NOTRE DAME OF TRECE MARTIREZ, INC.

RESEARCH PROJECT

Assessing the Feasibility and Potential Impact of the PenVironment Machine in Plastic Waste Management at Notre Dame of Trece Martirez

Armintia, John Christopher F.

Bacay, Kurt Vann Axl E.

Bantilan, Shiloh Denise C.

Bonuel, Justin G.

Caole, Tyrone Maenard A.

Dangdang, Rodney P.

Digman, Sarah Mae R.

Francisco, Princess Claire

Gadiaza, Kharl Angelo B.

Gotera, Ridja Mica R.

Madriaga, Noriel James P.

Mojica, Angel Marie F.

Pandita, Ansharie G.

In partial fulfillment of the Requirements for the

Research Project Subject

Ms. Jemie H. Federis

Research Project

2025

CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Introduction

Over the last decade, the issue of the accumulation of plastic waste has been tackled by a lot of researchers. The issue began when plastics were demanded as an alternative to the traditional raw materials used. The sleek and light characteristics of plastic gave way to its normalisation in the market. Large scale production and use of plastic dates back to only 1950. From the 1950's to 2018, plastic production increased by a factor of 239, with 1.5 million metric tons of plastic being produced in the 1950's and 359 million metric tons being made in 2018 (Citterich et al., 2023). And, the production not only harmed the environment, it also endangered some species mostly in the ocean.

This study aims to tackle the efforts that can be conducted towards plastic bottle waste management and is limited only to plastic bottle waste. Economic development and people's changing patterns of consumption and production have led to a drastic increase in plastic wastes all over the world. (Chow et al, 2017). Thus, the efforts utilized in the previous years may not be relevant anymore.

Due to the sheer amount of plastic bottle waste seen in the environment, an idea of a machine that benefits both the recycler and the environment was observed. An effort that makes the process of recycling more rewarding. Thus, encouraging the general public about plastic bottle waste management, since every bottle they recycle grants a reward that is useful especially as a student. Recycling plastic is an important step towards a circular economy (Lubongo & Alexandridis, 2022). This is highly relevant to the Science, Technology, Engineering, and Mathematics (STEM) strand since engineering plays a crucial role when it comes to designing an automated means of plastic bottle.

Therefore, this issue has a clear need for study, a study that circles around a possible solution to this global issue that will benefit not just the planet but also us humans, its inhabitants in a way that lasts for a very long time since it does not only affect the current generation, it also affects the future generations to come. Expanding current knowledge about proper plastic bottle waste management is one step forward towards a greener environment. It doesn't need a complex mechanism to achieve this goal, to encourage the students or the general public to this concept of plastic bottle waste management we'll be needing some sort of compensation for the effort of the recycler when using this machine; inserting a plastic bottle into the machine would dispense a ballpoint pen that can be used by the recycler.

The motivation behind conducting this study came from the growing need for more effective plastic waste management strategies in places like Notre Dame of Trece Martires (NDTM). The problem of plastic waste, with plastic bottles as one of the most common pollution, is to say the least, getting out of hand. Compromising one of the highest wastes produced would go a long way to a cleaner environment. As many strategies as there can be, to no avail, there is a lack of recycling that greatly caused plastic to be found within the oceans, garbage sites, and on the earth. On one hand, the objective of the research is to fill the gap left by the literatures in terms of explaining the correlation between modern technology and the recycling of plastic waste by exploring the potential of the PenVironment Machine with a view to advancing waste management practices.

This research also provides an opportunity to demonstrate the role of educational institutions in the implementation of sustainable development. Students gain from being at the forefront of change, as they are then able to be waste management specialists even in practice as technologies are put to use in society (Global Learning, 2024). As the rate of consciousness of global problems is raised, the impact on the behavior of students, staff, and faculty creates a ripple effect that extends beyond the campus.

In addition, this investigation will assist in determining the possibility of further diffusion of the PenVironment machine into the education or community setting towards the achievement of the wider agenda for sustainability and circular economy. Through this research, the study not only intends to deal with the local environmental problems of Notre Dame of Trece Martires (NDTM) but also attempts to understand the role of technology in addressing the global challenge of plastic waste management.

Furthermore, this research advances the objectives of the Philippines in connection with the reduction of plastic wastage and encouraging responsible consumption. This is accomplished by assessing the effectiveness of the PenVironment machine on the recycling rates within the campus. This research therefore provides valuable data that can be used to formulate or refine environmental policies or practices in the country. In general, the research aims to achieve a clean environment by addressing a large and growing global problem of plastic waste by developing effective and inexpensive approaches for managing plastic waste, and educating the university community on the issue.

Also, another feature of the PenVironment Machine is its ability to create a long-lasting change in people's waste management behavior. Studies suggest that machines of this kind have the potential to raise the level of environmental concern and promote good practices of environmental protection. A study conducted by Nkwo et al., (2021), also focuses on systems that include users and gives them feedback on the program and observes that such systems tend to improve recycling since people will want to participate because they notice the effect of their actions. This is consistent with the objective of the PenVironment Machine to promote correct waste disposal practices through strong interaction at the Notre Dame of Trece Martirez school and could trigger a recycling and waste reduction ethos within students and staff members. It is also accurate to say that there is rising consciousness and efforts touching on the global plastic waste problem, but there is a deficiency of focused studies on the applicability and success of the innovative

machine such as the "PenVironment Machine", especially with regard to the environment of schools. Most of the previous studies focus on the general effects of the technologies of waste management or the adverse effects of plastic waste on the environment, but hardly any have carried out studies on the application of the Machines that may help in the management of such wastes in universities or schools. There is also little or no literature focusing on such technologies, including self-service kiosks, their influence on behavioral change, waste minimization, and sustainability programs in schools including Notre Dame of Trece Martirez.

Therefore, there are meaningful gaps on the practical impact, effectiveness, and acceptance of these waste management technologies in real life settings that use specifically plastic bottle wastes in a variety of institutions. More work also needs to be done in what practicum methods for local communities that will encourage and even celebrate the use of the PenViroment Machine.

Statement of the Problem

Plastic bottle waste management remains a significant environmental challenge, particularly in school settings where single-use plastics are common. To address this, the researchers propose the development of the PenVironment Machine, a solution aimed at improving the proper collection and disposal of plastic bottles. This study aims to assess the needs, feasibility, and potential impact of such a project, and to determine the requirements for creating the PenVironment Machine and its expected contribution to plastic waste management at Notre Dame of Trece Martirez. Specifically, it seeks to answer the following questions:

1. What is the current state of plastic bottle waste management at Notre Dame of Trece Martirez?

2. What are the anticipated benefits of the PenVironment Machine in promoting proper plastic bottle waste management within the school?

3. What features and functions should the PenVironment Machine include to effectively address these challenges?

4. How can the PenVironment Machine be designed to encourage student participation in proper waste management?

Objectives of the Study

The primary aim of this study is to design, develop, and evaluate the PenVironment Machine, an innovative system designed to address plastic bottle waste management at Notre Dame of Trece Martirez. Through this initiative, the researchers aim to contribute to fostering a sustainable and environmentally conscious school community. Specifically, the objectives of the study are as follows:

1. Assess the current state of plastic bottle waste management practices at Notre Dame of Trece Martirez, including identifying common problems, gaps, and chances to improve the existing system.
2. Evaluate the anticipated benefits and potential impact of the PenVironment Machine, like environmental, social, and educational improvements, that the PenVironment Machine can provide to the school, focusing on how it can encourage sustainable waste management and raise awareness among everyone involved.
3. Identify and list the essential features and functions that the PenVironment Machine should incorporate to effectively address waste management challenges.
4. Plan and design the PenVironment Machine in a way that makes it easy and engaging for students to use, helping them to change their habits and properly manage plastic bottle waste.

Hypothesis

A. **H_0 :** The PenVironment Machine does not lead to a significant reduction in plastic bottle waste at Notre Dame of Trece Martirez.

H_1 : The PenVironment Machine contributes to a significant decrease in plastic bottle waste recovered within the school.

B. **H_0 :** The PenVironment Machine does not result in a significant change in student exercise of proper disposal practices for plastic bottle waste.

H_1 : The PenVironment Machine enhances the engagement of students in appropriate plastic bottle waste disposal.

C. **H_0 :** Student opinions on plastic bottle waste disposal remain unchanged despite the presence of the PenVironment Machine.

H_1 : The PenVironment Machine significantly influences students' perceptions regarding plastic bottle waste management.

D. **H_0 :** The PenVironment Machine does not significantly affect student awareness about proper plastic bottle disposal.

H_1 : The PenVironment Machine significantly increases students’ awareness of proper plastic bottle disposal.

Theoretical Framework

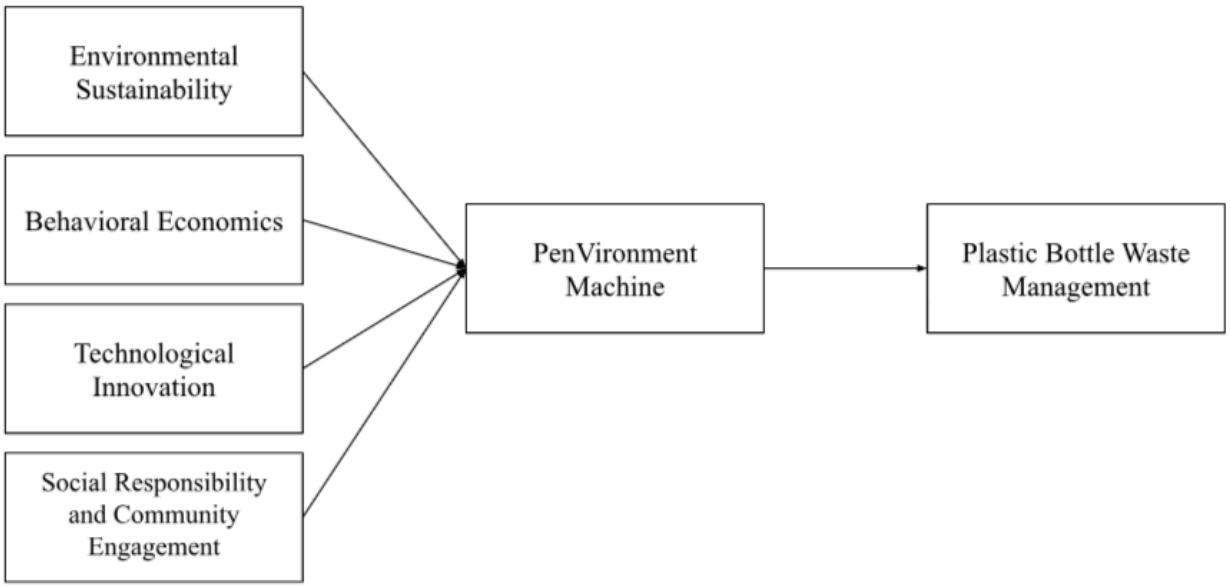

Figure 1. PenVironment Machine Theoretical Framework

Figure 1 of the PenVironment Machine theoretical framework integrates concepts from environmental sustainability, behavioral economics, technological innovation, and social responsibility and community engagement to address the growing issue of plastic waste. This framework supports the development and operation of a vending-machine-like system that promotes waste management by exchanging plastic bottles for pens.

Economic sustainability underpins the environmental goal of the PenVironment Machine, which is to reduce plastic waste accumulation by incentivizing proper disposal of plastic bottles. As a circular economy model, the PenVironment Machine embodies the principles of the circular economy, which aims to minimize waste and maximize resource use. By repurposing plastic bottles through recycling, the system promotes resource efficiency and waste reduction (Geissdoerfer et al., 2017).

Behavioral economics states the reasons that motivate an individual to use the PenVironment Machine. The reward system converts waste disposal into a rewarding and habitual activity. In incentive theory, it explains incentivizing appropriate behaviors, like proper waste disposal, by associating it with rewards (pens) for plastic bottles, which encourages individuals towards adopting sustainable ways of life (Deci & Ryan, 2018). Meanwhile, the nudge theory states how the design and accessibility of the Penvironment Machine act as a nudge, an indirect motivator towards making people take environment-friendly actions—by removing barriers to recycling and adding an immediate, tangible benefit (Sunstein, 2014).

Technological Innovation makes sure that the PenVironment Machine is developed to be user-friendly and efficient thus enhancing the users' interest and acceptance. Diffusion of innovation theory is used to understand the process of acceptance of new technologies and ideas in society (Greenhalgh et al., 2014). This is where the PenVironment Machine, being a novel solution, has the possibility of being embraced and used by the users since it offers several advantages such as convenience, effectiveness and even rewards in return for user's cooperation as well as having a positive environmental impact. And as a human-technology interaction framework the machine's interface and operation is well thought out to engage users by making the waste disposal method as easy, effective, and fun to use (Karapanos, 2015).

Social responsibility and community engagement advocate for the integration of the roles of community engagement and responsibility that can drive sustainable practices. The PenVironment Machine will usher in the culture of proper waste management through aligning individualism goals with group goals. People's activities towards each other are predicated on social exchange theory as they may engage in those activities, promising greater value to both parties (Zhang & Fang, 2014). The PenVironment Machine makes the individual's gain (receiving a pen) and a greater societal benefit (reduced plastic waste) efficient. The

theory of planned behavior contends that an individual's behavior is influenced by multiple factors, including attitudes, subjective norms, and perceived behavioral control (Conner & Armitage, 2016). PenVironment Machines can be conceived to solve such issues by creating a positive mindset towards the disposal of garbage, social norms regarding environmental responsibility, and access to easy participation.

Conceptual Framework

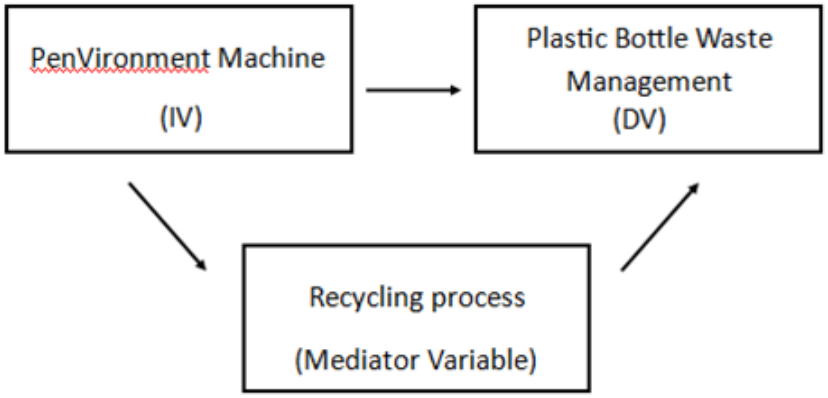

Figure 2. PenVironment Machine Conceptual Framework

The "Plastic Bottle for Pen" vending machine or PenVironment machine is a simple method to deal with the study problem. According to Francine (2023), plastic pollution was recognized globally as early as the 1960s, and even with environmentalists and the public's increased awareness and concern, it remains a problem today. One interesting thing about the PenVironment Machine is that it can change people's habits about dealing with waste in a way that lasts. Francine (2023), states that recycling plastic started in the 1980s, but due to several technological limitations, recycling largely became an ideal instead of a reality because the results were so different from what was expected. A PenViroment Machine serves like a Reverse Vending Machine (RVM). Whereas, aside from its easy mechanism to recycle for the environment, it also provides excitement for those who use it, by giving a pen in exchange for recycling plastic bottles.

The relationship between the PenVironment Machine (IV) and Plastic Bottle Waste Management (DV) aims to reduce the growing amount of plastic bottle waste. While, the relationship between the PenVironment Machine (IV) and the Recycling process (Mediator Variable) makes it more viable for students or individuals to recycle by having a machine that lets users input an empty plastic bottle to receive a reward. Lastly, the relationship between the Recycling process (Mediator Variable) and Plastic Bottle Waste Management (DV) is that recycling bottles can reduce the amount of plastic waste produced by many that adds to plastic pollution and protect the animal species that comprise the food chain in our environment.

Scope and Limitations of the Study

The participants of this study are the 40 grade 12 students under the strand Science, Technology, Engineering and Mathematics (STEM) at Notre Dame of Trece Martirez in School Year 2024-2025. Research will analyze how the vending machine fits into the existing waste management practices. Evaluating its role in promoting proper disposal and recycling of plastic waste.

The PenVironment Machine's environmental effectiveness is the main focus of the study, which is only meant for the target audience of Notre Dame of Trece Martirez who uses ballpens. It focuses on reducing waste from plastic bottles rather that other forms of environmental trash. Furthermore, users of the machine receive a ballpoint pen as a reward for reducing plastic bottle waste in the environment without having to spend money on writing instruments. Instead of tackling more significant environmental problems, the study shows how well the PenVironment Machine handles plastic bottle in our surroundings.

Significance of the Study

This study holds considerable significance for various stakeholders, offering valuable insights and practical implications for addressing the pressing issue of plastic waste management. By exploring the

potential of the PenVironment machine and its impact within the Notre Dame of Trece Martirez community and beyond, the research contributes to broader efforts in environmental sustainability and technological innovation. The benefits of this study extend to the following key beneficiaries:

Notre Dame of Trece Martirez Community. (a) Students, the study will contribute to a cleaner and healthier school environment by reducing plastic waste and promoting environmental awareness.

(b) Faculty and Staff, the research will provide insights into effective waste management strategies, leading to improved campus sustainability practices.

Local Government Unit of Trece Martirez. The findings of this study can inform local policies and initiatives related to waste management and environmental protection. The success of the PenVironment Machine can serve as a model for other schools and communities in the area.

Environment. By reducing plastic waste, this study contributes to the preservation of the environment and mitigating climate change. The research can promote sustainable practices and inspire others to adopt similar initiatives.

Future Researchers. The study can serve as a foundation for future research on waste management technologies and environmental sustainability. The findings can be used to refine existing methods and develop innovative solutions for addressing waste problems.

STEM Field. (a) Science, investigating the environmental impact of plastic waste, the chemical composition of plastics, and the biological processes involved in plastic degradation. (b) Technology, utilizing the PenVironment machine, a technological innovation designed to efficiently process plastic

waste. (c) Engineering, designing and optimizing the PenVironment Machine, considering factors such as energy efficiency, material handling, and waste reduction. (d) Mathematics, analyzing data on waste reduction, energy consumption, and cost-benefit analysis to evaluate the effectiveness of the machine.

Definition of Terms

These are the operational definitions used for the key concepts in this study:

Accumulation - Refers to a mass or quantity of something that has gradually gathered or been acquired. *(Oxford Languages)*

Consciousness - Refers to the state of being aware of one's surroundings. *(Oxford Languages)*

Drastic Increase - Refers to a sudden and significant rise in something. *(Oxford Languages)*

Deficiency - Refers to a lack or shortage. *(Oxford Languages)*

Endangered - Refers to the seriously at risk of extinction. *(Oxford Languages)*

Ethos - Refers to the characteristic spirit of a culture, era, or community as manifested in its beliefs and aspirations. *(Oxford Languages)*

Feasibility - Refers to the possibility that something can be made, done, or achieved, or is reasonable. *(Oxford Languages)*

Fostering - Refers to encourage or promote the development of something, typically something regarded as good. *(Oxford Languages)*

Implementation - Refers to the process of putting a decision or plan into effect; execution. *(Oxford Languages)*

Incentivizing - Refers to motivate someone to do something by offering them a reward or benefit. *(Oxford Languages)*

Inhabitants - Refers to a person or animal that lives in or occupies a place. *(Oxford Languages)*

Innovative - Refers to the relating or characterized by new ideas, methods, or products. *(Oxford Languages)*

Intuitive - Refers by using or based on what one feels to be true even without conscious reasoning; instinctive. *(Oxford Languages)*

Kiosks - Refers to a small structure with one or more open sides that is used to vend merchandise. *(Oxford Languages)*

Normalisation - Refers to the process of bringing or returning something to a normal condition or state. *(Oxford Languages)*

Practicum - Refers to the part of a course consisting of practical work in a particular field. *(Dictionary.com)*

Penetrating - Refers to being able to make a way through or into something. *(Oxford Languages)*

PenVironment Machine - Refers to an innovative system designed to address plastic bottle waste management

Perceived - Refers to becoming aware or conscious of (something); come to realize or understand. *(Oxford Languages)*

Persistence - Refers to the firm in a course of action in spite of difficulty or opposition. *(Oxford Languages)*

Stewardship - Refers to the job of supervising or taking care of something, such as an organization or property. *(Oxford Languages)*

CHAPTER II

REVIEW OF RELATED LITERATURE

LOCAL LITERATURE

According to Langit et al. (2024), management issues are caused by significant economic growth and population growth in the Municipality of Laguna Bay. The municipality intends to invest in Integrated Waste Management Technology (IWMTS) as a response. The system seeks to raise money for the government. Focus groups, surveys, and key informant interviews. Data was gathered through talks. The findings revealed that respondents don't know much about Integrated Waste Management Technology (IWMTS), however, they see minimal to no negative and favorable effects on municipal trash management and waste volume reduction. The effects on accessibility, livelihood, and health. The results of their investigation of the environment showed beneficial effects on lowering the amount of wastes, soil and nutrients, odor and air pollution, and water resources and quality. In light of these, the study offered suggestions for project execution to accomplish circular economy and sustainable waste management.

According to Flores et al. (2019), waste management is a widespread issue in today's globe, and it is only getting worse as cities grow in size. Waste Management plays an important role in creating an eco-friendly workplace. Proper trash disposal at dumping sites plays a crucial role. Sorting at the base level. The old method of sorting rubbish takes more time and requires more personnel. Waste can be sorted using a variety of procedures and forms. Analyzing and classifying rubbish through image processing can be a productive approach to process waste materials. This report seeks to analyze existing research offered in studies from throughout the world. This will allow us to determine the problems, algorithm, and technique of the cited studies. It can also determine the correct proper garbage disposal at dumping sites plays an important role in base level sorting. The old method of sorting rubbish takes more time and requires more personnel. Waste can be sorted using a variety of procedures and forms. Analyzing and classifying garbage

with image processing can be a highly productive waste management method. This report seeks to analyze existing research offered in studies from throughout the world. This will allow us to determine the problems, algorithm, and technique of the cited studies. It can also determine the best algorithm to apply in a future study. These papers discuss the various ways and planned systems used to segregate garbage. This paper provides numerous options to generate new information in the creation of a new system by examining the disadvantages of existing systems and the algorithms they utilized.

According to Sidhu (2021), for the elderly or disabled, managing and collecting home waste can be a challenging undertaking. In particular, the increased accumulation of plastic waste at home may be a concern for these groups, as this form of waste accumulates quickly and takes up a lot of room. This article provides a shared infrastructure for monitoring household plastic trash. It consists of simple smart bins with a weight scale and a smart application that anticipates the amount of plastic generated for each bin over various time horizons based on data provided by the smart bins. The application uses a route-planning algorithm to design ideal paths for the system's waste-pickers. This method considers the estimated amount of plastic for each. The location and mode of transportation of the bin, as well as the waste picker. This approach was assessed using a simulated situation in Quezon City, Philippines, where serious issues with plastic trash have been observed. A total of 176 experiments were conducted to acquire data that can be used to depict various user behaviors when generating plastic garbage. The findings demonstrate that their method allows waste pickers to collect more than 80% of domestic plastic waste bins before they are totally full.

In order to address the issue of plastic bottle waste, according to Baribad et al. (2024), the Plastic2Fantastic: Reverse Vending Machine (RVM) for Plastic Bottles was created. It is a device that takes and dumps empty plastic beverage containers in return for cash. Furthermore, consumers perceived the

machine to be easy to operate and effective for managing plastic waste. This solution addresses a serious problem of plastic pollution by promoting recycling and proper garbage disposal, therefore helping more sustainable environmental practices. Plastic bottles, as well as cans and glass bottles, may be accepted as deposits. The storage compartment could be expanding to handle more waste. Aside from offering one-peso coins as rewards, other coin and amount values could be considered.

According to Sira et al. (2024), the study of the Plastic Bottle Collector Bin with Dispenser (PBCBD) showed successful functioning, where gravity is used to gather plastic bottles and dispense them. The device got to the maximum dispensing time per single bag within one minute, with the implication of its efficiency and central role in waste management, especially recycling of plastic bottles. It highlights the involvement in a university-wide waste management program and emphasizes the ability of the study to provide remarkable improvement in recycling efforts, energy efficiency, and possibly work operations costs. This study proves to be very useful in designing new waste machinery for the management of wastes, particularly plastics, since the authors encourage the emulation of such machines that are capable of handling the increasing waste problem.

According to the World Bank (2022), the Philippines is submerged in a plastic waste problem, and the existing waste management is insufficient and ineffective to solve the root cause of this problem, it has weak institutional arrangements for waste management, inadequate funding, weak technical ability, and marginalization of the informal sector in the plastic chain. The announced strategies are vast and range from the complete ban of the most problematic single-use plastics to expanding the existing capabilities of plastics recycling and introducing a circular approach to the design of plastics. This study highlights the need to come up with such solutions as a waste management machine that can help deal with the issue of

plastics and plastics waste management in the context of the Philippines with a significant focus on waste segregation and efficient recycling.

FOREIGN LITERATURE

Nurfikri and Martono (2023) analyze Indonesian consumers' willingness to employ Reverse Vending Machines (RVMs) to manage plastic bottle waste. The authors identify critical factors influencing user acceptance, such as attitudes, subjective norms, and perceived behavioral control. After performing an 80-person survey and using Structural Equation Modeling, they discovered that both ease of use and reward incentives considerably increase the likelihood of people engaging with RVMs. Their findings suggest that including such technologies can significantly increase recycling behaviors and encourage sustainable waste management practices in urban areas.

Farghali and Osman (2024) discuss how technology is changing waste management, focusing on automated systems, forecasting waste trends, and making the most of energy recovery from non-recyclable materials. Machines using AI can sort waste more accurately and reduce contamination, while tools for predicting waste generation help communities plan better collection routes and allocate resources effectively. Moreover, systems that optimize energy recovery also make sure waste is used efficiently instead of going to landfills. Although technologies have such great potential, the authors point out challenges such as high costs, the need for skilled workers, and ethical issues. They note that in order to overcome these obstacles and improve the sustainability and efficiency of waste management, cross-disciplinary cooperation and additional research are essential.

Tomari et al. (2017) examines the integration of Reverse Vending Machines (RVMs) into recycling systems, emphasizing the advantages of automation and incentives for enhancing recycling practices. These

devices facilitate the collection and sorting of recyclables, increasing accessibility to the recycling process. The suggested framework has useful features like material-identifying sensors, an intuitive user interface, and a recycling incentive program. According to the authors, RVMs can decrease manual labor, increase sorting accuracy, and lessen contamination in recycling streams. They do admit, though, that there are obstacles to overcome, including maintenance problems, technological constraints, and public acceptance. They suggest continuing research, spreading awareness, and collaborating closely with policymakers to overcome these challenges. The study concludes that RVMs have the potential to greatly improve waste management procedures and advance sustainability in a variety of contexts if these issues are addressed.

Regarding what happens to the bottles after they are received by the reverse vending machine, Portilla (2023) noted that it enters a recycling stream and goes through a series of processes, at the end of which it is turned into raw materials for the manufacture of a variety of products. After it has been received through the reverse vending machine, the bottles are collected and then brought to the recycling facility. The recyclables then have been classified on the basis of material type through both manual labor and machines within that facility. These materials are then cleaned to rid them of any contaminants that include but should not be limited to labels, caps, and remaining residues of liquids. Mechanical shredding or material going through a crusher is done in order to increase surface area and preparedness for further processing. The materials that had been cleansed were sent to manufacturers, who would utilize those recycled materials feedstock to create more new bottles or other products. Such conditions call for more controlled disposal of plastic bottle wastes because those plastic bottles would not just be stacked upon one another.

As stated by Taylor (2021), more than 1.4 trillion beverage containers are used by consumers; thus the reverse vending machine (RVM) is meant to address this problem. Most unrecycled beverage bottles are usually scattered across different lands, buried under landfills, or in oceans and rivers. RVMs may have a

solution for this waste because they have incentives for recycling. Thus, users are most probably encouraged to recycle not just because of the good it does for the environment but also for themselves. Reverse vending machines can be really helpful. One could use them for environmental purposes where the recycled material minimizes the need for raw materials to manufacture new products. They also have decent positioning: many are conveniently placed in public venues like grocery stores, gas stations, schools, parks, etc. So much so, it concludes that other than the environment benefiting from using RVMs, recyclers proceed to benefit from these incentivizing eco-friendly devices.

In a study by Taylor (2022), developing economies, such as Nigeria, had already integrated specific environmental policies on a national level, such as the Extended Producer Responsibility (EPR) policy. Since the publication of the guidelines for the implementation of the EPR program, none of the Nigerian states has been able to incorporate the policy into its waste management legislation. The failure to implement the said program in Lagos State, Nigeria's economic hub, became a growing environmental problem of plastic waste. There were different initiatives to resolve the matter, but they are insufficient, as it has been reported that plastic waste accounts for 15% of total waste volume generated in Lagos state due to its various uses. Thus, they came up with a combined use of EPR and deposit-refund system (DRS) on empty plastic bottle waste collection vending machines. The study proves that several other innovative solutions like reverse vending machines will enhance improved waste management practices, primarily in urban settings.

LOCAL STUDIES

In the study of Dacay et al. (2020) they conducted 50 trials to test two functioning goods, a ballpoint pen and newsprint, with 41 successful outcomes, resulting in an 82% success rate due to incorrect positioning of the ballpoint pen in the dispenser. Therefore, all 50 trials for distributing newsprint were fully

effective at 100%. The VendoBin correctly detected both plastic and non-plastic bottles. Codes for both new and current users were successfully produced and saved to the database. Out of the 50 messages sent to the relevant authorities about the VendoBin's status, 43 were successfully delivered. The failures were due to the ultrasonic sensor failing to detect the garbage. The researchers successfully designed and created a vending machine and recycling bin for plastic bottles, which can also dispense ballpoint pens.

According to the study of Dumpayan et al. (2017) the Reverse Vending Machine was able to meet the study's objectives within the scope and limitations specified. The tests, which are based on and constrained by the design criteria, indicate that the device is accurate at reading Radio Frequency Identification (RFID) accounts, recognizing plastic bottles from other materials, gathering points, and exchanging products. The machine has a reaction time comparable to an existing vending machine, therefore the one-minute response time constraint was met. With the addition of a solar panel and a battery, the device becomes more efficient because it gives an alternate power source. The machine is dependable since it can function independently and requires little supervision.

According to Castro et al. (2020), one of the world's most pressing issues is the growing amount of solid waste pollution. With current needs for sustainable growth, the researchers created a waste segregator machine that achieves efficient segregation while also introducing the concept of an incentive system to encourage people to dump their waste into the machine. In this publication, the researchers developed an automatic segregation machine that employs Artificial Neural Network (ANN) as a machine learning method and is embedded with the notion of "Basura Advantage Points" The artificial neural network serves as the machine's brain, classifying plastic bottles into one category and other waste materials into another. The "Basura Advantage Points" is a revolutionary concept in which every time individuals dump waste into the sorting machine, They can earn points, which can subsequently be redeemed for policymaker-determined

incentives. According to the survey results of their study, the machine is popular with the general people. Based on the sample wastes, the machine's accuracy is approximately 80%. From favorable comments to successful evaluation, the study identified a promising approach for reducing incorrect trash disposal and encouraging individuals to participate in proper waste segregation.

After careful investigation by Rubio et al. (2016), a Solar Powered Reverse Trash Vendo Machine was created to encourage recycling, reduce the inappropriate garbage disposal habits of Filipinos, and apply the concept of green engineering. The gadget can determine if the substance being scanned is an aluminium can or a plastic bottle, each of which has a corresponding monetary compensation value. The Gizduino X ATMega 1281 and the Gizduino 644 are in charge of the entire procedure. Identifying the input, analysing the Liquid Crystal Display (LCD) display's outputs, crushing the input, distributing the inputs' equal monetary value, and finally communicating with the owner via the Global System for Mobile Communications (GSM) shield and the Android messaging app and Global System for Mobile Communications (GSM) shield. Summing up, the proponent has successfully integrated the concept of trash can and reverse vending machines into a device that is economic and environmentally friendly.

According to the study of Padios et al. (2021) recycling plastic waste offers substantial environmental advantages and plays a crucial role in creating a Green Campus community. To promote recycling and proper waste management at Iloilo State College of Fisheries, a Polyethylene Terephthalate (PET) Bottle Collection System was introduced to support the college’s Green Campus initiative. This system consists of a Reverse Vending Machine (RVM) prototype and a cross-platform mobile monitoring application. The RVM identifies and accepts Polyethylene Terephthalate (PET) bottles while rejecting non Polyethylene Terephthalate (PET) ones, dispensing a one-peso coin for every four accepted bottles. Additionally, a mobile app tracks the number of coins remaining in the machine, the total Polyethylene

terephthalate (PET) bottles collected, and the Reverse Vending machines (RVM) status, such as whether it's full. The system was tested for functionality, accuracy, efficiency, and response time, with results confirming it met the design objectives. In conclusion, the researchers successfully created an effective Polyethylene Terephthalate (PET) Bottle Collection System suitable for Iloilo State College Of fisheries (ISCOF).

According to Bugarin et al. (2023), the weighing scale's accuracy test revealed an average disparity of 1.47% over three trials, suggesting accurate readings with little variations. Users who bring in Polyethylene Terephthalate (PET) plastic bottles are rewarded by the recycling machine; the incentives are calculated based on actual weight but are conveniently adjusted to the closest peso. This approach seeks to address waste management concerns and encourage recycling, especially in areas where trash segregation and budgetary limitations are problems. All things considered, the machine is marketed as a useful tool for encouraging environmental stewardship and offering financial incentives in underprivileged communities.

FOREIGN STUDIES

In the study conducted by Fatima et al. (2022) managing the large volume of discarded plastic bottles is currently a significant issue due to its heavy burden on landfills and waste processing facilities. Since plastic takes centuries to decompose once discarded, recycling not only offers efficient waste management but also diminishes environmental effects and opens up economic prospects. Utilizing incentive-based Reverse Vending machines (RVM) proves to be an effective method for engaging the public in plastic waste management.

Azeez et al. (2020) stated that Reverse Vending Machines (RVMs) are effective in incentivizing the public to recycle by offering rewards such as cash or vouchers for each item recycled, encouraging active participation in recycling initiatives. Placing RVMs in accessible public spaces like train stations, bus

terminals, and shopping malls facilitates the disposal of recyclable materials, particularly in areas with high foot traffic where significant plastic waste is generated can be advantageous as the huge amount of plastic bottles or plastic waste which are dumped can be collected easily. These machines are capable of sorting and segregating different types of waste, such as plastic bottles and aluminium cans, improving waste management efficiency and reducing the need for manual sorting. Some RVMs even utilize technology like image processing to differentiate between various types of bottles or distinguish bottles, cans, and other items. By promoting recycling, RVMs help reduce the amount of waste sent to landfills, especially crucial for the slow decomposition of plastic waste. Additionally, recycling plastic using RVMs not only lessens its impact on biodiversity but also decreases the reliance on oil in plastic production, a non-renewable resource.

This study, conducted by Kehinde et al. (2020), employs a review-based approach to investigate the challenges of managing plastic waste and the potential for recycling to generate wealth in Nigeria. The authors thoroughly examine the existing literature regarding different types of plastics, their production, their environmental and health impacts, and various waste management methods (such as recycling, incineration, landfills, pyrolysis, and bioremediation). Their results emphasize the global relevance of plastic pollution, highlighting its harmful effects on ecosystems. Recycling is a vital solution, with the paper outlining different recycling techniques and their economic advantages in sectors such as construction, architecture, and textiles. The authors underline the necessity for enhanced waste management practices in Nigeria, urging actions from the government, agencies, and individuals to foster sustainable plastic production, usage, and disposal. Although the review offers a valuable summary, its limitations include dependence on secondary sources and concentrating solely on the Nigerian framework. The implications of the paper are substantial, making a strong argument for investing in waste management infrastructure and sustainable practices while also highlighting the economic promise of recycling to encourage private sector

participation. The comprehensive reference list underlines the extensive nature of the review, covering diverse aspects of plastic waste management and recycling technologies.

Evode et al. (2021) provide a comprehensive overview of strategies for managing plastic waste that are pertinent to the responsible handling of plastic bottle waste, emphasizing environmentally friendly solutions. The authors explore a range of methods, such as mechanical and chemical recycling, pyrolysis, gasification, and biodegradation, assessing their environmental implications and economic feasibility. Their study underscores the urgent need for effective plastic waste management to reduce pollution and facilitate a transition to a circular economy. The research stresses the significance of evaluating the entire lifecycle of plastics, from creation to disposal, to devise genuinely sustainable solutions. Although the focus is not solely on plastic bottles, the principles and techniques discussed are directly relevant to enhancing their management. The authors' examination of various recycling methods, for instance, is particularly pertinent to establishing efficient and eco-friendly systems for handling plastic bottle waste. Nonetheless, the study does not include specific data on the efficacy of various strategies for plastic bottle waste, indicating a need for further investigation to identify the best solutions for this specific waste stream.

Based on the study conducted by Abu Rahim and Khatib (2021) in other countries such as Finland and Japan, they already introduced the Reverse Vending Machine and it was a great success. For example, TOMRA, a Norwegian Multinational Corporation placed around 1200 RVMs in Japan and the machine collected 300 million Polyethylene Terephthalate (PET) bottles to be recycled. The RVM is placed at accessible areas such as convenience stores to allow the customers to return the empty PET containers for recycling purposes. The machine encourages the consumers to recycle by rewarding them in the form of cash or credit points. While in Malaysia, they're still operating in introducing and installation of RVMs.

Jungthawan et al. (2023) Several studies demonstrated the existence of a variety of micro plastics (MPs), including those generated from operational loss, road dust, synthetic fabrics, vehicular tires, and plastic packaging. These particles can become airborne. Various research were conducted to identify the types of polymers present in micro plastics, including Polyethylene Terephthalate (PET), high-density polyethylene (HDPE), low-density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), and polystyrene (PS). These polymers were found to be mixed into particulate matter 2.5 (PM2.5) particles in numerous regions of Thailand. Plastic waste management is a major issue that is significant to environmental concern in Thailand. In 2018-2022 the average plastic waste generated is 26.54 million tons per year, out of which only about 9.47 million tons (35.68%) were recycled per year. In addition, the average plastic waste per person has increased by approximately 14.20% every year over the past 5 years.

SYNTHESIS OF RELATED LITERATURE AND STUDIES

The issue of plastic waste management is a well-worn path, it has been around as early as the 1950's. Issues like this generally stem from human actions. it's easy to miss that there are efforts being utilized in order to battle this global issue, Due to the sheer amount of waste accumulated worldwide, annually. According to the World Bank (2022), the Philippines alone is submerged in this plastic waste issue and if there is an existing waste management effort, it is deemed to be very insufficient and ineffective in solving the root cause of this problem.

Langit et al. (2024) states that this issue mainly branches from significant economic growth and population growth, this directly relates accordingly to Flores et al. (2019), Wherein they stated that not only is this issue widespread in today's world in time, it's also getting worse as cities grow therefore increasing the population and the accumulation of such waste. Initially, Flores et al. (2019), Found that Proper trash disposal at dumping sites plays a crucial role when disposing of waste accumulated at cities or urban

settings. This method was good and all but it's a heavy burden on landfills and waste processing facilities according to the study conducted by Fatima et al. (2022). Therefore, they found that the use of technology that can analyze and classify rubbish through image processing or machines that use AI to sort waste more accurately can be a more successful way of combatting this struggle according to Farghali and Osman (2024), as they discussed that Technology is changing how waste management is observed by the use of automated systems of waste management. Tomari et al. (2017), also shares the same perspective as Farghali and Osman, as they examine the integration of Reverse Vending Machines (RVMs) into recycling systems, therefore emphasizing the advantages of automation and incentives for enhancing recycling practices. The same goes with what Langit et al. has found to be a useful approach, the use of an Integrated Waste Management Technology (IWMTS).

This idea quickly grew and didn't stay in one place as it continues to get used and innovated by other researchers such as Sidhu (2021), wherein he designed smart bins with a weight scale and a smart application that anticipates the amount of plastic generated by households especially those housing elderly people or people with disabilities. Due to these factors, accumulation of waste may be imminent. That's why, the system onboard the smart bins uses a route-planning algorithm to design an ideal route for the waste collectors in a specific place to pick up these trash in order to avoid the accumulation. Farghali And Osman (2024), also had the same idea in mind in order to help communities with the collection of the waste and allocate resources effectively. A similar weight scale function was tested by Bugarin et al. and it revealed an average disparity of 1.47% over three trials, this suggests that it can accurately read whether if the material inputted are actually Plastic bottles. Users who bring Polyethylene Terephthalate (PET) Plastic bottles were rewarded by the machine. Also, according to the study of Padios et al. (2021), in order to achieve a Green Campus community, a similar machine was used and it also detects Polyethylene Terephthalate (PET) Bottles specifically, it rejected non-Polyethylene Terephthalate bottles which helped in maintaining a a level

of uniformity in the trashes that the machine collects. Azeez et al. (2020) stated that these machines are specially effective in incentivizing the public to recycle when put in accessible public spaces such as train stations, bus terminals, and shopping malls.

As stated by Taylor (2021), more than 1.4 trillion beverage containers are used by consumers. With the current needs for sustainable growth, Castro et al. (2020), created a waste segregator machine that achieves efficient segregation while also introducing the concept of an incentive system to encourage people to dump their waste into the machine. Also, another approach was observed, the usage of Reverse Vending Machines that requires plastic bottles, a machine that grants a reward by simply using it. However, the dispensed reward may vary from machine to machine. For example, in the case of Baribad et al. (2025), their usage of the machine rewarded the recycler with cash, be it 1 peso or other amount. In the case of the study of Dacay et al. (2020), however, the recycler is rewarded with a ballpoint pen. Approaches like these proved to be effective for managing plastic waste as consumers perceive it to be easy to operate. More and more countries are starting to employ this type of solution like in the analysis conducted by Nurfikri and Martino (2023) where they analyzed the Indonesian consumers' willingness to employ reverse vending machines to manage their plastic bottle waste. In their analysis, they identified the critical factors that led to the acceptance of the consumers on this approach. The ease of use and the incentives provided by these machines is what increased the likelihood of people to engage with these machines. In fact, according to Sira et al. (2024), the Plastic Bottle Collector Bin with Dispenser (PBCBD) they studied showed successful functioning where they used gravity to gather the plastic bottles. Regarding what happens to the bottle after they are received by the reverse vending machines, Portilla (2023) noted that it is collected and then brought to the recycling facility. It then goes into a recycling stream at the end of which, a new product can be formed from the previously recycled Plastic bottles or it goes through different strategies like what the study of Evode et al. (2021), had provided. Emphasizing environmentally friendly strategies at handling the

collected plastic waste. According to the study of Jungthawan et al. (2023), micro plastics can become airborne, thus, endangering the environment. Since Thailand focuses on solutions with extreme concern in regards of the environment, the study of Evode et al. (2021) proved to be useful and reliable.

With the direness of the issue especially to developing countries such as Nigeria, management methods of waste such as recycling, incineration, landfills pyrolysis, and biomediation were discussed by the study of Kehinde et al. (2020), as one and they found out that recycling is the vital solution to their problem as this approach resulted in less damage to the environment unlike the technique of incineration. They also underlined the necessity for an enhanced waste management practices in Nigeria to the point that they urge actions from the government, agencies, and individuals to foster sustainable plastic production, usage, and disposal. According to the recent study of Taylor (2022), Nigeria, already implemented some sort of a Reverse Vending Machine (RVM) in their environmental policies as a way of compensation for the lack of action from higher government. This proved that machines of this nature would do well in managing waste primarily in urban settings. Other countries such as Finland and Japan, had also already implemented reverse vending machines according to Khatib (2021) and it showed great success. Malaysia also is starting to introduce and install such machines in order to help in waste management in their country. Machines like these are designed to function independently and to require little to no supervision according to the study of Dumpayan et al. (2017), some even utilize solar power as an alternative power source and to make the device more efficient. In fact, Rubio et al. (2016). Created a solar powered reverse trash vendo machine to try to encourage recycling and eliminates the inappropriate garbage disposal of Filipinos.

With all of that in mind, nipping this global issue at its bud would go a long way as humanity continues to advance forward. Utilizing the remarkable advancements made by us, humans, in helping us to do tasks that are quite difficult would surely make our lives easier in the long run.

CHAPTER III

METHODOLOGY

Research Design

In aiming to evaluate the effectiveness of the PenVironment Machine, a device that exchanges plastic bottles for pens, in encouraging recycling behaviors and assessing user satisfaction and engagement, the researchers will use non-experimental quantitative research - survey type research because conducting surveys as a non-experimental method, is often more cost-effective compared to experimental designs. Our product practices environmental sustainability, hence, funding constraints may limit the feasibility of long-term experimental research. Non-experimental methods provide large-scale data collecting without the significant costs associated with controlled experiments (Frölich et al., 2014). Hence, this study will employ a non-experimental quantitative research, using quantitative data collection techniques:

1) likert scale;
2) survey questionnaire.

According to South et al., (2022), the likert scale are particularly effective for quantifying attitudes and perceptions. This allows respondents to express varying degrees of agreement or disagreement with statements about the PenVironment Machine, such as its ease of use, its effectiveness in promoting recycling, or its overall satisfaction. This quantification facilitates statistical analysis, allowing researchers to uncover patterns and connections in feedback provided by users. Although survey questionnaires are primarily used to obtain numerical data, open-ended questions can complement this by providing additional context (Singer & Couper, 2017). The responses from these open-ended questions can be coded and analyzed quantitatively to identify trends, frequencies, or specific patterns related to the PenVironment Machine.

Locale of the Study

The study will be conducted in Notre Dame of Trece Martirez Senior High School, a private school located at Don Bosco Executive Village, Barangay Cabuco, Trece Martires City, Cavite. The PenVironment Machine, which attempts to eliminate bottles in the environment, will be tested by the respondents at this school, which was selected as the locale of the study due to its convenience for the researcher.

Respondents of the Study

The respondents of this study will be 40 Grade 12 Science, Technology, Engineering, and Mathematics (STEM) students from Notre Dame of Trece Martirez, identified through stratified random sampling. Selection criteria included grade level and strand, age range, enrollment status, and availability ensuring that the sample was representative of the target population and aligned with the study's objectives.

These students were chosen because of their potential involvement in and knowledge of plastic bottle usage and disposal, making them key stakeholders in assessing and addressing waste management challenges. Prior to participation, the respondents were briefed on the purpose of the study, and informed consent was obtained to ensure ethical and meaningful engagement.

Research Instrument

A five-point researcher made likert scale validated by a researcher and graduate (master's degree) teacher in English will be used to know the current state of plastic bottle waste management at Notre Dame of Trece Martirez and identify the anticipated benefits of the PenVironment Machine in promoting proper plastic bottle waste management within the school. The rating scales to be used are: 1 - Strongly Disagree, 2 - Disagree, 3 - Neutral, 4 - Agree and 5- Strongly Agree.

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1	2	3	4	5

To ensure the instrument's reliability, the likert scale and survey questionnaire will be reviewed by a graduate English validator; her feedback will be used to refine the questions to ensure clarity, relevance, and appropriateness for the study's objectives. A survey questionnaire will also be used to determine the features and functions should the PenVironment Machine include for improvements and how can the PenVironment Machine be designed to encourage student participation in proper waste management. The survey questionnaire will be composed of five (5) questions. The instruments will be made through online means using google forms.

a. Likert Scale

1. The current waste management at Notre Dame of Trece Martirez effectively handles plastic bottle waste.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)
2. There are sufficient recycling bins and facilities for plastic bottles on the school premises.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)
3. Students actively participate in properly disposing of plastic bottles in designated waste bins.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)
4. The school provides adequate education and awareness programs about proper plastic bottle waste management.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4)

	☐ Strongly Agree (5)
5. Using the PenViroment Machine will make one feel like they're positively contributing to the environment.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)
6. The presence of the PenViroment Machine will encourage students to dispose of plastic bottles properly.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)
7. The machine can bring long-term positive environmental change.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)
8. The PenViroment Machine has the potential to become the leading solution for plastic bottle waste management.	☐ Strongly Disagree (1) ☐ Disagree (2) ☐ Neutral (3) ☐ Agree (4) ☐ Strongly Agree (5)

b. Survey Questionnaire

1. What features and functions should the PenVironment Machine include for better usage?
2. How can the PenVironment Machine be designed to encourage student participation in proper waste management?

Data Gathering Procedure

The data will be gathered during the second semester of the school year 2024-2025. The researchers of this study will instruct the respondents through messenger (an online way of communication) or face-to-face. The respondents will then be asked to answer the likert scale in a google form and send it back

through e-mail or messenger (in whichever form of communication they are most comfortable in). Moreover, a google form copy will also be used for conducting the survey questionnaire and will be sent back through e-mail or messenger. The form was made in an online survey to enable the learners to answer it at their most convenient time and when the resources are available. Respondents will be assured that their participation is entirely voluntary and that they may choose not to participate or withdraw at any time without any consequences.

After gathering the data, the researchers will conduct data analysis by assessing responses from the google forms copy. Research questions will be answered through systematic data interpretation followed by organized analysis leading to conclusion drawing from the data. The research team will present findings through both a detailed report and statistical and graphical analysis, as well as tabular data to communicate study results.

Statistical Treatment of Data

Once the researchers gather the data, it will be organized, classified, and categorized. They were depending on statistical treatment in order to answer the questions proposed in the study. The statistical tools that will be implemented to analyze the data collected will be the simple percentage and likert scale.

Simple Percentage will be used to determine the demographic profile variables of the respondents with the following formula:

$$P = F/N \times 100$$

Where:

P - Percentage

F - Frequency for each category

N - Total number of cases

100 - Constant multiplier

Simple Percentage is used to show the distribution of Grade 12 under the strand Science, Technology, Engineering, and Mathematics (STEM) at Notre Dame of Trece Martirez in a particular range with respect to their academic performances.

Likert Scale applies data that are divided to different categories that can be ranked. This scale of measurement will be employed to rate the weighted mean of each item of five (5) variables.

SCALE	WEIGHTED MEAN/EQUIVALENT	CORRESPONDING REMARKS
5	4.20 - 5.00	Strongly Agree
4	3.40 - 4.19	Agree
3	2.60 - 3.39	Neutral
2	1.80 - 2.59	Disagree
1	1.00 - 1.79	Strongly Disagree

Thematic Analysis is a qualitative data collection method aimed at identifying, analyzing, and reporting patterns within data from the survey interview questionnaire. This will be used to determine the key patterns, insights, or ideas that can be used to help answer a research question or further inform a more general understanding of the subject matter. Thematic Analysis will be used to identify different answers from the respondents through categorizing a variety of codes that are generated from the study.

CHAPTER IV

PRESENTATION ANALYSIS AND INTERPRETATION OF DATA

This chapter presents the data gathered from the study, along with the results of the statistical analyses conducted. The findings are systematically arranged in tabular form, following the sequence of the research problems identified. The analysis aims to interpret the data objectively, providing insights into the effectiveness and feasibility of the PenVironment Machine in promoting proper plastic bottle waste management. Through this, the study evaluates the machine's efficiency, user acceptance, and potential impact on environmental sustainability.

Table 1 presents the results of the Likert scale survey questions one (1) to four (4), conducted to assess the current state of plastic bottle waste management at Notre Dame of Trece Martirez. The survey included questions regarding the effectiveness of waste management practices, the availability of recycling facilities, and the level of participation and awareness among students.

Table 1

Summary of Likert Scale Responses on the Current Plastic Bottle Waste Management Practices at Notre Dame of Trece Martirez.

Likert Scale Item	5	4	3	2	1	Weighted Mean	Interpretation
1. The current waste management at Notre Dame of	7.5% (3)	47.5 (19)	40% (16)	5% (2)	0% (0)	3.57	Agree

Trece Martirez effectively handles plastic bottle waste.							
2. There are sufficient recycling bins and facilities for plastic bottles on the school premises.	12.5% (5)	40% (16)	42.5% (17)	5% (2)	0% (0)	3.60	Agree
3. Students actively participate in properly disposing of plastic bottles in designated waste bins.	7.5% (3)	27.5 (11)	45% (18)	12.5% (5)	7.5% (3)	3.15	Neutral
4. The school provides adequate education and awareness programs about proper plastic bottle waste managemen t.	5% (2)	50% (20)	32.5 (13)	12.5% (5)	0% (0)	3.47	Agree

Legend: 4.20-5.00-Strongly Agree; 3.40-4.19 Agree; 2.60-2.39-Neutral; 1.80-2.59-Disagree; 1.00-1.79-Strongly Disagree

In question number 1, a total of 55% (7.5% Strongly Agree, 47.5% Agree) of the respondents believed that the plastic bottle waste management practices within the school premises are highly effective and are in effect. Among the total number of respondents 40% of them are neutral about the situation as they are neither satisfied nor dissatisfied with how the plastic bottle waste is managed at the school. Although there has not been any respondents that thinks that the plastic bottle waste management at the school completely fails, there has been 5% of the total number of respondents that believes that the plastic bottle waste management at the school is highly ineffective.

The weighted mean of 3.57 falls within the "agree" range since it is closer to 4 (Agree) than to 3 (Neutral) therefore suggesting that overall, respondents are generally positive about the plastic bottle waste management system but not overwhelmingly so. It indicates that the majority of the respondents believe that the system is adequate but has plenty of room for improvements. This also indicates that the school is enforcing efforts to prevent the accumulation of plastic bottle waste within the school. According to Zorpas, A., et al. (2017), Understanding waste prevention could enable school's principals, local authorities and committees as well as decision-makers to design and implement more effective policies for reducing the amount of specific waste streams generated.

In question number 2, a large portion of respondents 52.5% (40% Agree, 12.5% Strongly Agree) agrees that the amount of recycling bins and facilities at the school are sufficient enough. Almost half, (42.5%) of the respondents are neutral, suggesting that they might not have a strong opinion or don't feel that the availability of recycling bins is either notably good or bad. While a small portion, (5%) of the total respondents disagrees, indicating that they feel the recycling facilities are lacking. Again, no respondents strongly disagreed, indicating that the dissatisfaction with the recycling bins and facilities are not severe.

The weighted mean being at 3.60, it falls within the "agree" range. This indicates a positive outlook on the availability of recycling bins and facilities but not to an overwhelming degree. Because the mean isn't closer to 4 or 5, it implies that improvements might still be needed. The significant amount of neutral responses also becomes concerning as they may not fully utilize or perhaps not even know where the school's recycling bins and facilities are at therefore them having no opinion on this matter whatsoever. This aligns with the findings of Purkayastha, D., et al. (2015), where they found out the importance of the location of centers or facilities and recycling bins towards successful waste management within schools and other areas.

In question number 3, based on respondents' opinions, only 35% (7.5% strongly agree, 27.5% agree) actively participate in proper disposal. Meanwhile, 45% remain neutral, and 20% (12.5% disagree, 7.5% strongly disagree) do not believe there is active participation. With a weighted mean of 3.15, the responses fall within the "Neutral" range– indicating that respondents are uncertain or divided on whether students actively dispose of plastic bottles in designated waste bins.

The significant percentage of neutral responses suggests that while some individuals may properly dispose of plastic bottles, others may not; this highlights a potential inconsistency in waste management participation. Aligned with findings by Nnonyelu and Niu (2024) they emphasize that a lack of awareness among students presents a significant challenge to effective waste management. They suggest that implementing educational initiatives and fostering community involvement are crucial strategies for encouraging proper waste disposal behaviors, such as utilizing designated bins for plastic bottles.

In question number 4, results indicate that 55% (5% strongly agree, 50% agree) believe the school provides sufficient education on waste management; 32.5% are neutral, while 12.5% disagree. The weighted

mean of 3.50 (or 3.475) falls within the "Agree" category– suggesting that respondents generally recognize the school's efforts in educating about plastic bottle waste management. However, the significant neutral and disagree responses imply that while programs exist, they may require improvement or better promotion for greater effectiveness. Aligns with findings by Gada (2024) found that education and awareness initiatives on plastic waste management were the most effective solution, with 53.3% of participants highlighting the importance of behavior change in addressing mismanagement and its consequences in schools within Gwadabawa Local Government, Sokoto, Nigeria.

Table 2 presents the results of the Likert scale responses questions five (5) to eight (8) concerning the anticipated benefits of the PenVironment Machine in enhancing plastic bottle waste management within the school. The survey aimed to analyze students regarding the machine's potential impact on environment and waste disposal practices.

Table 2

Summary of likert scale responses on the anticipated benefits of the PenVironment Machine in promoting proper plastic bottle waste management within the school.

Likert Scale Item	5	4	3	2	1	Weighted Mean	Interpretation
5. Using the PenVironment Machine will make one feel like they're positively contributing to the environment	37.5% (15)	52.5% (21)	10% (4)	0% (0)	0% 0	4.27	Strongly Agree

6. The presence of the PenVironment Machine will encourage students to dispose of plastic bottles properly.	45% (18)	47.5% (19)	7.5% (3)	0% (0)	0% (0)	4.37	Strongly Agree
7. The machine can bring long-term positive environmental change.	35% (14)	37.5% (15)	25% (10)	2.5% (1)	0% (0)	4.05	Agree
8. The PenVironment Machine has the potential to become the leading solution for plastic bottle waste management.	35% (14)	42.5% (17)	22.5% (9)	0% (0)	0% (0)	4.12	Agree

Legend : 4.20-5.00-Strongly Agree; 3.40-4.19 Agree; 2.60-2.39-Neutral; 1.80-2.59-Disagree; 1.00-1.79-Strongly Disagree

In question number 5, the results show a weighted mean score of 4.27, falling within the "Strongly Agree" range. A significant majority of respondents (37.5% strongly agree, 52.5% agree, 10% neutral). This indicates a very positive perception of the PenVironment Machine's ability to make users feel like they are

positively contributing to the environment. The high mean suggests the machine's design and functionality effectively communicate its environmental benefits.

Aligned with findings by Passafaro & Stefano (2017) People must be able to identify recyclables, know which container to put them in, and know where and how to get more information when needed . Confusion regarding what can be recycled was shown to be a significant obstacle to recycling among participants, as an incorrect perception of plastic materials themselves developed. When participants saw packaging made of multiple types of plastic or other materials like paper, their bewilderment was increased.

In question number 6, the presence of the PenVironment Machine will encourage students to dispose of plastic bottles properly received the highest weighted mean score (4.37), reflecting a very strong positive response. A significant majority of respondents (45% strongly agree, 47.5% agree, 7.5% neutral). This strongly suggests that respondents believe the presence of the PenVironment Machine will significantly encourage proper disposal of plastic bottles. The overwhelming positive response highlights the machine's potential to directly impact waste management behavior.

Aligned with findings by Miller et al. (2019) that the implementation of recycling machines in schools result in an increase in proper waste disposal behaviors among students. Their findings show that when students have access to convenient disposal options they are more likely to dispose of waste responsibly.

In question number 7, the weighted mean score of 4.05 for "The machine can bring long-term positive environmental change" falls within the "Agree" range. A significant majority of respondents (35% srongly agree, 37.5% agree, 25% neutral, 2.5% disagree) demonstrate substantial agreement with the machine's potential for long-term positive environmental impact. While not as high as the agreement for Item 6, it still indicates a significant positive perception of the machine's long-term sustainability benefits.

Aligned with findings by Rume et al. (2020) that all of these environmental effects are thought to be short-term. So it is essential to develop a suitable plan for both sustainable environmental management and long-term benefits.

In question 8, the results shows a weighted mean score of 4.12 "The PenVironment Machine has the potential to become the leading solution for plastic bottle waste management" shows considerable agreement with the machine's potential to become a leading solution. A significant majority of respondents (35% srongly agree, 42.5% agree, 22.5% neutral). This indicates a strong belief in the machine's capacity to significantly impact plastic bottle waste management. The high level of agreement across all statements points to a generally positive outlook on the PenVironment Machine's effectiveness.

Aligned with findings by Sharma (2023), artificial intelligence (AI) has the potential to help manage plastic waste by addressing its problems. This includes monitoring, collecting and recycling plastic waste, converting waste into energy, and managing landfills, all of which can result in more effective and sustainable methods of managing plastic waste.

Table 3 demonstrates the coding of themes and patterns based on the participants' responses to what additional features and functions the PenVironment Machine should include to better address plastic bottle waste management.

Table 3

Coding of Survey Questionnaire responses regarding what features and functions should the PenVironment Machine include to effectively address the plastic bottle waste management issue.

Category	Number of Mentions	Percentage
Automation & Efficiency	8	20%
Design & User Experience	10	25%
Reward System & Accuracy	5	12.5%
Security & Durability	4	10%
Expanded Waste Collection	6	15%
Ease of Use	7	17.5%
Total	40	100%

When respondents were asked about the key features they expect from the PenVironment Machine, design and user experience (25%) emerged as the most important factor. This suggests that users want a machine that is both visually appealing and easy to operate. Automation and efficiency (20%) were also highly valued, indicating a preference for a system that minimizes manual effort and speeds up the waste disposal process. Yousif & Moalosi (2024) states how industrial design is essential in driving the circular economy by encouraging system changes that enhance sustainability, maximize resource efficiency, and minimize waste. This underscores the need for well-designed recycling systems that are user-friendly and efficient. Additionally, ease of use (17.5%) highlights the need for an intuitive interface that anyone can navigate without difficulty. Some respondents (12.5%) suggested that a reward system would be an effective way to encourage participation. Expanded waste collection (15%) shows that users prefer a machine capable of handling more than just plastic bottles. Finally, security and durability (10%) were noted as essential to ensure the machine remains functional and protected from damage. Overall, the responses highlight that a well-designed, efficient, and easy-to-use machine with incentives and strong durability will be most effective.

Table 4 displays the coding of the participants' answers in accordance with how we might further develop the PenVironment Machine to completely encourage student participation in effective plastic bottle waste management.

Table 4

Coding of Survey Questionnaire responses about how can the PenVironment Machine be designed to encourage student participation in proper waste management.

Category	Number of Mentions	Percentage
Informative and Interactive Design	8	20%
Aesthetic Appeal	7	17.5%
Strategic Placement and Demonstration	6	15%
Reward and Incentive System	6	15%
School Partnerships	5	12.5%
Transparency and Visibility	4	10%
Total	40	100%

In response to the question about how to encourage student participation, informative and interactive design (20%) was the most common suggestion. This implies that educational features and engaging elements can help raise awareness about plastic waste management. Aesthetic appeal (17.5%) was also mentioned, showing that a visually attractive machine may draw more users. Strategic placement and demonstration (15%) were identified as key factors, meaning the machine should be installed in areas with high foot traffic and should come with proper instructions. A reward and incentive system (15%) was another popular suggestion, reinforcing the idea that people are more likely to participate when given a tangible benefit. Some respondents (12.5%) emphasized the importance of school partnerships, suggesting

that collaboration with institutions could improve adoption. Lastly, transparency and visibility (10%) were noted, indicating that users want clear information on how their contributions impact the environment. These insights suggest that a combination of education, strategic placement, incentives, and attractive design can enhance engagement.

Table 5

PenVironment Machine's impact on plastic bottle waste management.

Hypothesis	**Null Hypothesis (H_0)**	**Alternative Hypothesis (H_1)**	**Statistical Test Used**	**p-Value**	**Decision**	**Conclusion**
Impact on Plastic Bottle Waste	The PenVironment Machine does not lead to a significant reduction in plastic bottle waste.	The PenVironment Machine contributes to a significant decrease in plastic bottle waste recovered within the school.	Wilcoxon Signed-Rank Test	0.12	Accepted H_0	No significant change in plastic bottle waste.

This table examines whether the machine effectively reduces overall plastic bottle waste. The Wilcoxon Signed-Rank test yielded a p-value of 0.12, indicating no statistically significant reduction. However, as noted by Hartley et al. (2024), waste reduction initiatives often require long-term behavioral shifts, which may not immediately translate into significant statistical changes but can still indicate meaningful progress in sustainability efforts.

Table 6

Effectiveness of the PenVironment Machine in the proper way of disposing waste.

Hypothesis	**Null Hypothesis (H_0)**	**Alternative Hypothesis (H_1)**	**Statistical Test Used**	**p-Value**	**Decision**	**Conclusion**
Proper Disposal Practices	The PenVironment Machine does not result in a significant change in proper disposal practices.	The PenVironment Machine enhances the engagement of students in appropriate plastic bottle waste disposal.	Chi-Square Test	0.02	Rejected H_0	Significant increase in engagement.

Based on this hypothesis of the machine's effect on proper disposal practices; the Chi-Square test's p-value (0.02) shows a significant increase in engagement with proper disposal. By showing a significant increase in engagement, the study by Endaya et al., (2022) provides evidence that installing and promoting incentivizing products like the use of the PenVironment Machine can encourage better waste disposal habits.

Table 7

Perception about the PenVironment Machine's way of plastic bottle waste management.

Hypothesis	**Null Hypothesis (H_0)**	**Alternative Hypothesis (H_1)**	**Statistical Test Used**	**p-Value**	**Decision**	**Conclusion**
Opinion on Waste Disposal	Students' opinions on waste disposal remain unchanged.	The PenVironment Machine significantly influences students' perceptions of waste management.	Mann-Whitney U Test	0.10	Accepted H_0	No significant change in opinions.

Students' perceptions of the Penvironment machine as an effective method for disposing of plastic bottle waste have been observed. The impact on opinions about waste disposal was analyzed using the Mann-Whitney U test, which yielded a p-value of 0.10, indicating no significant change in perceptions. According to Ghahramani (n.d.), comparing natural waste disposal methods with the Penvironment machine's approach helps students better understand their environmental goals and the necessary steps to achieve them.

Table 8

Student's awareness in proper disposal of plastic bottle waste in relations with the PenVironment Machine.

Hypothesis	**Null Hypothesis (H_0)**	**Alternative Hypothesis (H_1)**	**Statistical Test Used**	**p-Value**	**Decision**	**Conclusion**
Awareness of Proper Disposal	The PenVironment Machine does not significantly affect awareness of proper disposal.	The PenVironment Machine significantly increases students' and members' awareness of proper plastic bottle disposal.	Chi-Square Test	0.01	Rejected H_0	Awareness significantly increased.

This table presents the influence of the PenVironment Machine on awareness of proper disposal practices. The Chi-Square test yielded a p-value of 0.01, indicating a statistically significant increase in awareness. This finding aligns with Conti et al., (2024), who conducted a systematic review and meta-analysis demonstrating that educational interventions effectively enhance waste management knowledge and practices among healthcare workers. Their research emphasizes the importance of multi-component educational approaches in improving waste management standards. Similarly, the current study highlights the Penvironment Machine's role as an educational tool that significantly boosts awareness of proper disposal methods. This underscores the necessity of integrating innovative educational interventions to address gaps in waste management practices and promote environmental sustainability.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

This study's main objective is to evaluate the effectiveness of the PenVironment Machine, an innovative recycling initiative that gives pens in exchange for plastic bottles. And it aims to assess its impact on promoting environmental sustainability, encouraging recycling behavior, and increasing awareness of plastic bottle waste management. Hence, the study also examines user engagement and the machine's efficiency in collecting the said plastic bottle waste. Furthermore, it explores the potential contribution of the PenVironment Machine to reducing environmental pollution through incentivized recycling.

The researchers used surveys to evaluate how well the machine encouraged recycling and engaged users. This cost-effective method allowed for collecting a large amount of data within funding limits. The researcher used quantitative techniques like Likert scale assessments and survey questionnaires to gain a thorough understanding of the PenVironment Machine's effects. Once tested, the machine is expected to enhance recycling efforts and user participation in the school. Its user-friendly design and focus on waste management challenges may contribute to significant progress in sustainable practices. Consequently, it could lead to positive changes in students' behavior toward proper waste disposal, promoting environmental awareness and social responsibility within the school community.

The following are the findings of the study:

1. Respondents rated Notre Dame of Trece Martirez's plastic bottle waste management 3.57 (Agree) overall. Recycling bins/facilities scored 3.60 (Agree), awareness programs 3.47 (Agree), and proper disposal participation 3.15 (Neutral), highlighting the need to improve active waste disposal.

2. Respondents felt the PenVironment Machine positively impacts the environment (4.27), encourages proper disposal (4.37), promotes long-term change (4.05), and has potential as a leading waste management solution (4.12).
3. The following are the findings on the perception and improvement of the PenVironment Machine:

   3.1. Respondents prioritized Design & User Experience (25%) and Automation & Efficiency (20%) for the PenVironment Machine. Other key features included Ease of Use (17.5%), Expanded Waste Collection (15%), Reward System & Accuracy (12.5%), and Security & Durability (10%), highlighting the importance of user experience and automation.

   3.2. The findings highlight key factors in encouraging participation in plastic waste management, including informative and interactive design (20%), aesthetic appeal (17.5%), strategic placement and demonstration (15%), rewards and incentives (15%), school partnerships (12.5%), and transparency (10%). Combining these with education and incentives can enhance engagement.
4. The impact of the PenVironment Machine on plastic bottle waste management was analyzed using the Wilcoxon Signed-Rank Test, resulting in a p-value of 0.12. Since this value is above the 0.05 significance level, the null hypothesis (H_0) was accepted, indicating no significant change in plastic bottle waste.
5. The effectiveness of the PenVironment Machine in proper waste disposal was analyzed using the Chi-Square Test, resulting in a p-value of 0.02. Since this is below the 0.05 significance level, the null hypothesis (H_0) was rejected, indicating a significant increase in engagement among students in disposing of plastic bottles properly.
6. The impact of the PenVironment Machine on opinions about waste disposal was analyzed using the Mann-Whitney U Test, resulting in a p-value of 0.10. Since this is above the 0.05

significance level, the null hypothesis (H_0) was accepted, indicating no significant change in students' and opinions on waste management.

7. The impact of the PenVironment Machine on awareness of proper disposal was analyzed using the Chi-Square Test, resulting in a p-value of 0.01. Since this is below the 0.05 significance level, the null hypothesis (H_0) was rejected, indicating that awareness of proper plastic bottle disposal significantly increased.

CONCLUSION

Based on the findings of the study, the following conclusions were drawn:

1. The select population of the STEM strand at Notre Dame of Trece Martirez find the current Plastic Bottle Waste Management to be effective and reliable.

   1.1. The null hypothesis that states that the PenVironment Machine does not lead to a significant reduction in plastic bottle waste management was accepted as the findings of the study suggests that there was no significant change in plastic bottle waste.

   1.2. While the alternative hypothesis that states that the PenVironment Machine contributes to a significant decrease in plastic bottle waste recovered within the school was rejected based on the findings of the study.

2. Easy usage, reliability, and wider range of waste collection is what the PenViroment Machine needs in order to address the issues within the campus.

   2.1. The null hypothesis that states that the PenViroment Machine does not result in a significant change in proper disposal practices was rejected based on the findings of the study.

2.2. While the alternative hypothesis that states that the PenViroment Machine enhances engagement of students in appropriate Plastic Bottle Waste Disposal is accepted based on the findings of the study that there is a significant increase in engaement.

3. Strategic placement of the machine, appealing design, and other incentives such as voucher codes is what encourages students at the campus to properly manage waste.

   3.1. The null hypothesis that states that student opinions on waste disposal remain unchanged is therefore accepted based on the findings suggesting that the factors stated above are not sufficient to change the opinion of the students about waste disposal.

   3.2. While the alternative hypothesis that states that The PenVironment Machine significantly influences students' perception of waste management is rejected as the findings concluded that there is no significant change in the opinion of the students about waste disposal.

4. Installing such machines in school settings would start a fad within the students to start disposing of their plastic bottle waste properly, suggesting a long-term positive effect.

   4.1. The null hypothesis that states that The PenVironment Machine does not significantly affect awareness of proper disposal was therefore rejected due to there being a significant increase in the awareness towards proper disposal.

   4.2. While the Alternative Hypothesis that states that the PenViroment Machine significantly increases students' awareness of proper plastic bottle disposal is accepted based on the findings of the study.

Overall, the findings of the study revealed how the implementation of such machines in school settings affects the plastic bottle waste management system. It also shows how it affects the students' waste disposal behaviours with the presence of the machine.

RECOMMENDATIONS

Based on the conclusions of the study, the following recommendations are presented.

1. The local government unit of Trece Martirez should consider investing a lot of PenViroment Machines in various public areas, not just within the campus ,to improve the overall plastic bottle waste management system in Trece Martires. This will provide residents with easier access to proper disposal.
2. Students should continue to deal with the PenViroment Machine using it for proper waste disposal as their active participation is important for the system's effectiveness and longterm use.
3. Future researchers should pursue multiple essential directions as a basis for this work. The machine's operation needs thorough investigation to establish its precise contribution toward plastic bottle collection and recycling performance.

REFERENCES

Allen-Taylor, K. O. (2022). Combining extended producer responsibility (epr) and deposit refund system (drs) policy for higher recovery and recycling of plastic bottles and sachet water waste: Application of vending machine and designated return depot centre in Lagos, Nigeria. *Open Journal of Environmental Research*, 3(1), 22–34. https://doi.org/10.52417/ojer.v3i1.380

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. *J Mater Cycles Waste Manag* 23, 872–884 (2021). https://doi.org/10.1007/s10163-020-01161-9

Baribad, J. A., Cabauatan, T., Guingab, E., & Tarun, 1. (2024). Plastic2 Fantastic: Reverse Vending Machine for Plastic Bottles. Isabela State University Linker: Journal of Engineering, Computing and Technology, 1(1). https://www.isujournals.ph/index.php/ject/article/view/20

Braun, V., Clarke, V., Boulton, E., Davey, L., & McEvoy, C. (2021). The online survey as a qualitative research tool. *International journal of social research methodology,* 24(6), 641-654. https://doi.org/10.1080/13645579.2020.1805550

Bugarin, R., Masagca, G., Enojas, M., Morgado, J., Rufo, J., Arribas, R., Bongao, H. L., Calising, J., Dioso, I., Guanzon, N., Legaspi, R. E., Constancio, Jr., & Odiña, J. (2023). *Design of plastic bottle shredder machine with monetary reward system*, 10(1), 58–60. https://www.researchgate.net/publication/377500095

Castro, C., Magsakay, R., Geronimo, S., Cristopher Conato, Jamella Denise Cruz, & Juan Rafael Alvara. (2020). Development of Waste Management System using the Concept of 'Basura Advantage Points' through Artificial Neural Network", IEEE 12th International Conference on Humanoid,

Nanotechnology, Information Technology, Communication and Control, Environment, and Management (HNICEM), 1-5. https://ieeexplore.ieee.org/abstract/document/9400123

Chow, C. F., So, W. M. W., Cheung, T. Y., & Yeung, S. K. D. (2017). Plastic waste problem and education for plastic waste management. *Emerging practices in scholarship of learning and teaching in a digital era,* 125-140. https://link.springer.com/chapter/10.1007/978-981-10-3344-5_8

Citterich, F., Giudice, A. L., & Azzaro, M. (2023). A plastic world: A review of microplastic pollution in the freshwaters of the Earth's poles. *Science of The Total Environment,* 869, 161847. https://www.sciencedirect.com/science/article/pii/S004896972300462X

Conner, M., & Armitage, C. J. (2016). Extending the Theory of Planned Behavior: A review and avenues for further research. *Journal of Applied Social Psychology*, 46(6), 293-302. https://doi.org/10.1111/jasp.12247

Conti, A., Viottini, E., Comoretto, R. I., Piovan, C., Martin, B., Albanesi, B., Clari, M., Dimonte, V., & Campagna, S. (2024). The Effectiveness of Educational Interventions in Improving Waste Management Knowledge, Attitudes, and Practices among Healthcare Workers: A Systematic Review and Meta-Analysis. *Sustainability,* 16(9), 3513. https://doi.org/10.3390/su16093513

Dacay, W. J., Sapida, D., Jumawan, I.Z & Dela, M. K. (2020) VENDOBIN: An IOT-based Plastic Bottle Waste Disposal Vending Machine. http://dx.doi.org/10.31838/jcr.07.15.808

Deci, E. L., & Ryan, R. M. (2018). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology/Psychologie canadienne*, 49(3), 182–185. https://doi.org/10.1037/a0012801

Dumpayan, W. G. P., De Mesa, M. L. M., Yucor, N. D. F., Gabion, E. T., Reynoso, J. D., & Geslani, G. R. M. (2017). Two-way powered microcontroller-based plastic bottles 'drop-and- tap' reverse vending

machine with stored value system using radio frequency identification (RFID) scanner technology. *2017IEEE 9th International Conference on Humanoid, Nanotechnology, Information Technology, Communication and Control, Environment and Management (HNICEM),* pp. 1-8. https://doi.org/10.1109/HNICEM.2017.8269433

Endaya, J. P. S., Mabitasan, F. S. Jr., & Gonzales, J. C. M. (2022). LPULAGUNA University. *Design and implementation of automated waste segregator with smart compression*. https://lpulaguna.edu.ph/wp-content/uploads/2022/01/6.-Endaya-Mabitasan-Gonzales-Waste-Segregator.pdf

Evode, N., Qamar, S. A., Bilal, M., Barceló, D., & Iqbal, H. M. (2021). Plastic waste and its management strategies for environmental sustainability. Case Studies in Chemical and Environmental Engineering, 4, 100142. https://doi.org/10.1016/j.cscee.2021.100142

Farghali, M., & Osman, A. (2024). Revolutionizing waste management: unleashing the power of artificial intelligence and machine learning. *Advances in Energy from Waste: Transformation Methods, Application and Limitations Under Sustainability (Woodhead Advances in Pollution Research),* 225-279. https://doi.org/10.1016/B978-0-443-13847-8.00007-5

Flores, M., & Tan, J., Jr. (2019). Literature Review of Automated Waste Segregation System Using Machine Learning: A Comprehensive Analysis. *International Journal of Simulation Systems Science & Technology*. https://ijssst.info/Vol-20/No-S2/paper15.pdf

Francine, A. N. G. (2023). OPPORTUNITIES AND CHALLENGES OF RECYCLED PLASTIC BUILDING MATERIALS IN THE CONSTRUCTION INDUSTRY OF THE PHILIPPINES. https://epub.fh-joanneum.at/obvfhjhs/content/titleinfo/9639841/full.pdf

Frölich, M., Landmann, A., Olapade, M., & Poppe, R. (2014). Non-experimental methodologies for quantitative analysis. *A practical guide to impact assessments in micro-insurance*, 111-129. https://shorturl.at/jTk8P

Gada, S. N. (2024). Plastic solid waste management assessment among selected schools in Gwadabawa Local Government, Sokoto, Nigeria. 74–91. https://doi.org/10.58578/mjaei.v1i1.2851

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757-768. https://doi.org/10.1016/j.jclepro.2016.12.048

Ghahramani, B. (n.d.). Solid waste management: Comparison of methods. *American Society for Engineering Education*. https://peer.asee.org/solid-waste-management-comparison-of-methods.pdf

Gibovic, D., & Bikfalvi, A. (2021) Incentives for Plastic Recycling: How to Engage Citizens in Active Collection. Empirical Evidence from Spain. *Advances in the Recycling and Processing of Plastic Waste,* 6(2), 29. https://doi.org/10.3390/recycling6020029

Global Learning (2024). The role of educational institutions in promoting recycling and waste reduction. Global Learning. https://globallearning.world.edu/2024/06/14/the-role-of-educational-institutions-in-promoting-recycling-and-waste-reduction/

Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., & Kyriakidou, O. (2014). Diffusion of innovations in service organizations: Systematic review and recommendations. *The Milbank Quarterly*, 82(4), 581-629. https://doi.org/10.1111/j.0887-378X.2004.00325.x

Hartley, B. L., Pahl, S., Thompson, R. C., & Vlachogianni, T. (2024). Global scoping review of behavioral interventions to reduce plastic pollution. *Conservation Science and Practice,* 6(8). https://doi.org/10.1111/csp2.13174

Jungthawan, S., Tiyarattanachai, R., & Anantavrasilp, I. (2023). Feasibility of reverse vending machine for PET bottle recycling in case of ABC hypermarket. *Current Applied Science and Technology*, 24 (2). https://doi.org/10.55003/cast.2023.258442

Karapanos, E. (2015). Sustaining user engagement with behavior-change tools. *Interactions*, 22(4), 48–52. https://doi.org/10.1145/2776888

Kehinde, O., Ramonu, O., Babaremu, K., & Justin, L. (2020). Plastic wastes: Environmental hazard and instrument for wealth creation in Nigeria. Heliyon, 6(10). https://doi.org/10.1016/j.heliyon.2020.e05131

Langit, A., Parungao, S., Gregorio, A., et. al, (2024). Feasibility Study of an Integrated Waste Management Technology System for a Circular Economy in the Philippines. *Deleted Journal*, (Vol, 2, Issue 3), 3.https://doi.org/10.56237/jhes24ichspd05

Lubongo, C., & Alexandridis, P. (2022). Assessment of performance and challenges in use of commercial automated sorting technology for plastic waste. *Recycling,* 7(2), 11. https://www.mdpi.com/2313-4321/7/2/11

Mariya, D., Usman, J., Mathew, N., Ph, H., Azeez, A., & Tech Student. (2020). Reverse Vending Machine for Plastic Bottle Recycling. International Journal of Computer Science Trends and Technology (IJCST), 8. https://www.ijcstjournal.org/volume-8/issue-2/IJCST-V8I2P11.pdf

Miller, J. L., Wentzel, M. T., Clark, J. H., & Hurst, G. A. (2019). Green machine: A card game introducing students to systems thinking in green chemistry by strategizing the creation of a recycling plant. Journal of chemical education, 96(12), 3006-3013. https://pubs.acs.org/doi/epdf/10.1021/acs.jchemed.9b00278?ref=article_openPDF

Nkwo, M., Suruliraj, B., & Orji, R. (2021). Persuasive apps for sustainable waste management: a comparative systematic evaluation of behavior change strategies and state-of-the-art. *Frontiers in artificial intelligence,* 4, 748454. https://www.frontiersin.org/journals/artificial-intelligence/articles/10.3389/frai.2021.748454/full

Nnonyelu, P., & Niu, D. (2024). Strategies for enhancing solid waste management practices in urban secondary schools in developing countries. European Journal of Theoretical and Applied Sciences, 2(4), 770–786. https://doi.org/10.59324/ejtas.2024.2(4).66

Nurfikri, A., & Martono, D. N. (2023). Willingness to use reverse vending machine in plastic bottle waste management. *Proceedings of the 6th International Conference on Vocational Education Applied Science and Technology (ICVEAST 2023)*, 733-743. https://doi.org/10.2991/978-2-38476-132-6_62

Padios, J., Gulmatico, R., Cruz, J. D., Cruz, J., Agustino, K. F., & Valle, K. J. (2021). Development of a PET Bottle Collection System for a Green Campus Community. *International Journal of Synergy in Engineering and Technology*, 2(2), 113-124. https://www.tatiuc.e

Passafaro , Stefano L. Comparing determinants of perceived and actual recycling skills: The role of motivational, behavioral and dispositional factors, Journal of Environmental Education. 2017l; 48(5): pp. 347–356. https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0267284#pone.0267284.ref037

Portilla, N. (2023). Reverse Vending Machines – what are they and how do they work? *Recycle Track Systems; RTS - Recycle Track Systems.* https://www.rts.com//reverse-vending-machine/

Purkayastha, D., Majumder, M., & Chakrabarti, S. (2015). Collection and recycle bin location-allocation problem in solid waste management: A review. *Pollution,* 1(2), 175-191. https://jpoll.ut.ac.ir/article_52927_7f3c6c2744324db252eaead57db03019.pdf

Rubio, A. J., & Lazaro, J. P. (2016). Solar Powered Reverse Trash Vendo Machine. *Asia Pacific Journal of Multidisciplinary Research,* 4(2). https://www.academia.edu/41970038/Solar_Powered_Reverse_Trash_Vendo_Machine

Rume, T., & Islam, S. D. U. (2020). Environmental effects of COVID-19 pandemic and potential strategies of sustainability. *Heliyon,* 6(9). https://www.cell.com/heliyon/fulltext/S2405-8440(20)31808-9

Sharma, R. (2023). Plastic Waste Management: Challenges and Potential Solution With the application of AI. *International Journal of Sustainable Development Through AI, ML and IoT,* 2(1), 1-27. https://ijsdai.com/index.php/IJSDAI/article/view/19

Sidhu, N., Pons-Buttazzo, A., Muñoz, A., & Terroso-Saenz, F. (2021). A Collaborative Application for Assisting the Management of Household Plastic Waste through Smart Bins: A Case of Study in the Philippines. *Sensors* (Vol. 21, Issue 13), 4534. https://doi.org/10.3390/s21134534

Singer, E., & Couper, M. P. (2017). Some methodological uses of responses to open questions and other verbatim comments in quantitative surveys. *Methods, data, analyses*, *11*(2), 20. https://doi.org/10.12758/mda.2017.01

Sira, S., Dr., Minerva, N., Jr, Daitao, A., Dr., & Arthur E. Villagracia. (2024). Plastic Bottle Collector Bin with Dispenser. *In Iloilo Science and Technology University, Journal of Harbin Engineering University* (Vol. 45, Issue 3). https://sg.docworkspace.com/d/sIAmniObUAcDd5LsG

South, L., Saffo, D., Vitek, O., Dunne, C., & Borkin, M. A. (2022). Effective use of Likert scales in visualization evaluations: A systematic review. *In Computer Graphics Forum*, 41(3), 43-55. https://doi.org/10.1111/cgf.14521

Sunstein, C. R. (2014). The Ethics of Influence: Government in the Age of Behavioral Science. *Cambridge University Press*. https://doi.org/10.1017/CBO9781316493021

Taylor, M. (2021). Reduce, reuse, recycle with the reverse vending machine. *USC Viterbi School of Engineering - USC Viterbi School of Engineering*. https://illumin.usc.edu/reduce-reuse-recycle-with-the-reverse-vending-machine/

Tomari et al. (2017). Development of Reverse Vending Machine (RVM) Framework for Implementation to a Standard Recycle Bin. *Procedia Computer Science,* Vol. 105, P. 75-80. https://doi.org/10.1016/j.procs.2017.01.202

Viscusi, W. Kip, Joel Huber, and Jason Bell. (2011). Promoting Recycling: Private Values, Social Norms, and Economic Incentives. *American Economic Review,* 101 (3), 65–70. https://www.aeaweb.org/articles?id=10.1257/aer.101.3.65

Yousif, T., & Moalosi, R. (2024). The Role of Industrial Designers in Achieving the Green Economy Through Recycling. *Journal of Engineering*. https://doi.org/10.1155/2024/7291504

Zhang, X., & Fang, Y. (2014). The Theory of Social Exchange and its Application to Organizational Research. *Journal of Business* Ethics, 121(1), 1-10. https://doi.org/10.1007/s10551-014-2041-9

Zia, H., Muhammad Uzair, Hafiza Sundus Fatima, & Muhammad Khurram. (2022, September 22). Plastic Waste Management through the Development of a Low Cost and Light Weight Deep Learning Based... ResearchGate; MDPI. https://doi.org/10.3390/recycling7050070

Zorpas, A. A., Voukkali, I., & Loizia, P. (2017). Effectiveness of waste prevention program in primary students' schools. *Environmental Science and Pollution Research,* 24(16), 14304-14311. https://link.springer.com/article/10.1007/s11356-017-8968-7

APPENDICES

Documentation







PEN
V/RON
MENT