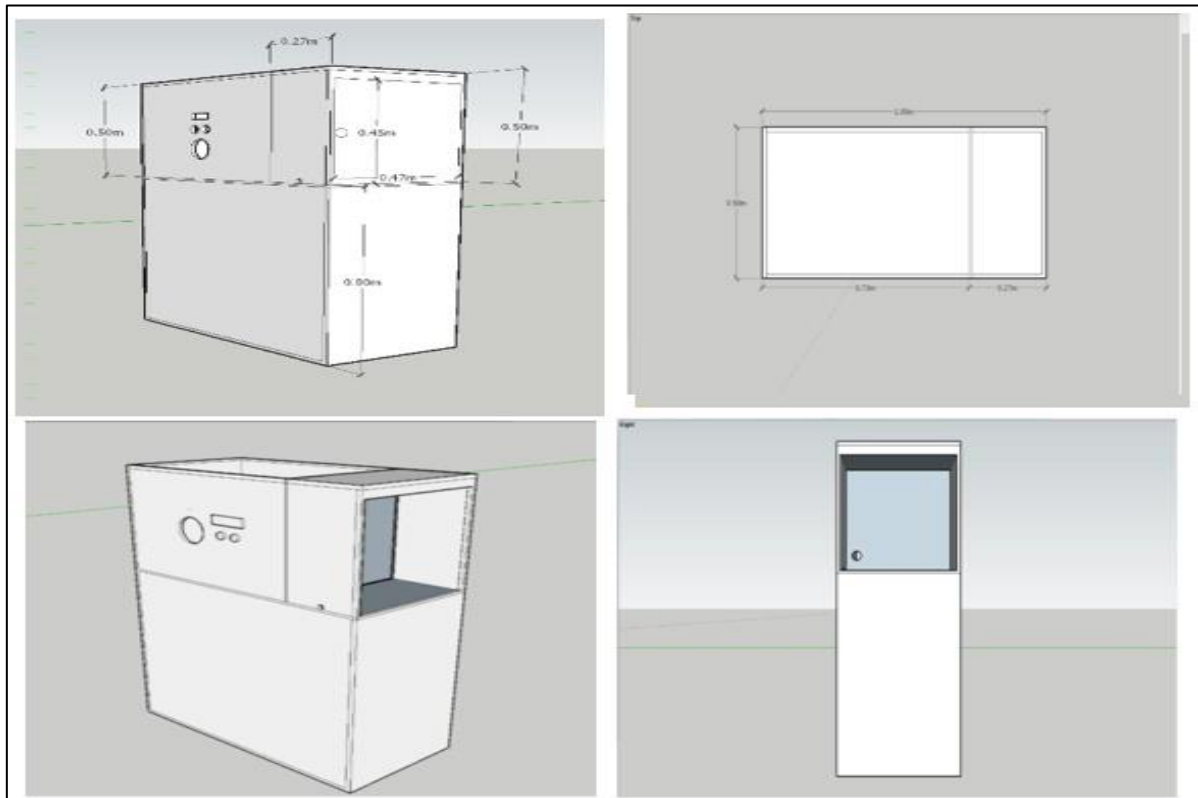


Fig 1 System Architectural Design

➤ *Structural Materials*

- Plywood ($\frac{1}{2}$ and $\frac{1}{4}$)
- Cocolumber
- Nails
- Wood Paint

- PVC Hose ($\frac{3}{4}$)
- PVC Pipe (#4)
- Faucet
- Hinges
- Lock



Fig 2 Structural Materials

➤ *Electronic Components*

- Arduino Uno R3
- Ultrasonic Sensor
- Infrared Sensor

- LCD 6×12 Display
- Push Buttons (Red and Green)
- Red and Green LEDs
- Buzzer

- Breadboard
- Male Plug with Wire
- AC-DC Power Supply (12V)
- DC-DC Buck Converter (12V–5V)
- Jumper Wires (M-M, M-F, and F-F)

➤ Development Procedures

• Step 1: Conceptualization and Functional Aim

The initial phase involved defining the core objectives of the SWJ-PBDS. The system was engineered to incentivize proper waste management through a reward-based mechanism. Key functional requirements included automated plastic bottle detection and a synchronized counting system that triggers a clean water reward upon reaching a specified threshold.

• Step 2: Structural Design and System Layout

Following the conceptual phase, a comprehensive structural layout was drafted to optimize the placement of electronic and mechanical components. The prototype was designed as a rectangular unit measuring 1.00 meters in width and 1.30 meters in height.

- ✓ Internal Partitioning: The interior was organized into functional zones using horizontal partitions at 0.50m and 0.80m.
- ✓ Zone Allocation: The upper section (0.73m) was reserved for the electronic control system and bottle insertion mechanism, while the remaining 0.27m was allocated for the water jug. The lower section served as the primary storage collected recyclables.

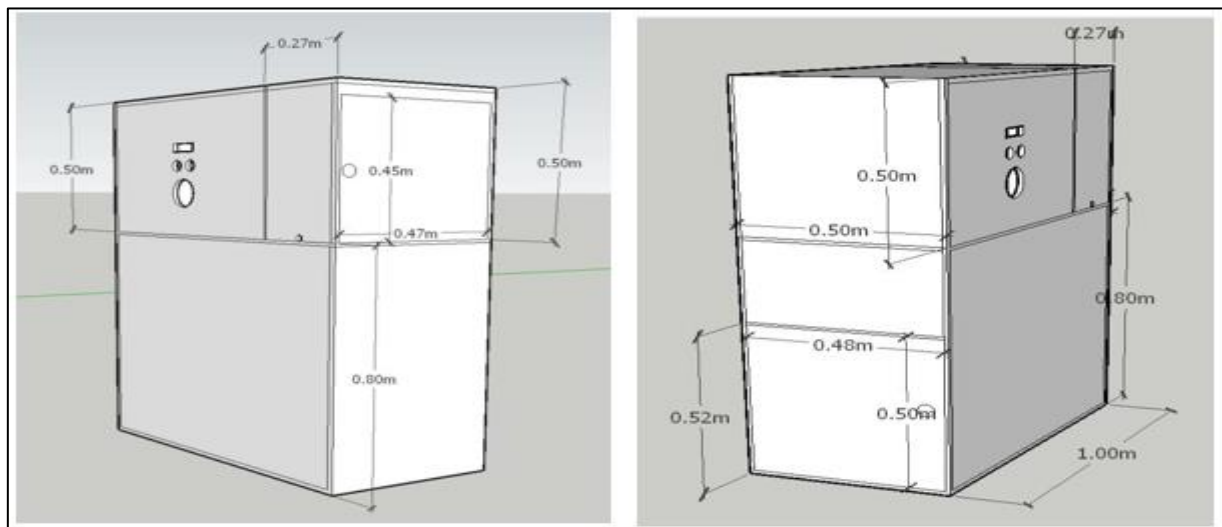


Fig 3 Development Procedures

This design layout ensured that the machine components were organized properly and that the system would operate efficiently.

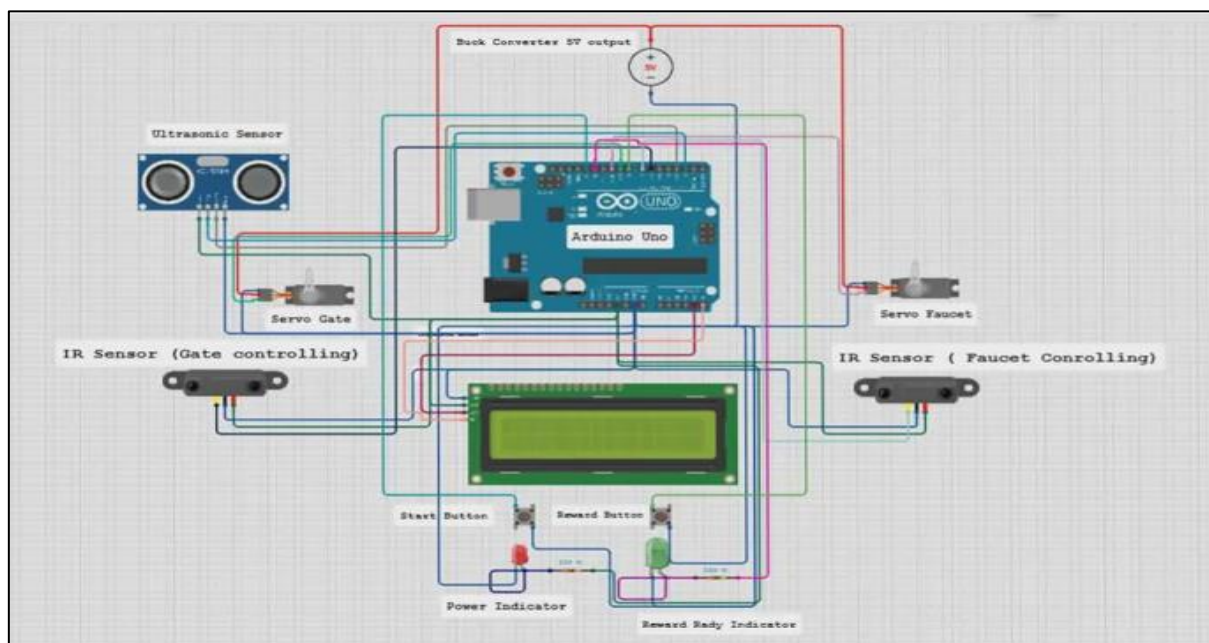


Fig 4 System Would Operate Efficiently

- *Step 3: Material Preparation and Precision Cutting*

Based on the finalized schematics, structural materials—specifically plywood and cocolumber—were measured and cut to precise dimensions. This accuracy ensured seamless assembly and structural integrity of the final prototype.

- *Step 4: Structural Assembly*

The measured components were assembled piece-by-piece to form the main chassis. Critical mechanical features were integrated during this stage, including the PVC bottle insertion holder and dedicated access doors for maintenance and waste collection.

- *Step 5: Software Programming and Systems Integration*

The technical logic of the system was developed using the Arduino IDE. In collaboration with computer engineering consultants, the researchers programmed the system to manage sensor-based bottle detection, real-time bottle counting, LCD status updates, and the precise control of servo motors for the bottle gate and water dispenser. The researchers used c++.

- *Step 6: Hardware Installation*

Following the successful compilation of the system code, electronic components were fixed in their designated positions. Sensors, displays, and actuators were interconnected via the Arduino Uno R3 and powered through a regulated 12V-to-5V power circuit to ensure electrical stability.

- *Step 7: Final Finishing and Durability Treatment*

The final stage focused on the aesthetic and physical longevity of the system. The wooden chassis underwent rigorous sanding and cleaning to achieve a smooth finish. A protective layer of wood paint was applied to enhance the prototype's appearance and provide a weather-resistant coating for long-term use.

➤ *Functional Description of the Prototype*

The Smart Water Jug – Plastic Bottle Disposal System (SWJ-PBDS) is engineered to automate waste segregation and incentivize the responsible disposal of plastic bottles. The system utilizes integrated ultrasonic and infrared sensors to detect and validate plastic bottles deposited into the machine. Upon detection, the system facilitates the collection and storage of the waste within an internal compartment. This mechanism was aimed at mitigating improper plastic disposal within the school environment and foster proactive waste management habits among students.

➤ *Operating System Process*

The SWJ-PBDS operates through a synchronized sequence of automated procedures managed by a central microcontroller. The system integration includes an LCD interface, infrared sensors, ultrasonic sensors, and fluid control actuators to manage detection, monitoring, and reward distribution. The operational workflow is detailed as follows:

- **System Initialization:** Upon powering the device, the user engages the red "Start" button to initialize the system. The LCD interface then displays the prompt "Push Start Button" to guide the user through the initial phase.
- **Detection and Input:** The user inserts three empty plastic bottles individually through the designated circular aperture. As each bottle passes the entry point, an infrared (IR) sensor identifies the object and transmits a signal to the microcontroller, which registers and tallies the insertion.
- **Data Processing:** Once the system validates the insertion of the required three bottles, the microcontroller updates the system status. The LCD interface then displays "Reward Ready," notifying the user that the reward criteria have been met.
- **Reward Activation:** The user initiates the dispensing sequence by pressing the green button. The system requires the placement of a receptacle (e.g., cup or tumbler) beneath the faucet prior to activation.
- **Automated Dispensing:** Upon activation, the system dispenses clean drinking water for a calibrated duration of approximately 10 seconds. The electronic valve automatically closes after this interval to ensure precise portion control and prevent overflow.
- **Capacity Monitoring:** Concurrently, an ultrasonic sensor is utilized to monitor the volume of the internal storage container. This sensor continuously measures the fill level of the collected bottles to determine when the container reaches maximum capacity.

➤ *Respondents of the Study*

The respondents of this study consisted of 20 Grade 12 students from the Science, Technology, Engineering, and Mathematics (STEM) strand, specifically from the 12 – Biescas section of Ocampo National High School – Senior High School. This group was selected to provide a comprehensive perspective on waste management practices and to evaluate the technical effectiveness of the SWJ – PBDS within the school environment. The uniform academic background of the participants ensured a consistent level of understanding regarding the technical and environmental objectives of the study.

➤ *Data Gathering Tools*

To comprehensively assess the technical evaluation of the Smart Water Jug-Plastic Bottle Disposal System, this study utilized a structured survey administered to 20 purposively selected Grade 12 Biescas students at Ocampo National High School. The data gathering process was divided into two phases: a Pre-Test to establish baseline disposal habits and perceived needs, and a Post-Test to evaluate the system's usability, impact, and reward mechanism. The questionnaire employed a 5-point Likert Scale, which allows researchers to quantify the students' levels of agreement or disagreement regarding the system's functionality, convenience, and environmental impact. This approach ensured a measurable analysis of both the students' behavioral motivations and their overall perception of the innovation.

To evaluate SWJ – PBDS on waste management outcomes, quantitative data were collected through waste audits conducted before and after the system's implementation. These audits measured the total volume of plastic bottle waste generated by the 12-Biescas students, providing a robust assessment of the system's effectiveness in achieving its intended waste management goals.

➤ *Procedure of the Investigation*

- *Conceptualization of the Study.*

The researchers initiate the study by conceptualizing the problem related to waste management at Ocampo National High School – Senior High School and formulating the research title. This involves identifying the specific issues regarding plastic bottle waste and how a Smart Water Jug-Plastic Bottle Disposal System can potentially address these issues. Reviewing existing literature and studies to gain a comprehensive understanding of smart waste systems and their effectiveness, drawing insights from Alourani et al. (2025), Verzosa et al. (2024), and others to shape the research focus.

- *Approval of the Title.*

After conceptualizing the problem and formulating the research title, the researchers submit the proposed title for approval to their subject teacher under Practical Research 2. Presenting the research idea, its significance, and the intended methodology, they have provided feedback and suggestions for improvement, ensuring the research aligns with the objectives of Ocampo National High School – Senior High School.

- *Seeking Permit to Conduct Study.*

The researchers will prepare a permit to conduct the study and will send it to the relevant authorities and focal persons involved, including the school principal and department heads. Ensuring that the research adheres to ethical guidelines and protocols, respecting the privacy and anonymity of the student respondents. The permit will outline the research objectives, methodology, and the potential benefits of the study to the school community.

- *Questionnaire Preparation and Content Validation.*

The researchers designed a survey questionnaire to gather data on the design, ease of use, and user experience of the Smart Water Jug-Plastic Bottle Disposal System. The questionnaire incorporated Likert scale questions to measure students' attitudes and perceptions, drawing on insights from Khan et al. (2023) about the importance of interactive features. To ensure the questionnaire's validity and reliability, it will be subjected to content validation by experts in waste management, environmental science, and survey design.

- *Questionnaire Administration.*

The researchers administer questionnaires to the selected number of students in 12 - Biescas at Ocampo National High School – Senior High School. This process involves distributing the questionnaires, providing clear instructions, and ensuring that students understand the

purpose of the study and their right to confidentiality. The researcher collected the completed questionnaires and verified all the responses.

- *Gathering, Analysis, and Data Interpretation.*

The researcher gathered the data from the completed questionnaires and proceed with analysis and interpretation. This involves organizing the data, coding responses, and applying appropriate statistical techniques such as frequency counts and weighted mean calculation. The researcher analyzed the data to identify the characteristics of the Smart Water Jug-Plastic Bottle Disposal System and its impact on waste management outcomes.

- *Research Reporting/Writing.*

The researchers compiled the findings, conclusions, and recommendations into a comprehensive research report. This report includes a detailed description of the research design, methodology, data analysis, and results. Adhering to the academic writing standards and ensure that the report is clear, concise, and well-organized. Submitting it to the research adviser, contributing to the body of knowledge on smart waste systems and their effectiveness in promoting environmental sustainability.

➤ *Statistical Tools*

This study used Frequency Count and Weighted Mean. The frequency analysis is used to determine the actual number of plastic bottles deposited in regular trash bins compared with those disposed of via vending machines. By applying this statistical tool, the researchers identified the patterns in user interaction and engagement with the Smart Water Jug – Plastic Bottle Disposal System. Furthermore, a frequency count is a critical component of the waste audit phase, as it enables researchers to track the actual volume of plastic bottles successfully diverted into the system versus those remaining in general waste bins, both before and after implementation. This method facilitates the interpretation of data through tabular representations, providing a clear visual overview of the system's impact on the disposal behavior of 12-Biescas at Ocampo National High School.

The weighted mean is also used as a statistical tool used to determine the overall perception or level of agreement among respondents regarding specific aspects of the study. It serves to assess the evaluation of the Smart Water Jug – Plastic Bottle Disposal System in terms of its design, usability, waste reduction impact, and environmental perception. Each response from the Pre-test and Post-test surveys is assigned a numerical value based on a 5-point Likert scale, allowing the researchers to summarize collective opinions into a single, interpretable score. By applying the weighted mean, the researchers identified which features of the system are effective and which require improvement. This method is particularly appropriate for descriptive studies utilizing Likert scales, as it provides a clear basis for evaluating the system's effectiveness, efficiency, and impact on the recycling behavior of students at Ocampo National High School.

IV. RESULTS AND FINDINGS

This study presents the presentation, analysis, and interpretation of the data gathered in the study titled “Technical Evaluation of the Smart Water Jug – Plastic Bottle Disposal System.” The results are organized and interpreted based on the responses collected from the respondents. The data were obtained through a pre-test and post-test survey questionnaire using a five-point Likert scale, where a total of 20 respondents rated their level of agreement from Strongly Disagree (1) to Strongly Agree (5). Their responses were

carefully analyzed to determine how effective the Smart Water Jug – Plastic Bottle Disposal System is in promoting proper plastic bottle disposal and improving waste management practices.

➤ Pre-Test Data

The following tables present the baseline data gathered during pre-test phase, before the implementation of the Smart Water Jug - Plastic Bottle Disposal System. This data establishes the initial disposal habits, perceived needs, and environmental awareness of the respondents.

Table 1 Tally of the Pre-Test Result on Current Disposal Habits and Infrastructure

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. I find it easy to locate dedicated trash bins for plastic bottles on campus.	1.8	Strongly Disagree	n=20
B. The existing waste bins are clearly labeled to help me segregate my trash correctly.	2.0	Disagree	n=20
C. I consistently dispose of my plastic bottles in the designated areas rather than general waste.	3.3	Neutral	n=20
D. I believe the current trash bins is sufficient for the student population.	2.5	Disagree	n=20
GRAND MEAN	2.4	Disagree	

Table 1 highlights the participants' evaluation of the existing waste management infrastructure before the implementation of the smart system. Among the twenty (20) respondents: Statement A, regarding the ease of locating dedicated trash bins, received a mean of 1.8, interpreted as Strongly Disagree. This indicates a significant lack of accessible recycling points on campus. Statement B, which assesses the clarity of bin labeling for segregation, earned a mean score of 2.0 (Disagree), suggesting that current manual bins do not provide enough guidance for students to sort waste correctly. Statement C, concerning the consistency of disposing bottles in designated areas, garnered a mean of 3.3 (Neutral). This reflects that while some students attempt to recycle, the lack of infrastructure prevents it from being a consistent habit. Statement D, which asks if current bins are sufficient for the population, resulted in a mean of 2.5 (Disagree). Overall, the Grand Mean of 2.4 indicates a Disagree interpretation, confirming that the baseline waste management system was perceived as inadequate and

difficult to use, justifying the need for a technological intervention.

Table 2 presents the participants' evaluation of the necessity for technological advancement in school waste management prior to the implementation of the Smart Water Jug. Among the twenty (20) respondents: Statement A, regarding whether the manual process of segregating plastic is time-consuming, achieved a weighted mean of 4.5, interpreted as Strongly Agree. This indicates that students find existing non-automated methods inefficient.

Statement B, which assesses the belief that automated sensors would make waste segregation more effective, earned the highest mean score in this category at 4.55 (Strongly Agree). This highlights a strong consensus among the student population that technological integration is a superior solution for accurate waste sorting.

Table 2 Tally of the Pre-Test Survey Results on Perceived Need for Innovation

Statement	Weighted Mean	Verbal Interpretation	Frequency
I find the current manual process of segregating plastic from general waste is time-consuming.	4.5	Strongly Agree	n=20
B. I believe that using technology, such as automated sensors, would make waste segregation more effective.	4.55	Strongly Agree	n=20
C. I am often frustrated by the lack of organized disposal systems for plastic materials.	4.45	Strongly Agree	n=20
D. I am willing to try a “Smart” disposal system to improve my disposal habits.	4.4	Strongly Agree	n=20
GRAND MEAN	4.48	Strongly Agree	

Statement C, concerning frustration over the lack of organized disposal systems, garnered a mean of 4.45 (Strongly Agree). This reflects a significant level of dissatisfaction with current traditional facilities.

Furthermore, Statement D, which measures the willingness of students to try a “Smart” disposal system, resulted in a mean of 4.4 (Strongly Agree). This suggests that the target users are highly receptive to behavioral changes

when supported by innovative tools.

Overall, the Grand Mean of 4.48 signifies a Strongly Agree interpretation. These results demonstrate a clear and

urgent perceived need for innovation, establishing a strong justification for the development and deployment of the Smart Water Jug system.

Table 3 Tally of the Pre-Test Survey Results on Motivation and Incentive

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. I feel a strong personal motivation to put plastic bottles into proper trash areas even without receiving a reward.	4.3	Strongly Agree	n=20
A. I would be more likely to dispose my plastic bottle properly if I received an immediate incentive, such as clean drinking water.	3.6	Agree	n=20
C. A reward system would increase my interest in disposing of plastic bottles correctly.	3.85	Agree	n=20
D. I believe that incentives are necessary to encourage high participate in school waste management program.	4.55	Strongly Agree	n=20
GRAND MEAN	4.08	Agree	

Table 3 analyzes how the prospect of incentives and rewards influences the recycling behavior of the twenty (20) respondents before the system's launch.

Statement A, regarding personal motivation to recycle even without a reward, achieved a weighted mean of 4.3, interpreted as Strongly Agree. This indicates that students possess a foundational sense of environmental duty. However, Statement B, which evaluates if an immediate incentive like clean water would increase the likelihood of proper disposal, earned a mean of 3.6 (Agree). While positive, this suggests that water is viewed as a helpful supplement rather than the sole reason for participation. Statement C, concerning whether a reward system would

increase overall interest in correct disposal, garnered a mean of 3.85 (Agree). This reflects a general openness to gamified or incentivized waste management. Most significantly, Statement D, which asserts that incentives are necessary to encourage high participation across the school, received a mean of 4.55 (Strongly Agree). This highlights a collective belief that while individuals may be motivated, a school-wide program requires tangible benefits to ensure maximum engagement.

Overall, the Grand Mean of 4.08 signifies an Agree interpretation, concluding that the integrated reward system of the Smart Water Jug is a strategically sound method for reinforcing positive disposal habits.

Table 4 Tally of the Pre-Test Survey Results on Environmental Awareness and Impact

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. I am fully aware of the negative impact cause by unsegregated plastic waste.	4.75	Strongly Agree	n=20
B. I believe that the current waste management practices at school significantly reduce pollution.	3.15	Neutral	n=20
C. I feel that my individual actions in placing my used plastic into proper garbage bin, contribute to a more sustainable environment.	4.3	Strongly Agree	n=20
D. I believe there is a need for more awareness-raising tools regarding plastic bottle disposal.	4.5	Strongly Agree	n=20
	4.18	Agree	n=20

Table 4 provides an overview of the participants' baseline environmental consciousness and their perception of current school practices. Among the twenty (20) respondents:

Statement A, regarding awareness of the negative impacts of unsegregated waste, achieved the highest mean in the pre-test at 4.75, interpreted as Strongly Agree. This confirms that the student body is highly informed about environmental issues. Conversely, Statement B, which assesses if current school practices significantly reduce pollution, earned a mean of 3.15 (Neutral). This indicates a lack of confidence in existing traditional waste methods. Statement C, focusing on the belief that individual actions

contribute to sustainability, garnered a mean of 4.3 (Strongly Agree). This shows that students feel a sense of personal agency in waste management.

Finally, Statement D, regarding the need for more awareness-raising tools, resulted in a mean of 4.5 (Strongly Agree). This high score reinforces the demand for visible, interactive tools like the Smart Water Jug to bridge the gap between student awareness and effective action. The Grand Mean of 4.18 signifies an Agree interpretation, suggesting that while awareness is high, the school environment lacked the necessary "Smart" infrastructure to translate that awareness into measurable impact.

➤ *Post-Test Data*

Table 5 Tally of the Survey Results on the Effectiveness of the Smart Water Jug – Plastic Bottle Disposal System in Terms of System Design and Usability.

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. The system's design makes it easy to deposit plastic bottles quickly.	4.6	Strongly Agree	n=20
B. The automated sensors accurately detect and accept my plastic bottles.	4.3	Strongly Agree	n=20
C. The instructions on the Smart Water Jug are clear and easy to follow.	4.65	Strongly Agree	n=20
D. I find the machine convenient and easy to use.	4.1	Agree	n=20
GRAND MEAN	4.41	Strongly Agree	

The Table 5 survey findings highlight the participants' evaluation of the physical and operational design of the smart disposal system following the post-test phase. Among the twenty (20) respondents:

Statement A, regarding whether the design makes it easy to deposit bottles quickly, received a mean interval of 4.6, interpreted as Strongly Agree. This indicates that the physical opening and intake process are efficient for the users.

Statement B, which assesses the accuracy of the automated sensors in detecting and accepting bottles, earned a mean score of 4.3, interpreted as Strongly Agree. This confirms that the technical components of the jug are performing reliably in a real-world setting. Statement C, concerning the clarity of instructions on the Smart Water Jug,

garnered a mean of 4.65 (Strongly Agree). This reflects that the labeling or guidance provided on the machine is highly effective and easy for the student population to follow. Statement D, which asks if users find the machine convenient and easy to use, resulted in a mean of 4.1, which falls under the Agree category. This suggests that while the machine is considered easy to use, there may be minor factors—such as location or processing speed—that could be further optimized to reach a “Strongly Agree” level of convenience. Overall, the Grand Mean of 4.41 indicates that the Smart Water Jug – Plastic Bottle Disposal System is perceived as highly effective in terms of its system design and usability. These results demonstrate that the prototype is a viable and user-friendly tool for plastic waste management in a school environment.

Table 6 Tally of the Survey Results on the Effectiveness of the Smart Water Jug – Plastic Bottle Disposal System in Terms of Impact on Disposal Habits.

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. Since the system was installed, I rarely throw plastic bottles into the general waste.	4.35	Strongly Agree	n=20
B. Using this system has made me more conscious of segregating my trash.	4.3	Strongly Agree	n=20
C. I now use the Smart Water Jug system regularly for my bottle disposal.	4.75	Strongly Agree	n=20
D. The system has successfully reduced the amount of plastic litter in our classroom area.	4.45	Strongly Agree	n=20
GRANDMEAN	4.46	Strongly Agree	

Table 6 findings examine how the implementation of the Smart Water Jug influences the waste disposal behavior of the twenty (20) participants. Statement A, regarding the reduction of plastic bottles thrown into general waste, achieved a mean of 4.35 (Strongly Agree). This suggests that the system is successfully diverting plastic waste away from non-recyclable bins.

Statement B, which evaluates user consciousness regarding trash segregation, reached a mean of 4.3 (Strongly Agree). This indicates that the presence of the smart system serves as a psychological prompt, making students more mindful of their disposal choices.

Statement C received the highest mean in this category at 4.75 (Strongly Agree). This high score highlights a strong

adoption rate, with fifteen (15) out of twenty participants strongly agreeing that they now use the system regularly as their primary method for bottle disposal.

Statement D, focusing on the visible reduction of litter in the classroom area, resulted in a mean of 4.45 (Strongly Agree). This provides evidence of the system's tangible impact on the cleanliness of the immediate school environment.

The Grand Mean of 4.46 reflects a “Strongly Agree” interpretation, signifying that the Smart Water Jug – Plastic Disposal System has a profound positive impact on the disposal habits of its users. It effectively promotes regular recycling and enhances overall environmental responsibility within the school setting.

Table 7 Tally of the Survey Results on the Effectiveness of the Smart Water Jug – Plastic Bottle Disposal System in Terms of Motivation and Reward System.

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. Receiving potable water as a reward encourages me to use the vending machine.	4.47	Strongly Agree	n=20
B. I am more likely to dispose of my bottle properly because there is a tangible benefit.	4.5	Strongly Agree	n=20
C. The reward of clean water is a sufficient incentive for my participation.	3.8	Agree	n=20
D. I would continue to use the system even if the amount of water provided was small.	3.9	Agree	n=20
GRAND MEAN	4.24	Strongly Agree	

Table 7 findings analyze how the incentive mechanism of the Smart Water Jug, specifically the provision of potable water, serves to motivate student participation in recycling efforts.

Statement A, which evaluates if the potable water reward encourages use of the machine, achieved a mean of 4.75 (Strongly Agree). This suggests that the basic concept of the “reward” is highly effective in driving initial engagement with the system.

Statement B, regarding the likelihood of proper disposal due to a tangible benefit, reached a mean of 4.5 (Strongly Agree). This indicates that the physical nature of the reward (water) provides a stronger motivation for disposal than traditional, non-incentivized bins.

Statement C resulted in a mean of 3.8 (Agree). While still positive, the slightly lower score and the 9 “Neutral” votes in your tally suggest that some users may feel the amount or type of reward could be further optimized to ensure long-term participation.

Statement D, concerning the willingness to use the system even for smaller amounts of water, earned a mean of 3.9 (Agree). This reflects a positive commitment to the environment, though it reinforces that the perceived value of the reward plays a role in user consistency.

The Grand Mean of 4.24 signifies a “Strongly Agree” interpretation, concluding that the motivation and reward system is a key factor in the effectiveness of the Smart Water Jug. It successfully utilizes a tangible incentive to reinforce positive environmental behaviors among the participants.

Table 8 Tally of the Survey Results on the Effectiveness of the Smart Water Jug – Plastic Bottle Disposal System in Terms of Environmental Perception.

Statement	Weighted Mean	Verbal Interpretation	Frequency
A. I believe this vending machine significantly helps in reducing our school’s plastic waste.	3.8	Agree	n=20
B. I feel that my individual actions with this system contribute to a greener campus.	4.2	Agree	n=20
C. The system has increased my overall interest in environmental sustainability.	3.0	Neutral	n=20
D. I recommend expanding this smart vending machine to other areas of the school.	4.75	Strongly Agree	n=20
GRANDMEAN	3.94	Agree	

Table 8 findings provide an overview of how the system has shifted the participants’ views on school-wide sustainability and their personal contribution to environmental efforts.

Statement A, which assesses the machine’s perceived impact on school plastic waste, achieved a mean of 3.8 (Agree). This suggests that while students see the benefit, they recognize it as one part of a larger waste management solution.

Statement B, regarding the sense of contributing to a “greener campus,” reached a mean of 4.2 (Agree). This indicates that the system successfully empowers individuals by making their environmental contributions feel tangible and direct.

Statement C resulted in a mean of 3.0 (Neutral). This is the lowest score in the study, suggesting that while the system is a useful tool for disposal, a single intervention may not be enough to significantly change a student’s overall long-term interest in sustainability without additional educational support.

Statement D received the highest mean of 4.75 (Strongly Agree). With fifteen (15) out of twenty participants strongly supporting the expansion of the system, there is a clear demand for more “smart” disposal points across different school areas.

The Grand Mean of 3.94 signifies an “Agree” interpretation. This concludes that the Smart Water Jug – Plastic Disposal System is viewed as a highly positive

environmental addition to the campus. The overwhelming support for its expansion indicates that the student body

considers the technology both effective and necessary for the school's future waste-management goals.

➤ Waste Audit

Table 9 Waste Audit Checklist

Phase	Disposal Location	Frequency (f)	Percentage (%)
Pre-Implementation (Baseline)	Regular Trash Bin	18	100%
	Smart Water Jug	0	0%
Total		18	100%
Post-Implementation (Evaluation)	Regular Trash Bin	2	3.23%
	Smart Water Jug	60	96.77%
Total		62	100%

Table 9 presents the frequency count of plastic bottles collected during the waste audit phases. This statistical tool was utilized to track the actual volume of waste and monitor changes in the disposal patterns of the 20 Grade 12 Biescas students.

- **Baseline Data (Pre-Implementation):** During the initial audit, a frequency of 18 plastic bottles was recorded in the regular trash bins. At this stage, there was no dedicated "smart" system, resulting in 100% of plastic waste being disposed of in non-specialized bins.
- **Evaluation Data (Post-Implementation):** Following the introduction of the Smart Water Jug, the frequency count

showed a dramatic shift. A total of 60 bottles were successfully diverted into the smart vending machine, representing 96.77% of the total bottles recorded in the post-test phase. Conversely, the frequency of bottles found in regular trash bins dropped significantly to only 2 bottles (3.23%).

The sharp increase in the frequency of bottles deposited in the Smart Water Jug compared to the regular trash bins indicates that the system is highly effective in capturing plastic bottles. This data suggests that the integration of automated sensors and the incentive mechanism successfully encouraged students to move away from traditional disposal habits toward more sustainable waste management practices.

Table 10 Summary of Pre-Test and Post-Test Results

Category	Pre-Test Grand Mean	Verbal Interpretation	Post-Test Grand Mean	Verbal Interpretation
Infrastructure & Usability	2.4	Disagree	4.41	Strongly Agree
Disposal Habits & Impact	4.48	Strongly Agree	4.46	Strongly Agree
Motivation & Rewards	4.08	Agree	4.24	Strongly Agree
Environmental Perception	4.18	Agree	3.94	Agree

Table 10 shows the summary and the transformative shift in the school's waste management landscape. Initially, students expressed significant dissatisfaction with existing infrastructure, as evidenced by a pre-test Grand Mean of 2.4 (Disagree) regarding the ease of locating and using traditional bins. Following the implementation of the Smart Water Jug, this perception shifted dramatically to a Grand Mean of 4.41 (Strongly Agree), confirming that the prototype's design and automated sensors are both reliable and user-friendly. While students initially showed a high Strongly Agree (4.48) perceived need for technological intervention, the post-test data confirms that the system effectively met this demand by instilling a 4.46 (Strongly Agree) positive impact on actual disposal habits.

Most notably, the waste audit data supports these qualitative findings: prior to implementation, 100% of plastic bottles were disposed of in regular trash bins. After the introduction of the Smart Water Jug, 96.77% of recorded

plastic waste was successfully diverted into the smart system. These results collectively suggest that the integration of automated sensors and tangible incentives successfully bridges the gap between high environmental awareness and effective waste management action.

V. CONCLUSION AND RECOMMENDATIONS

The research indicates that the Smart Water Jug is a highly effective dual-purpose tool, blending user-centric design with tangible environmental results. From a structural standpoint, the system is regarded as both convenient and reliable, utilizing automated sensors and clear instructional interfaces that achieved a high satisfaction rating with a grand mean of 4.41. This ease of use directly translated into a dramatic shift in student behavior; the waste audit revealed that plastic waste diverted into the smart system skyrocketed from 0% to 96.77%, significantly reducing the volume of bottles thrown into general waste bins. A primary driver for

this participation was the integrated reward mechanism, where the provision of potable water acted as a functional incentive that motivated students to recycle more frequently. While the system successfully fostered a cleaner school environment and improved the general perception of campus sustainability, some students remained neutral on whether the technology alone could sustain long-term environmental interest without further academic support.

The researchers concluded that the Smart Water Jug is a practical and functional waste management tool whose success is rooted in its integrated sensor system and clear user interface. By providing a tangible incentive—potable water—the system creates a value-added cycle that successfully reinforces positive recycling behaviors and significantly reduces classroom plastic waste. While the system effectively serves as a behavioral catalyst and improves the perception of campus sustainability, it is most successful as a practical component of a broader environmental strategy. It functions best as a hands-on application of waste management rather than a standalone solution for developing long-term theoretical interest in sustainability.

To ensure the long-term viability and growth of this initiative, the researchers propose a multi-faceted approach to maintenance and expansion. First, the system requires a consistent schedule of technical updates and mechanical maintenance to ensure the sensors and dispensing units remain reliable. Beyond the initial pilot classroom, school administrators should look toward scaling the project by installing units in high-traffic areas across the campus to maximize the reduction of plastic waste. To keep student motivation high, the reward system should be periodically optimized, potentially by adjusting the water volume dispensed or introducing varied incentives. Finally, to move beyond simple habit formation, the school must pair the use of this technology with comprehensive environmental education and seminars to deepen the students' underlying commitment to sustainability.

REFERENCES

- [1.] Allied Market Research. (n.d.). Smart water bottle market size, share, growth | forecast 2035. <https://www.alliedmarketresearch.com/smart-water-bottle-market-A35349>
- [2.] Alourani, A., Ashraf, M. U., & Aloraini, M. (2025). Smart waste management and classification system using advanced IoT and AI technologies. *PeerJ Computer Science*, 11, e2777. <https://doi.org/10.7717/peerj-cs.2777>
- [3.] Amaechi. (2022, June 20). Waste disposal problems in the Philippines. *Environmentgo*. <https://environmentgo.com/waste-disposal-problems-in-the-philippines/>
- [4.] Amantayeva, A., Alkuatova, A., Kanafin, I., Tokbolat, S., & Shehab, E. (2021). A systems engineering study of integration reverse vending machines into the waste management system of Kazakhstan. *Journal of Material Cycles and Waste Management*, 23(3), 872–884. <https://doi.org/10.1007/s10163-020-01161-w>
- [5.] Chariot Energy. (2024, February 13). How long has it been for plastic to decompose? <https://chariotenergy.com/blog/how-long-until-plastic-decomposes/>
- [6.] Climate Change Commission. (n.d.). Plastic ban and regulation. <https://climate.gov.ph/our-programs/anti-single-use-plastic-campaign/plastic-ban-and-regulation>
- [7.] Coherent Market Insights. (2025). Eco friendly water bottle market size & forecast, 2025-2032. <https://www.coherentmarketinsights.com/industry-reports/eco-friendly-water-bottle-market>
- [8.] Credence Research. (n.d.). Smart water bottles market size, growth & forecast to 2032. <https://www.credenceresearch.com/report/smart-water-bottles-market>
- [9.] Ellen MacArthur Foundation. (2016). The new plastics economy: Rethinking the future of plastics. <https://ellenmacarthurfoundation.org/>
- [10.] Gito, E. G., Sarmiento, J. R., & Espinosa, M. L. (2024). Wireless internet-connected incentive system for collecting plastic bottles. *Global Scientific Journals*, 12(3), 433–444.
- [11.] Global Insight Services. (n.d.). Smart water bottle market size, growth, trends and forecast. <https://www.globalinsightservices.com/reports/smart-water-bottle-market/>
- [12.] GMA Integrated News. (2024). Philippines' adoption of smart waste management technologies. <https://www.gmanetwork.com/news/>
- [13.] Grand View Research. (2025). Smart waste management market analysis report by solution (hardware, software, services), by waste type, by application, by region, and segment forecasts, 2019 – 2025. <https://www.grandviewresearch.com/industry-analysis/smart-waste-management-market>
- [14.] Homewater. (n.d.). Everyday solutions to eliminate plastic bottle waste. <https://www.homewater.com/blog/everyday-solutions-to-eliminate-plastic-bottle-waste>
- [15.] Jangira, L. (2023, November 18). 10 scientific solutions to plastic pollution. *Earth.org*. <https://earth.org/scientific-solutions-to-plastic-pollution/>
- [16.] Khan, A., et al. (2023). Impact of interactive waste disposal systems on recycling rates: A case study. *Journal of Environmental Management*.
- [17.] Lai, O. (2022). The detrimental impacts of plastic pollution on animals. *Earth.org*. <https://earth.org/plastic-pollution-animals/>
- [18.] Manjares, H. E. S., Mindiola, S. P., & Rey, A. M. P. (2025). Arduino-based automatic color segregator for efficient waste management [Research proposal]. *Scribd*. <https://www.scribd.com/document/674240426/GROUP-13-RESEARCH-IV-PROPOSAL-1>
- [19.] Mohamed et al. (2023). Prototype smart recycling machine for plastic bottles using IoT technology.
- [20.] International Journal of Environmental Technology. Rosales, C. (2023, February 3). Turn used plastic

bottles into discount coupons at this futuristic vending machine.

SPOT.PH.

<https://www.spot.ph/newsfeatures/culture/103640/plastic-recycling-vending-machines-at-sm-malls-a4373-20230203>

- [21.] Sampulna, J. (2022). Waste management problems in the Philippines. Department of Environment and Natural Resources.
- [22.] Silva, M. J., et al. (2019). Smart waste management technologies: Innovations and applications. Environmental Science & Technology.
- [23.] Singson, A. (2022). Solid waste management in the Philippines as a means of mitigating the adverse effects of climate change. Journal of Environmental Research.
- [24.] Statista Research Department. (2025, March 27). Global waste generation – statistics & facts. <https://www.statista.com/topics/4983/waste-generation-worldwide/#topicOverview>
- [25.] TOMRA. (2023, August 30). Germany's effective deposit return scheme. <https://www.tomra.com/reverse-vending/media-center/feature-articles/germany-deposit-return-scheme>
- [26.] Verzosa, R. C., Katipunan, F. J. M., Lumangyao, J. G. B., & Antonio, E. S. (2024). Solid waste management awareness and practices among residents in the East Coast of Malaysia. *Davao Research Journal*, 15(3), 60–77.
- [27.] World Health Organization. (2024, June 25). Health consequences of air pollution on populations. <https://www.who.int/news/item/25-06-2024-what-are-health-consequences-of-air-pollution-on-populations>.