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Bill Vending Machine for Chits at Siena College of San Jose Inc. Canteen Using Arduino

A Research Proposal Presented to the IBED Faculty
of Siena College of San Jose Inc.
City of San Jose Del Monte,
Bulacan

In Partial Fulfillment of the Requirements
for the Subject Practical Research II

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CERTIFICATION

This research entitled **"BILL VENDING MACHINE FOR CHITS AT SIENA COLLEGE OF SAN JOSE INC. CANTEEN USING ARDUINO"**, prepared by **Nicole A. Elmedorial, Joshua Antonio O. Umadhay, Catrina Yna G. De Vera, Arbhy A. De Belen, Miles A. Hermano, Jahziel Devorah L. Mazo, and Vivienne Leigh Osorio**, in partial fulfillment of the requirements for Practical Research II, have been examined and recommended for ORAL EXAMINATION.

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President

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ABSTRACT

Title : Bill Vending Machine for Chits at Siena College of San Jose Inc.,
Using
Arduino

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The research design used in this study is Quantitative method. The study focuses on the design and development of a bill vending machine specifically for dispensing chits in the canteen of Siena College of San Jose Inc. The project aims to address the inefficiencies caused by long queues, especially during rush hours such as lunch time. Utilizing Arduino Technology, the vending machine accepts bill paper money such as 20, 50, and 100 pesos, and dispenses the equivalent amount of chits in 5, 10, and 20. The TCS3200 Color Sensor is used for bill detection, while a combination of motors and dispensing mechanisms ensures accurate chit delivery.

The findings revealed that the machine shows an atleast 65% accuracy in bill detection and chit dispensing, with an average processing time of 6.5 seconds per transaction. While the machine demonstrated potential for reducing manual errors and delays, it was noted that improvements are necessary to enhance reliability and operational speed. Recommendations for future development include upgrading to



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camera-based sensors, improving the chit transportation mechanism, and conducting further testing.

TABLE OF CONTENTS

Approval Sheet	ii
Acknowledgment	iii
Abstract	iv
Table of Contents	vi
List of Figures	viii
List of Tables	ix

CHAPTER I: THE PROBLEM AND ITS BACKGROUND

Introduction	1
Theoretical Framework	3
Conceptual Framework	5
Statement of the Problem	6
Hypothesis	7
Significance of the Study	7
Scope and Delimitation	8
Definition of Terms	10

CHAPTER II: REVIEWS OF RELATED LITERATURE AND STUDIES

History of Vending Machines	11
Efficiency of Vending Machines	11
Designs of Vending Machines	12

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Factors that Influence the Reliability and Efficiency of Vending Machines	12
Barriers and Challenges in using Bill Vending Machines	13
Arduino	14
Arduino Reliability in Bill Vending Machines	15
Construction Techniques in constructing vending machines	16
Synthesis and Relevance to the Study	17

CHAPTER III: RESEARCH METHODOLOGY

Research Method	19
Research Design	19
Materials and Equipment	20
Prototype	21
Research Instrument	23
Data Gathering Procedure	23
Treatment of the Data	25
Ethical Consideration	25

CHAPTER IV: Presentation, Analysis, and Interpretation of Data

Presentation, Analysis, and Interpretation of Data	27
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Chapter V: Summary of the Findings, Conclusion and Recommendations

Summary of Findings	35
Conclusion	38

Integrated Basic Education Department

Recommendation	38
----------------	----

REFERENCES

References	40
------------	----

APPENDICES

1 Checklist	48
2 Letter to the School Administrators	51
3 Turnitin Report	53
4 Documentation	54
5 Materials	54
6 Exterior of the Bill Vending Machine Making	56
7 Testing and Trials	57
8 Code for the Arduino Technology Software using Arduino IDE	58

CURRICULUM VITAE	62
-------------------------	----

LIST OF FIGURES

Number	Title	Page
1	Theoretical Framework	3
2	Conceptual Framework	5
3	Prototype of the External Bill Vending Machine	21



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4

Integrated Basic Education Department
Pin-out of the Bill Vending Machine

22

LIST OF TABLES

1	Pre-Experiment Phase	28
2	Experiment Phase	31
3	Post-Experiment Phase	33

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CHAPTER I THE PROBLEM AND ITS BACKGROUND

Introduction

In today's fast-paced educational environments, schools and universities have increasingly adopted advanced technologies, using different tools, platforms, and websites. Additionally, they also provided opportunities to expose students to these advancements, to improve further the student experience (Statti, A., & Torres, K.M., 2020). Automated technologies, such as vending machines, became a staple in various situations. From retail to dining, their abilities were greatly utilized to reduce wait times and provide efficiency. Vending Machines provided solutions to high transactions with minimal supervision, particularly what was needed in time-sensitive environments such as the canteen.

In this research study, the researchers aimed to design and implement a Bill Vending Machine for Chits at Siena College of San Jose Canteen. The primary objective of this project was to address the long queues that formed due to the manual process of exchanging real money for chits, a currency used exclusively in the Siena College of San Jose Canteen. This was a system proven to be inefficient and time-consuming, particularly during rush hours such as recess and lunchtime. By automating the chit-exchange process, the researchers aimed to optimize the students' limited break time, allowing them more time to

eat, relax, and prepare before returning and resuming their classes (Ratnasri et al., 2021). The researchers' goal was to develop a vending machine that was not only cost-effective but also reliable and capable of handling many transactions quickly and accurately.

In a bustling school canteen, especially during recess or lunchtime, students would often witness the frustration caused by long queues at the canteen. Students had to wait in line for minutes to exchange money for chits and also had to wait in another line to buy their food for recess and lunch (Sibanda et al., 2020). Due to this common situation in the canteen, students had their break time reduced furthermore from just exchanging chits and ordering food. According to Pebble (n.d), this common problem could also be a cause for dissatisfaction among students and personnel. They would try to find other meal options for their recess and lunch, which could be a cause of reduced income opportunities for the school canteen.

This research study would provide a significant contribution to a specific challenge faced by the Siena College of San Jose Canteen. By automating the chit process, the researchers can address the issue of long queues and dissatisfaction among students and personnel. In addition, the study utilizes

Arduino technology is an open-source electronics platform known for its flexibility, affordability, and ease of use. This technology is widely used in various engineering projects. This is also cost-effective with functionality, accessible to institutions even with a limited budget, and is utilized while being fully customized depending on use (López-Belmonte et al., 2020). Lastly, the successful development of this project can serve as a model for other educational institutions that face similar challenges in canteen services, and be made available for future research.

Theoretical Framework

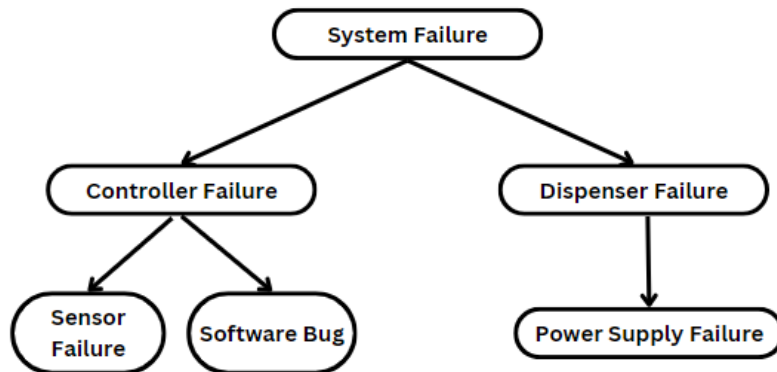


Figure 1. Theoretical Framework of the Study

This study was based on the System Reliability Theory (SRT) by Sheldon M. Ross and was introduced to the probability model in 2014 (Ross, 2014).

Reliability theory focuses on the probability that a system will function, depending on the condition of its components. This theory observes how the function of the system relies on each part and the chances of those parts working independently. The theory also investigates how the lifespan of each component affects the overall lifespan of the system. Furthermore, it is stated that if the component fails more frequently over time, the system is likely to show similar patterns in its reliability.

The Bill Vending Machine for Chits functions with Arduino Technology, followed by proper programming and assembling of module components. This theory is relevant and applicable to the researchers' study due to the research being focused on the creation of the product. It ensures that the product will maximize reliability through its parts while minimizing chances of failure. This allows the researcher to focus on the quality of the product, enabling greater effectiveness, user satisfaction, and performance.

The figure above illustrates the System Reliability Theory, including the components for the Bill Vending Machine for Chits at Siena College of San Jose Canteen. It also illustrates the potential pathways for a System Failure within the project. At the top level, System Failure is labeled with a potential two main failures in controller and dispenser, indicating that these two can be a cause for

system failure of the Bill Vending Machine. Further down, the Controller Failure can be triggered by both Sensor Failure or Software Bug. Lastly, the Dispenser Failure can be caused by the Power Supply Failure. This diagram focuses on the critical parts wherein there are possibilities where failures can lead to a breakdown of the Bill Vending Machine for Chits.

Conceptual Framework

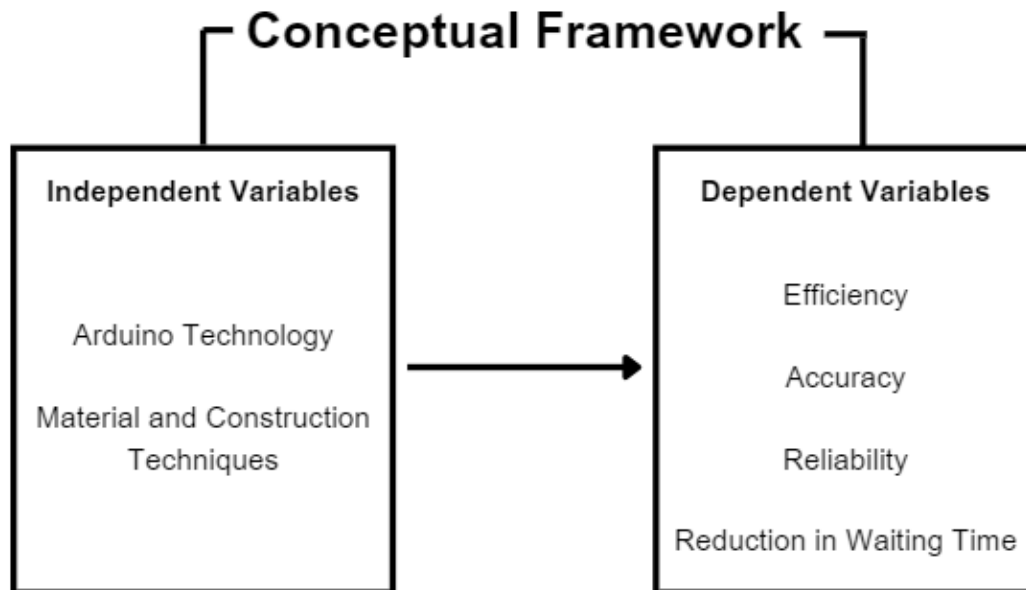


Figure 2. Conceptual Framework of the Study

The figure above illustrates the conceptual framework of the research study. This includes the independent variables: 1.) Arduino Technology which is used as hardware and software of the Bill Vending Machine. These includes the programming itself, as well as the following modules: Color Sensor TCS3200,

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servo motor, and the Arduino Uno., 2.) Material and Construction Techniques which includes the following materials: Marine Plywood (Taylor, 2024), Box Nails (The Editors of Encyclopaedia Britannica, 1998). The dependent variables includes the efficiency which refers to the Bill Vending Machine's ability to manage the workload while effectively optimizes the resources used, accuracy which refers to the correct number of chits dispensed according to the input without error, reliability which refers to the consistency of the Bill Vending Machine over time without multiple errors, and lastly, reduction in waiting time refers to the decrease of time where users have to fall in line to receive chits with the Bill Vending Machine compared to the manual process.

Statement of the Problem

The goal of the researchers' study was to develop the Bill Vending Machine for Chits at Siena College of San Jose Canteen Using Arduino, to acquire research findings, and to assess the benefits through a quantitative process during SY. 2024-2025.

1. How can Arduino Technology be effectively utilized to create a reliable and cost-effective vending machine for dispensing chits?
2. What are the key factors that will contribute to the reliability and efficiency of the Bill Vending Machine?

3. To what extent does the vending machine reduce errors and delays associated with the manual exchange of chits in the canteen?
4. What materials and construction techniques should be used to ensure the durability of the Bill Vending Machine in a high-traffic school environment?

Hypothesis

The following Null Hypothesis will be tested in this study.

H_0 : The application of Arduino Technology in the Bill Vending Machine, along with the modules, does not meet the standard to provide a speedy and accurate dispense of chits when compared to the current manual exchange of chits.

The following Alternative Hypothesis will be tested in this study.

H_1 : The application of Arduino Technology in the Bill Vending Machine, along with the modules, significantly meets the standard to provide a speedy and accurate dispense of chits when compared to the current manual exchange of chits.

Significance of the Study

The researchers of this study believes that not only can they gather data that will be helpful in successfully implementing and evaluating the benefits of a



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Bill Vending Machine for Chits at Siena College of San Jose Canteen Using

Arduino, but also to the following groups of people:

Teacher. This study allows teachers to exchange chits quickly and efficiently, as well as provide more enjoyment during their break time, which can be both convenient and pleasurable for them.

Learners. This study enables students to have more time to eat and enjoy their meals, as well as having ample time to prepare for their next class.

Administrator. This study can provide recommendations for the administrators on improving the canteen operations and the canteen experience for both personnel and students.

Community. This study can reduce waiting times and long queues which can result in a more satisfied, productive, and well-organized environment for the canteen.

Future Researchers. This research is a beneficial reference for researchers who will be constructing a similar study about vending machines using Arduino.

Scope and Delimitation

The study focuses on the use of Arduino Technology and its associated modules (Color Sensor TCS3200, servo motor, and the Arduino Uno) in developing a Bill Vending Machine for dispensing chits at Siena College of San

Jose Canteen. The study also uses quantitative methods in evaluating the performance of the machine based on reliability and effectiveness in dispensing chits compared to the manual chit-exchange process. The study also includes tests such as time trials and accurate dispensing of chit, to determine the machine's overall performance.

The machine does not explore any alternative transaction or technologies outside of its focused research. The Bill Vending Machine for Chits only accepts bills or paper money and only dispenses chits to be used exclusively in the Siena College of San Jose Canteen (or any schools with the same currency used in their canteen). The research study does not study user satisfaction or other aspects related, and will only focus on the speed, accuracy, and reliability of the machine itself. It is limited to Siena College of San Jose Canteen and does not consider any long-term operational issues unless suitable for use outside the initial testing place. Lastly, the study does not address the maintenance and support requirements beyond the initial setup and performance evaluation.

Definition of Terms

For a better understanding of this study, the following terms are defined in the context of this research:

Arduino. an open-source electronics platform with low-cost and easy-to-use hardware and software. (J. López-Belmonte et al., 2020)

Arduino-Based Bill Vending Machine. A model of a Vending Machine that is powered by Arduino only accepts bill or paper money and dispenses chits exclusively for the school canteen.

Cashless Payments. This refers to transactions made without the use of cash, either by electronic transfer or cheque payment. (Tee & Ong, 2016)

Chits. The currency is exclusively used in Siena College of San Jose Canteen.

Self-Service Machine. These are machines that allow customers to do service tasks without the need for support or interventions made by other people.

System Reliability Theory. A theory made by Sheldon M. Ross that focuses on the probability that a system will function, as well as its failure rates (Ross, 2014)

CHAPTER II REVIEW OF THE RELATED LITERATURE

History of Vending Machines

One of the researchers' variables in their study was the Bill Vending Machine.

1. The History of Vending Machines Goes Back to the 1st Century

According to Smith, E. (2024), Heron of Alexandria was the first to invent the vending machine possible. Later in 1883, the Vending Machine was created by Percival Everett for making postcards and notepapers. As of today, nearly 20 billion dollars in revenue each year is earned by different vending machine industries. On Amazon, vending machines cost about 3,400 dollars.

Efficiency of Vending Machines

The researchers sought to discover the efficiency of Bill Vending Machines in exchanging chits at the Siena College of San Jose Canteen.

2. Vending Machine Technologies: A Review Article

According to Ratnasri, et al. (2021), vending machines can significantly reduce the waiting times and the long queues made by traditional cashiers, where they manually count the money and transactions.

In crowded places, customers often feel disappointed which can result in vendors losing profit. With this, automated machines are popular due to instant customer services and efficiency, where minimal human work is required.

Designs of Vending Machines

The researchers sought to investigate the design and effectiveness of Bill Vending Machines in exchanging chits at Siena College of San Jose Canteen.

3. How do Vending Machines Work?

According to Benson (2023), Vending Machines traditionally allow customers to pay for products by depositing coins and bills. These are developed to be smart enough to differentiate and read many types of bills through their physical properties. The first vending machine identifies paper money through a magnetic head that reads magnetic ink in paper currencies. Vending Machines would reject the paper money if it could not read the bill.

Factors that influence the reliability and efficiency of Vending Machine

The researchers sought to find the factors that influence the reliability and efficiency of the Bill Vending Machine for Chits at Siena College of San Jose Canteen.

4. Understanding the technology behind modern vending machines

According to an article from Snack Spot Vending (2023), the quality of the individual components of the machine, such as the sensors, motors, vending machine controller, dispensing mechanisms, etc., as well as the complex combination of technology are utilized to provide convenience and efficiency. These advanced features are customized, not only to provide convenience but also to enhance the overall vending experience.

Barriers and Challenges in Using Bill Vending Machines

The researchers sought to find the barriers and challenges when using Bill Vending Machines.

5. Determining the Drivers and Barriers to the Adoption of Smart Vending Machine

According to Mnyakin, M. (2020), the biggest impediments to the adaptation of Vending Machines are initial costs and technological challenges. The initial cost of purchasing and installing a vending machine can be prohibitively expensive for businesses or schools. The inability of Vending Machines to use different methods of payment is also one of the significant limitations of the device. It is also stated that vending machines are inefficient

when it comes to restocking supplies. Operators carry the responsibility of manually maintaining the inventory levels which must be refilled when needed.

Arduino

One of the researchers' variables in their study was Arduino.

6.1. Arduino Advances in Web of Science. A Scientific Mapping of Literary Production

According to Belmonte et al. (2020), Arduino is an open-source electronic board that uses its programming language. These boards are capable of reading inputs and turning them into outputs, such as using light bulbs and lighting them. Arduino is quickly taking off in the field of education thanks to its inexpensive cost, versatility in design and experimentation, capacity to be programmed on both software and hardware, and compatibility with a variety of operating systems, including Windows, Linux, and Macintosh OS X.

6.2. Using Arduino to develop research competencies of students in school physics education

According to Zadorozhnii (2023), Arduino is a popular hardware and software platform that allows users to create different engineering projects, particularly in physics and computer science. Arduino allows students to explore and encourage their enthusiasm and imagination in science and technology

subjects. Hands-on experimentation and project-based learning can provide students with knowledge and curiosity to discover new opportunities for innovation.

Arduino Reliability in Bill Vending Machines

The researchers sought to discover the dependability of applying Arduino in Bill Vending Machines for accurate chit dispensing and transaction processing.

7. DIY Vending Machine – Arduino-based Mechatronics Project

Based on the detailed Arduino-based tutorial created by Dejan (2022), a DIY Vending Machine project combines mechanical, electronic, and programming skills into a single mechatronics endeavor. Through constructing the machine's frame from MDF boards, integrating servomotors for discharging units, and implementing a coin detection system for operation. It also includes interfacing an LCD and selection buttons for user interaction and provides the Arduino code necessary for controlling the vending mechanisms.

Construction Techniques in Constructing Vending Machines

The researchers sought to discover the construction techniques for constructing the Bill Vending Machine for Chits at Siena College of San Jose Canteen.

8. Basics on how to make a vending machine

According to Francis (2023), it is important to first understand how a vending machine works and what makes a good design. It is important to incorporate these basic components when constructing a vending machine: product storage area, product dispenser, coin mechanism, and access door. There are also numerous design types in constructing vending machines, such as Full-Line Vending Machines, Specialty Vending Machine, Reverse Vending Machine, and Custom Vending Machine. Additionally, there are numerous building components in a vending machine, namely: frame material, product shelves, electrical components, coin mechanisms, and tools.

Synthesis

In an environment where a different currency is used, Bill Vending Machines could be beneficial due to it being accessible, convenient, time-saving, efficient, and accurate in currency exchange (Marwade, 2023; Masters, P., 2023). In Siena College of San Jose, the system of manual exchange of chits was used as a way to provide students and personnel with the currency exclusively used in the canteen. This method can be further enhanced or improved with the use of Bill Vending Machines.

The construction of Vending Machines traditionally allows users to pay with the use of bills, and certain components are useful in reading different types of bills or paper money (Benson, 2023). With the use of Arduino technology, the Bill Vending Machine can be customized and programmed to the specific needs of the Siena College of San Jose Canteen, with its versatility in design and experimentation and capacity to be programmed in software and hardware (Belmonte, et al., 2020).

The researchers can also implement numerous designs for the Bill Vending Machine, wherein planning is important as well as visualizing the vending machine is of utmost importance (Francis, 2023). Being that the product



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dispensed will be chits, the type of Vending Machine that will be used is the Custom Vending Machine. Incorporating the basic components of a Vending Machine, such as the product storage area, product dispenser, coin mechanism, and access door, as well as the building components: frame material, product shelves, electrical components, coin mechanisms, and tools, is as important for the researchers to take note of.

CHAPTER III RESEARCH METHODOLOGY

This chapter presents the research design and methodology, which consists of methods on how the data was gathered, the data gathering procedure, and the statistical treatment used to obtain the results needed for the Bill Vending Machine for Chits at Siena College of San Jose Canteen Using Arduino.

Research Method

The researchers used a quantitative research mode for their study. According to Hassan (2023), Quantitative Research is a type of research that collects and analyzes data to test hypothesis and answer research questions. The research aimed to gather data from a product-focused research about the Bill Vending Machine for Chits at Siena College of San Jose Canteen Using Arduino.

Research Design

The research design that the researchers utilized in this study is the Experimental Research Design. According to Hassan (2023), Experimental Research Design studies the relationship between the independent and dependent variables, and observes the effects of manipulating the independent variable to the dependent variable.

This is deemed suitable for the researchers' study due to the manipulation of the Arduino technology that will be incorporated to the Bill Vending Machine for Chits at Siena College of San Jose Canteen Using Arduino. With this, the dependent variable, which is the speed, accuracy, and reliability of the components of the machine, was put into testing through different tests that is used to gather data within the product.

Materials and Equipment

The researchers used the following materials and equipment for the Bill Vending Machine for Chits at Siena College of San Jose Canteen Using Arduino:

Arduino Uno - the main component of the Bill Vending Machine.

Box Nails – a nail with a slim shank, commonly used on lighter pieces of wood (The Editors of Encyclopaedia Britannica, 1998)

C++ Programming Language - the coding language to be used in programming the Bill Vending Machine for Chits

Digital Equipments (Laptop/PC, Type C Cable) - gadgets that will be used to program the software and hardware components of the Bill Vending Machine.

Marine Plywood – made with 5 layers of 100% hardwood veneer, used to build the external of the Bill Vending Machine. (Taylor 2024).

Pioneer Pro Builders Bond Construction Adhesive – one-part mild solvent and rubber-based all-purpose construction adhesive (Pioneer, 2024).

TCS3200 Color Sensor - an arduino module that can detect and differentiate colors. This allows the project to use colors as basis for different reactions or commands for the Bill Vending Machine for Chits.

Prototype

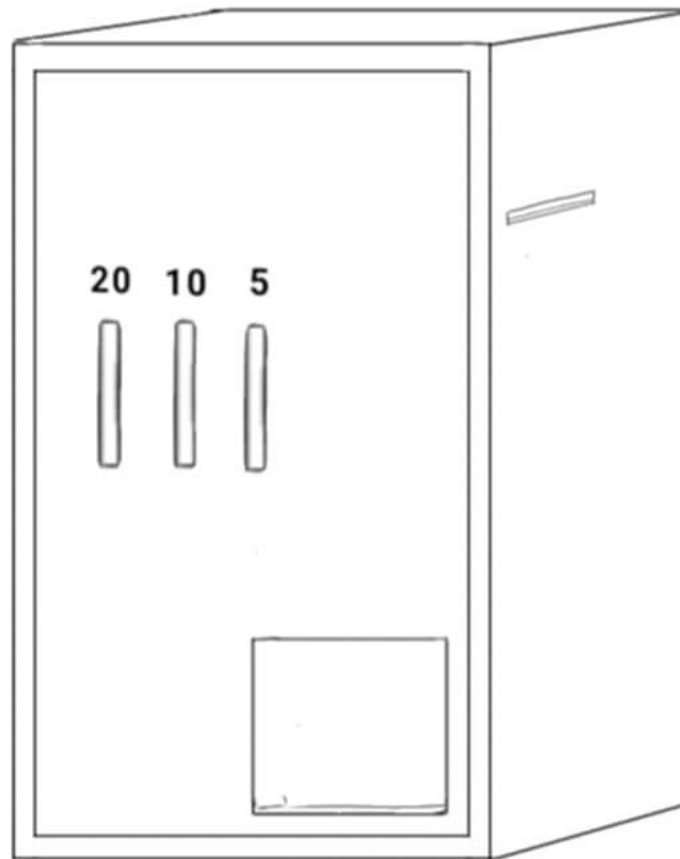


Figure 3. Prototype of the External Bill Vending Machine

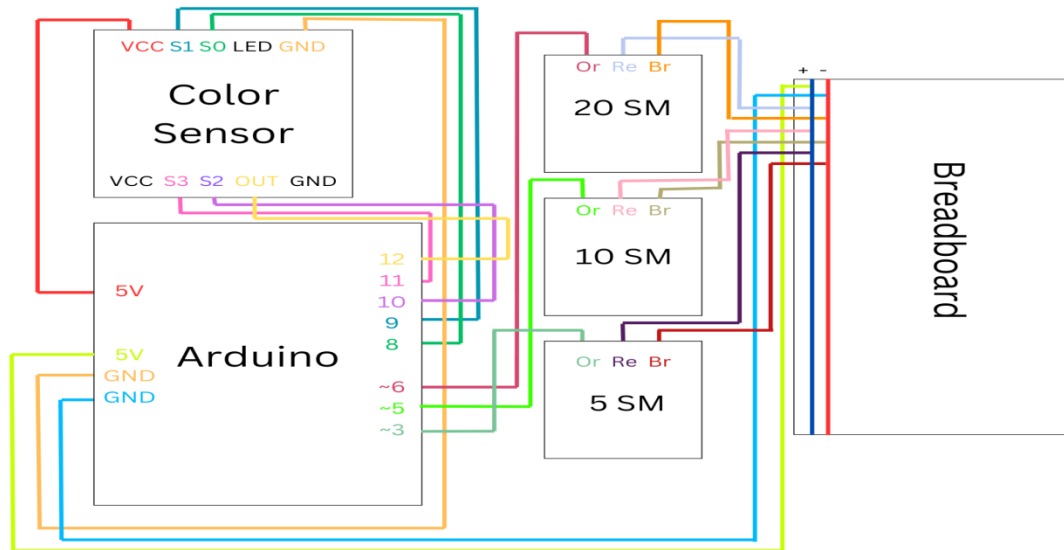


Figure 4. Pinout of the Bill Vending Machine

The illustration above shows the appearance of the product that the researchers of the study envisioned, both the external and the pinout of the Bill Vending Machine. It highlights the important parts of the product. In Figure 3, the illustration portrays the external design of the Bill Vending Machine. In the front lower right, there is an open space wherein the user will receive the chits. The front middle to center shows the internal parts wherein it is specifically shown to let the user see if there is enough chits for a next purchase. In the right of the external design of the Bill Vending Machine, this is where the location of which the bill should be put into in order for the Bill Vending Machine to accept, read, and push the exact amount of chits.

In Figure 4, the illustration portrays the pinout or the visual image of the pins or wires that is used to connect the TCS3200 Color Sensor, Arduino Uno, 3 Servo Motors (indicated as 5, 10, and 20 SM), and Breadboard. The TCS3200 reads the money once it is received by the Bill Vending Machine. Once it encodes the values into the Arduino, the corresponding Servo Motors moves to push the chits in order for the user to receive them.

Research Instrument

To collect the necessary data and information, the researchers conducted several tests and trials that help evaluate the overall machine performance of the Bill Vending Machine. According to Bangayan (2024), test mode for vending machines are important and offer many benefits, such as that it offers valuable insights, and can provide diagnostics or troubleshooting to efficiently identify and fix issues or malfunctions within the mechanism.

Data Gathering Procedure

The following procedure entails the steps that the researchers did to gather data for the research study.

Step 1

Researchers gathered permission from the Computer Lab of Siena College of San Jose with the use of the Arduino and its modules.

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Step 2

After gaining permission, the researchers prepared the materials and equipment, and chose a proper testing environment.

Step 3

The researchers recorded the data provided from the tests: accuracy, servo performance, and error identification.

Step 4

The researchers analyzed the data through statistical methods.

Step 5

The researchers will compare the results with the manual process of exchanging chits.

Step 6

The researchers compiled and summarized the results, including the strengths and weaknesses of the machine's performance.

Treatment of the Data

The following statistical formula is used to interpret and evaluate the Bill Vending Machine for Chits' reliability and overall performance. (Iyer, 2013)

$$R(t) = P(X > t) = 1 - F(t)$$

$R(t)$ = probability that a system will work without failing up to time

$P(X > t)$ = probability that the machine lasts longer than the time t without failing.

$F(t)$ = the probability that the system will fail by time t .

t (Time) = a specific point in time

X = amount of time that passes before the machine fails

Ethical Considerations

The privacy and security of the data used in this study is ensured by the researchers in compliance with the Data Privacy Act of 2012 (RA 10173) (National Privacy Commission, 2022). Unauthorized individuals does not have access to any personal or sensitive information, and is securely protected. The researchers obtained the necessary permissions to use secondary data and honors all copyright and intellectual property rights. Throughout the study, proper



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attribution and citation of sources is maintained. There is no manipulation of the data during analysis and presentation to maintain the integrity of the research. Potential harm or misinterpretation is avoided by carefully considering the impact of the findings. The research process, including data collection and analysis methods, is thoroughly documented to uphold transparency and accountability, ensuring the credibility and reproducibility of the study.

CHAPTER IV PRESENTATION, ANALYSIS, AND INTERPRETATION OF DATA

This chapter includes the presentation, analysis, and interpretation of data collected from the experimentation of Grade 12 STEM Group 5 students enrolled in Siena College of San Jose school year 2024-2025.

The data are presented in tabular forms with corresponding in-depth discussions as answers to the statement of the problem: Utilization of Arduino Technology in creating a reliable and cost-effective vending machine for chits; Key Factors contributing to reliability and efficiency; and the extent of reduction of errors and delays; materials and construction techniques.



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Table 1

Pre-Experiment Phase		
		Data (Yes/No, number)
1.	Objectives	
1.1	Are the research objectives clearly defined? (Yes/No)	Yes
1.2	Are the roles of each component specified? (Yes/No)	Yes
2.	Literature Review	
2.1	Has research been conducted on similar technologies? (Yes/No)	Yes
2.2	Are potential challenges and solutions identified? (Yes/No)	Yes
3.	Materials	
3.1	Are all necessary materials acquired? (Yes/No)	Yes
3.2	Are the components verified for quality? (Yes/No)	No
4.	Design and Assembly	
4.1	Is the prototype designed? (Yes/No)	Yes
4.2	Is the hardware assembled properly? (Yes/No)	Yes
4.3	Are all the wiring connections verified? (Yes/No)	Yes
5.	Code Development	
5.1	Is the code for the color sensor and servo motor written? (Yes/No)	Yes



5.2	Does the code include conditions for detecting specific bills? (Yes/No)	Yes
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As shown in Table 1, the corresponding data are recorded based on the pre-experiment phase of the researchers. The objectives were clearly defined, which was to create a Bill Vending Machine that is reliable and accurate for Siena College of San Jose Canteen. The roles of each component were clearly defined. The TCS3200 Color Sensor detects the colors of each bill inserted and inputs the data into the Arduino. The Arduino Uno therefore analyzes the data and passes it to the corresponding servo motors, which will move according to the amount of chits needed to push out of the machine, in order for the user to receive the chits.

There were a number of similar research conducted with the same technology, such as Yassine (2019), Richard (2024), and Cox (2021). Yassine (2019) used TCS3200 to move multiple servo motors and provided a pin-out chart for the hardware. Richard (2024) experimented with the use of TCS3200 and detecting multiple colors for the Arduino to read and interpret. Lastly, Cox (2021) experimented with the use of multiple servo motors and connecting them to the Arduino Uno and the breadboard, in order for them to be controlled simultaneously. With the experiment, multiple potential challenges and solutions were identified, such as having to detect a similar color between 20 and 50

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Pesos, with a low difference in their red values, which will make it difficult for the TCS3200 to read and differentiate them. The solutions were to make the red values specific, and the green and blue colors to also be verified and read as well.

All necessary materials were acquired both software and hardware. With the cost of almost P1,400.00, the materials for the exterior of the Bill Vending Machine were bought, including the TCS3200 Color Sensor. The rest of the materials were borrowed from the Siena College of San Jose Computer Laboratory. The materials were also verified and tested for quality and none were defective.

The prototype was designed, assembled, and verified according to the literature found in the research by Yassine (2019), Richard (2024), and Cox (2021). The code was also created based on the combination of their research and experimentation, crafted specifically to read different bills that will be inserted in the Bill Vending Machine.

Table 2

Experiment Phase		
		Data (Yes/No, number)
1.	System Calibration	
1.1	Is the color sensor calibrated for detecting 20, 50, and 100 pesos? (Yes/No)	Yes
1.2	Does the servo motor rotate correctly (180 degrees and back)? (Yes/No)	Yes
2.	Trials and Testing	
	Accuracy Trials	
2.1	Number of trials conducted for 20 pesos	75
2.2	Number of successful detections for 20 pesos	45
2.3	Number of trials conducted for 50 pesos	50
2.4	Number of successful detections for 50 pesos	33
2.5	Number of trials conducted for 100 pesos	35
2.6	Number of successful detections 100 pesos	27
3.	Servo Performance	
3.1	Does the servo move only when the correct bill is detected? (Yes/No)	No
3.2	Does the Servo return to its original position after moving? (Yes/No)	Yes
4	Error Identification	
4.1	Were any errors observed during testing? (Yes/No)	Yes
4.2	If yes, number of errors observed: ____	55
5.	Data Collection	
5.1	Time taken to dispense chits (average across trials)	6.5s



5.2	Number of incorrect chit dispensation	55
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As shown in Table 2, the corresponding data were written based on the experiment phase of the researchers. For the system calibration, the TCS3200 Color Sensor was coded, calibrated, and tested to specifically read the 20, 50, and 100 pesos. After reading these, the servo motor would rotate to push the chit according to the amount received by the color sensor, and go back to the previous position in order to push another chit. For the trials and testing, 75 trials were conducted for reading the 20 peso bill, and 45 were successful in reading and pushing the corresponding amount of chits for the user to receive. 50 trials were conducted for reading the 50 peso bill, and 33 were successful. Most of the errors came from the 20 and 50 peso bills, because of the similarity in their red color value. The coding and the TCS3200 Color Sensor were calibrated repeatedly to gain the specific value of the bill, in order to identify if it is a 20 or 50 peso bill. Lastly, with the least amount of errors due to being a high blue color value, there were 35 trials for the 100 peso bill and 27 were correctly read and dispensed.

The servo performance was quick and accurate. Once the TCS3200 color sensor and the Arduino Uno both process the data read, received, and analyzed, the motor would quickly move to push the chits in less than 3 seconds. The servo returns to its original position in order for it to push another chit forward and out.

of the machine. There were a lot of errors observed during the testing, due to the color values, as well as numerous prior testing for each and every component. In total, there were 55 out of 160 trials where errors were observed repeatedly. Lastly, the time taken to dispense the chits on average was 6.5 seconds.

Table 3

Post-Experiment Phase		
		Data (Yes/No, number)
1	Data Analysis	
1.1	Are accuracy and error rates calculated? (Yes/No)	Yes
1.2	Is the system's performance evaluated based on speed, reliability, and accuracy? (Yes/No)	Yes
2	Troubleshooting and Improvements	
2.1	Were identified issues addressed? (Yes/No)	Yes
2.2	Was the system re-tested after adjustments? (Yes/No)	Yes
3	Documentation	
3.1	Is a detailed report written, including objectives, methodology, results, and recommendations? (Yes/No)	Yes
4.	Presentation	
4.1	Are visual aids prepared (diagrams, charts, photos of the prototype)? (Yes/No)	Yes
4.2	Is a presentation summarizing findings created? (Yes/No)	Yes

As shown in Table 3, the corresponding data were written based on the Post-Experiment Phase of the researchers' experiment. The accuracy and reliability of the Bill Vending Machine scale is around 65% and the error rate with 35%. This is calculated according to the number of successful trials and the number of trials with errors. The evaluation of the speed, reliability, and accuracy was also conducted in the previous table, with a specific number of successful trials, the number of errors, and the average time for dispensing chits. The identified issues, specifically the reading of specific colors were addressed. Therefore, the system was re-tested after numerous adjustments to the code and the assembly of wires and components in the hardware of the Bill Vending Machine. There were also issues with the chit system in the interior of the product, which uses a chit container with the use of hard plastic. The size between the floor of the container and the chit container should be measured carefully in order for the chit to be dispensed one at a time. Lastly, the researchers documented and prepared tabular charts, and photos, and wrote a detailed report on the results and recommendations for the Bill Vending Machine for Chits at Siena College of San Jose Canteen using Arduino.

CHAPTER V

SUMMARY OF THE FINDINGS, CONCLUSION AND RECOMMENDATIONS

This chapter presents the summary of the research. It consists of findings from the gathered idea, conclusions that were drawn from the findings, and the recommendations offered by the researchers considering the findings and conclusions.

Summary of the Findings

The findings of the study have been summarized in relation to the statements of the problem outlined in Chapter 1. The statement of the problems that have been addressed and summarized in this study are:

Problem No. 1 How can Arduino Technology be effectively utilized to create a reliable and cost-effective vending machine for dispensing chits?

To effectively utilize Arduino Technology, the researchers first identified the materials and requirements needed to create the vending machine. This includes the TCS3200 Color Sensor, Servo Motors, wires, breadboard, and the Arduino Uno. Second, they gathered information regarding the pinout of the hardware and coding of the software from Yassine (2019), Richard (2024), and Cox (2021). Third, they provided tests and trials to calibrate and check the strengths,

weaknesses, and rooms for improvement. According to the results, 55 out of 160 errors were found. This leaves 105 correct dispenses that resulted, proving that

the reliability is more than 50%, from the tests and trials alone. Lastly, the Arduino Technology used by the researchers only cost about less than P300.00, which is considered a budget price and a cost-effective way of building the vending machine.

Problem No. 2 What are the key factors that will contribute to the reliability and efficiency of the Bill Vending Machine?

One of the major key factors that will contribute to the reliability and efficiency of the Bill Vending Machine is the accuracy of the TCS3200 Color Sensor. The TCS3200 detects the bill inserted in the machine, therefore it plays a major role will reading and analyzing what amount of chits should be dispensed. It also plays a big role that other components, such as the servo motor and the Arduino Uno depend on what the TCS3200 Color Sensor detects, to be able to do their respective actions. Consistent and accurate readings of the TCS3200 Color Sensor minimize the errors and delays of the Bill Vending Machine for Chits.

Another major key factor is the Chit Dispensing Mechanism, wherein the design and functionality of the dispensing mechanism ensures the precise release of the

correct denominations of chits, and also avoids jams or miscounts in dispensing chits. Lastly, another major key factor is testing and optimization. This is the repeated trials to identify issues in order to improve and calibrate. This further

contributes to minimizing inefficiencies and errors made by the Arduino components.

Problem No. 3 To what extent does the vending machine reduce errors and delays associated with the manual exchange of chits in the canteen?

According to the results of the data gathering, 65% from the testing and trials were concluded to have correct denominations, while the remaining 35% is the error rate of the Bill Vending Machine. With a specific number of 160 trials, there were 55 errors, while there were also 105 trials that were correct and were dispensed properly.

Problem No. 4 What materials and construction techniques should be used to ensure the durability of the Bill Vending Machine in a high-traffic school environment?

The materials and construction techniques used in designing the Bill Vending Machine were Marine Plywood, Locks for Security, Compartments for storage of cash and chits, and a Chit Dispensing Mechanism that allows the chits to be

pushed directly to where the user will receive the chits. According to Taylor (2024), Marine Plywood is generally stronger, harder, and has a finer grain than softwood. It can endure a high-traffic environment because it is constructed with at least five thin layers or plies of 100% hardwood veneer. On the other hand,

Francis (2023) stated that it is important to incorporate compartments dedicated to cash, and chits, as well as the Arduino components when constructing a vending machine, so that each is properly organized inside.

Conclusions

In conclusion, the study successfully explored the development of a cost-effective and reliable Bill Vending Machine for Chits at Siena College of San Jose using Arduino. By experimenting with design and testing, the vending machine demonstrated significant potential in reducing errors and delays associated with manual chit exchanges. While the prototype proved to be effective, certain limitations such as durability testing and accuracy of the TCS3200 Color Sensor remain areas for improvement. This research study highlights the importance of using technology in everyday challenges, to provide efficiency and creative innovation in school. The successful implementation of this vending machine could make way for similar advancements in other schools or communities.

Recommendation

After a thorough assessment and analysis of the results and conclusions of the study, the following recommendations are presented:

1. Upgrade the machine to include camera sensors to improve accuracy in reading and recognizing the bills inserted. This can further minimize errors and delays caused by the TCS3200 Color Sensor, due to reading the numbers or recognizing the bill as a whole instead of reading colors that may be similar and difficult to differentiate, such as the 20 and 50-peso bill. Camera Sensors can also recognize the bill designs without requiring too many hardware changes, making it adaptable for future updates.
2. Consider metal components for the construction of the Bill Vending Machine to improve durability, protection, and longevity in a high-traffic environment. This can be stainless steel or aluminum. Budgeting may be required to acquire this material and also makes the machine heavier, therefore the machine will need additional support for placement and transport.
3. To enhance user experience and clear communication, the researchers recommend LED lights or seven-segment displays in the vending machine. These can provide feedback to the user on how much money is being detected and processed.



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4. To improve the reliability and efficiency of the chit-dispensing process, it is also recommended by the researchers to upgrade the chit-dispensing mechanism or the design wherein the chit is transported from inside to outside of the vending machine. This may include anti-jam features, which will minimize friction and prevent chits from sticking and not being able to smoothly move from their original containers to the dispensing areas.

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APPENDICES

Appendix 1: Checklist

Title: Bill Vending Machine for Chits at Siena College of San Jose Inc. using Arduino

Pre-Experiment Phase		
		Data (Yes/No, number)
1.	Objectives	
1.1	Are the research objectives clearly defined? (Yes/No)	Yes
1.2	Are the roles of each component specified? (Yes/No)	Yes
2.	Literature Review	
2.1	Has research been conducted on similar technologies? (Yes/No)	Yes
2.2	Are potential challenges and solutions identified? (Yes/No)	Yes
3.	Materials	
3.1	Are all necessary materials acquired? (Yes/No)	Yes
3.2	Are the components verified for quality? (Yes/No)	No
4.	Design and Assembly	
4.1	Is the prototype designed? (Yes/No)	Yes
4.2	Is the hardware assembled properly? (Yes/No)	Yes
4.3	Are all the wiring connections verified? (Yes/No)	Yes
5.	Code Development	



5.1	Is the code for the color sensor and servo motor written? (Yes/No)	Yes
5.2	Does the code include conditions for detecting specific bills? (Yes/No)	Yes

Experiment Phase		
		Data (Yes/No, number)
1.	System Callibration	
1.1	Is the color sensor calibrated for detecting 20, 50, and 100 pesos? (Yes/No)	Yes
1.2	Does the servo motor rotate correctly (180 degrees and back)? (Yes/No)	Yes
2.	Trials and Testing	
	Accuracy Trials	
2.1	Number of trials conducted for 20 pesos	75
2.2	Number of successful detections for 20 pesos	45
2.3	Number of trials conducted for 50 pesos	50
2.4	Number of successful detections for 50 pesos	33
2.5	Number of trials conducted for 100 pesos	35
2.6	Number of successful detections 100 pesos	27
3.	Servo Performance	
3.1	Does the servo move only when the correct bill is detected? (Yes/No)	No
3.2	Does the Servo return to its original position after moving? (Yes/No)	Yes



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4	Error Identification	
4.1	Were any errors observed during testing? (Yes/No)	Yes
4.2	If yes, number of errors observed: ____	55
5.	Data Collection	
5.1	Time taken to dispense chits (average across trials)	6.5s
5.2	Number of incorrect chit dispensation	55

Post-Experiment Phase		
		Data (Yes/No, number)
1	Data Analysis	
1.1	Are accuracy and error rates calculated? (Yes/No)	Yes
1.2	Is the system's performance evaluated based on speed, reliability, and accuracy? (Yes/No)	Yes
2	Troubleshooting and Improvements	
2.1	Were identified issues addressed? (Yes/No)	Yes
2.2	Was the system re-tested after adjustments? (Yes/No)	Yes
3	Documentation	
3.1	Is a detailed report written, including objectives, methodology, results, and recommendations? (Yes/No)	Yes
4.	Presentation	
4.1	Are visual aids prepared (diagrams, charts, photos of the prototype)? (Yes/No)	Yes
4.2	Is a presentation summarizing findings created? (Yes/No)	Yes



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Appendix 2: Letter to the School Administrators



November 04, 2024

Sr. Mercedes R. Lalisan, OP
President/Principal
Siena College of San Jose Inc.

Dear Sr. Ched,

Mabuhay, and blessed be God forever!

We, the Grade 12 students, are requesting permission to conduct our experiments in the wet laboratory starting today and on the succeeding days. Our research activities will involve practical applications that require the resources and environment provided by the laboratory.

Moreover, We are also asking your permission to allow us to conduct our experiment outside school after classes and during weekends. Rest assured that all the members' parents are well-informed and have granted us permission to conduct the experiment, and we understand that the school is not liable for any loss, damages, and incidents during the experimentation outside.

We assure you that all experiments will be conducted under strict adherence to safety guidelines, and we will maintain orderly at all times. We seek your guidance on any additional safety or operational protocols we should follow.

Your support in allowing us access to the laboratory is greatly appreciated as it will significantly aid in the completion of our practical research requirements.

We are hoping for your positive response. Thank you and may God bless us all.

Sincerely yours,

Paquito B. Beldia III
STEM Vice-Mayor

Maria Avila B. Principe
HUMSS Mayor

Jenia Emmanuelle H. Malinao
ABM Mayor

Noted by

Mr. Jhonel A. Tizon
Research Coordinator

Recommended:

Mr. Ryan Jeffrey M. Garcia
Assistant Principal

Approved:

Sr. Mercedes R. Lalisan, OP
President/Principal

- However pls follow guideline.
- ① No teacher around, no lab allowed.
 - ② If after classes - up to 4:30pm only
 - ③ Not allowed on weekends if there is no teacher who will supervise
 - ④ Attach name of student to use the lab
 - ⑤ Always contact Mrs. Escalante whenever you need to use the lab.



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November 5, 2024

Mr. Herwin J. Menor
Computer Lab In-Charge
Siena College of San Jose Inc.

Dear Mr. Menor,

Good day, Mabuhay and Blessed be God Forever!

We are researchers from Grade 12 STEM, Group 5, seeking permission to have access to Computer Laboratory and use the Arduino kit for our research study. We will use the Computer Laboratory from November to December during our free class periods or during our practical research subject hours. You can rest assured as we will take care of the equipment we will use during our study.

We promise to take all responsibility with the materials that we will be using. We will also take note of the class hours of when the Arduino Kit will be required and will not conduct experiments during those time.

We are hoping for your favorable response. Thank you very much and may God bless us all!

Sincerely,

Nicole Elmedorial
Group Leader

Noted by

Mr. Jhannel Tizon
Subject Teacher

Approved by

Mr. Herwin J. Menor
Computer Lab In-Charge



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Appendix 3: Turnitin Report

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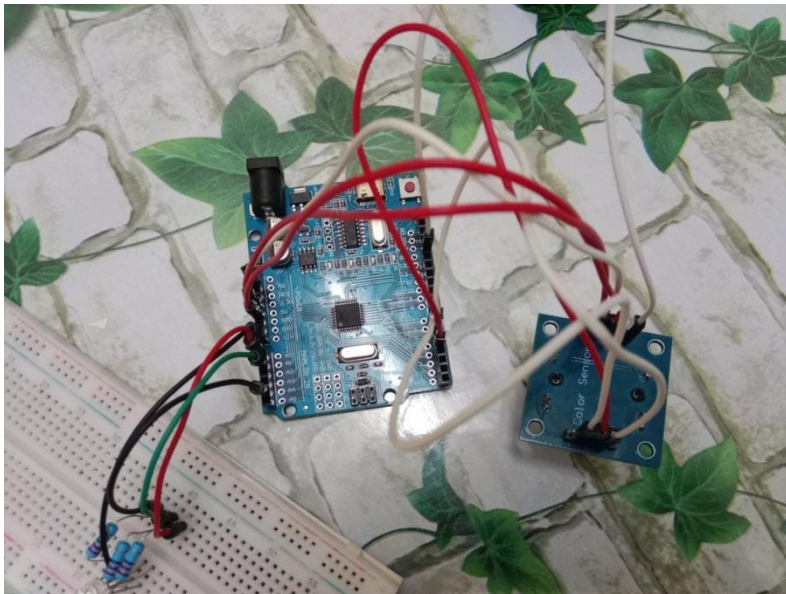
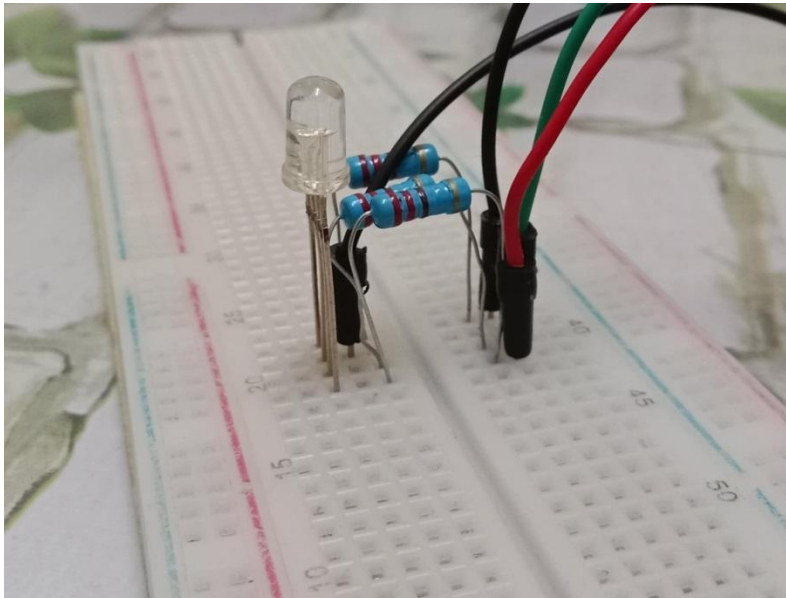
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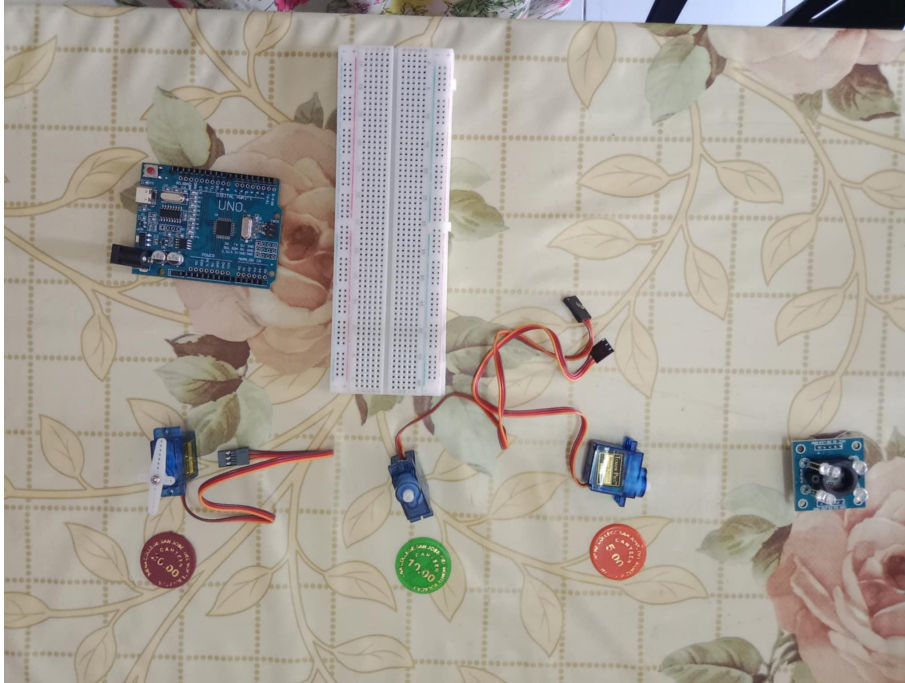
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Appendix 4: Documentation

a. Materials







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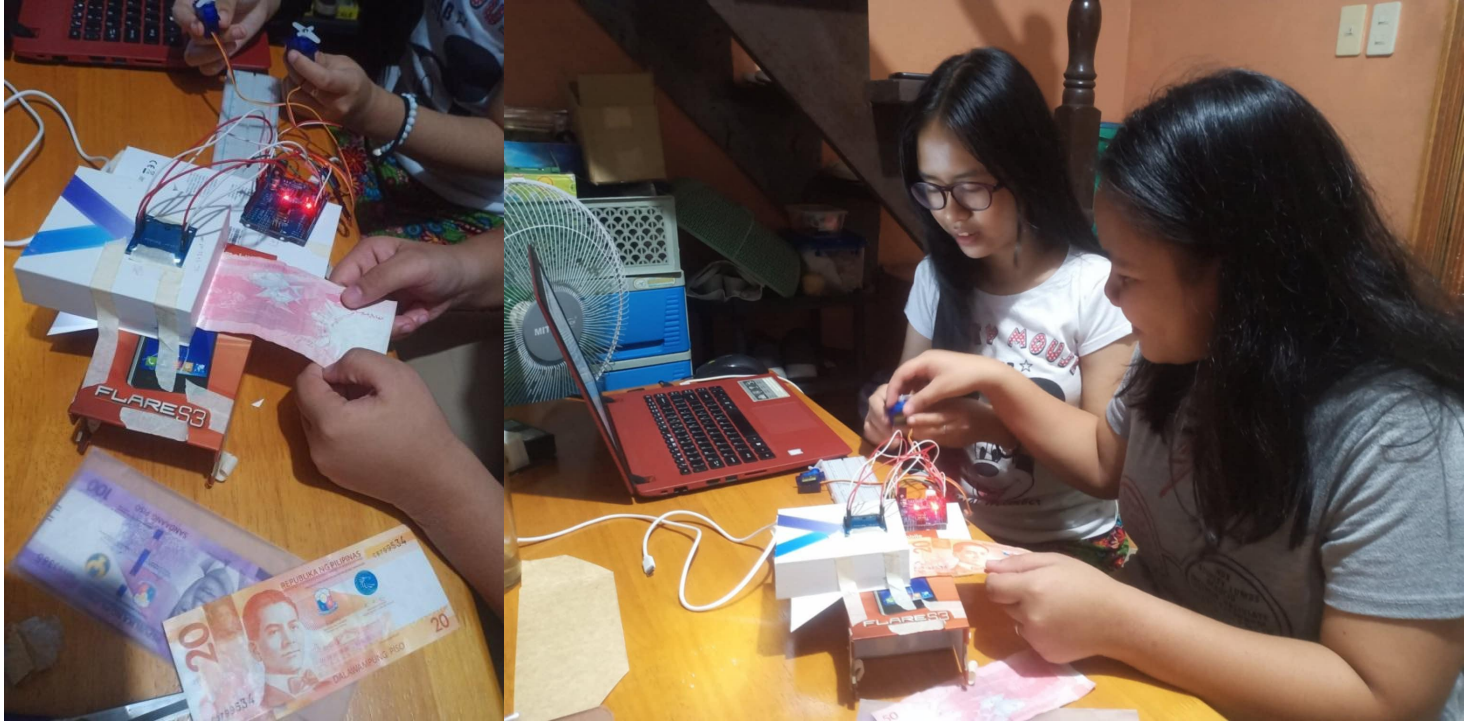
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b. Exterior of the Bill Vending Machine Making



c. Testing and Trials





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Appendix 5: Code for the Arduino Technology Software using Arduino IDE

```
#include<Servo.h>
Servo sm20;
Servo sm10;
Servo sm5;

#define s0 8 //Module pins wiring
#define s1 9
#define s2 10
#define s3 11
#define out 12
#define sm20Pin 6
#define sm10Pin 5
#define sm5Pin 3

int Red=0, Blue=0, Green=0; //RGB values

void setup()
{
  pinMode(s0,OUTPUT); //pin modes
  pinMode(s1,OUTPUT);
  pinMode(s2,OUTPUT);
  pinMode(s3,OUTPUT);
  pinMode(out,INPUT);

  Serial.begin(9600); //intialize the serial monitor baud rate

  digitalWrite(s0,HIGH); //Putting S0/S1 on HIGH/HIGH levels means the
  output frequency scalling is at 100% (recommended)
  digitalWrite(s1,HIGH); //LOW/LOW is off HIGH/LOW is 20% and LOW/HIGH is 2%

  sm20.attach(sm20Pin);
  sm20.write(0);
  sm10.attach(sm10Pin);
  sm10.write(0);
  sm5.attach(sm5Pin);
  sm5.write(0);
}

void loop(){
```



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```
GetColors(); //Execute the GetColors function to get the value of each RGB  
color
```

```
//Depending of the RGB values given by the sensor we can define the color  
and displays it on the monitor
```

```
if (Red <=7 && Green <=7 && Blue <=7) //no money  
Serial.println("No money");
```

```
if (Red>=7 && Red<=8 && Green <=11 && Green >=10 && Blue>=9 && Blue<=12)  
//20 pesos
```

```
{  
Serial.println("20 pesos");  
sm5.write(0);  
delay(1000);  
sm5.write(180);  
delay(1000);  
sm5.write(0);  
delay(1000);  
sm5.write(180);  
delay(1000);  
sm5.write(0);  
delay(1000);  
sm5.write(180);  
delay(1000);  
sm5.write(0);  
delay(1000);  
sm5.write(180);  
delay(1000);  
sm5.write(0);  
}  
}
```

```
if (Red>=10 && Red<=11 && Green <=13 && Green >=11 && Blue>=9 && Blue<=11)  
//100 pesos
```

```
{  
Serial.println("100 pesos");  
sm20.write(0);  
delay(1000);  
sm20.write(180);  
delay(1000);  
sm20.write(0);  
sm20.write(0);  
delay(1000);  
sm20.write(180);  
delay(1000);  
}
```



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```
sm20.write(0);
delay(1000);
sm20.write(180);
delay(1000);
sm20.write(0);
delay(1000);
sm20.write(180);
delay(1000);
sm20.write(0);
delay(1000);
sm20.write(180);
delay(1000);
sm20.write(0);

else
Serial.println("Unknown"); //if the color is not recognized, you can add
as many as you want

if (Red>=7 && Red<=8 && Green <=14 && Green >=12 && Blue>=10 && Blue<=12)
//50 pesos
{
Serial.println("50 pesos");
sm20.write(0);
delay(1000);
sm20.write(180);
delay(1000);
sm20.write(0);
delay(1000);
sm20.write(180);
delay(1000);
sm20.write(0);
delay(1000);
sm10.write(0);
delay(1000);
sm10.write(180);
delay(1000);
sm10.write(0);

}

delay(3000); //2s delay you can modify if you want
```



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}

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```
void GetColors()
{
    digitalWrite(s2, LOW); //S2/S3 levels define which set of photodiodes we
    are using LOW/LOW is for RED LOW/HIGH is for Blue and HIGH/HIGH is for
    green
    digitalWrite(s3, LOW);
    Red = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH); //here we wait
    until "out" go LOW, we start measuring the duration and stops when "out"
    is HIGH again, if you have trouble with this expression check the bottom
    of the code
    delay(20);
    digitalWrite(s3, HIGH); //Here we select the other color (set of
    photodiodes) and measure the other colors value using the same technique
    Blue = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH);
    delay(20);
    digitalWrite(s2, HIGH);
    Green = pulseIn(out, digitalRead(out) == HIGH ? LOW : HIGH);
    delay(20);
}
```



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