GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

GSJ: Volume 12, Issue 2, February 2024, Online: ISSN 2320-9186
www.globalscientificjournal.com

DEVELOPMENT AND EVALUATION OF MODERNIZED BINBOT OF EXPIRED AND UNUSED MEDICINES USING ARDUINO UNO

Shahadi Alaina D. Amoran, Annie Grace L. Escaño, Jenefer S. Fabular,Kimberly Jean B. Surmion, RPh, MSPharm, Erwin M. Faller, RPh, MSPharm, PhD, MMPS, FRIPharm
Department of Pharmacy, St. Alexius College, Koronadal City, South Cotabato

KeyWords
Modernized Binbot, Automated system, Expired medicines, Inventory management, Arduino uno, Disposal practices

ABSTRACT

Introduction: The escalating problem of pharmaceutical waste is a matter of mounting concern on a global scale. This issue has been steadily gaining prominence and is now recognized as a significant challenge that spans across borders, impacting communities and ecosystems worldwide. This study addresses this gap by introducing a novel approach—a modernized Binbot using Arduino Uno—to autonomously identify and sort expired and unused solid medicines (capsules, tablets), enhancing pharmacists' workflow. **Method:** This study utilized a mixed-method approach through purposive sampling technique among community pharmacists from five (5) chosen barangays of Koronadal City, South Cotabato. Qualitative data were collected through in-depth interviews and key informant interviews (KII) involving ten (10) participants. Thematic analysis was applied to these qualitative responses to gain insights into the design and development of the Binbot prototype, which four themes emerged. Concurrently, the same participants were surveyed using questionnaires based on the Binbot's user manual, the System Usability Scale (SUS), and the Post-Study System Usability Questionnaire (PSSUQ). Descriptive statistics were used to analyze the quantitative data. **Results:** The study's findings revealed participants' high enthusiasm for the modernized Binbot, recognizing its potential to improve operational efficiency, system functionality, inventory management, and medication identification. Based on the results in the evaluation, the prototype showed a very high level of accuracy in terms of withdrawal verification system (4.44), accurate counting system for pulled–out medicine cap/tab (4.52), efficient inventory management system (4.62), and sorting expired medicines (4.64).**Conclusion:** Overall, these findings underscore the transformative potential of modernized Binbot in improving accuracy, efficiency, and safety in healthcare and pharmacy settings.

INTRODUCTION

Pharmaceutical waste is an escalating global concern with far-reaching implications. Defined as drugs that are no longer suitable for use due to expiration, disuse, spillage, recall, damage, contamination, or other reasons. Such waste is most commonly disposed of in the different countries surveyed (between 63% and 79%) and Disposing of pharmaceuticals into the sewage system is the second-most common practice in some countries (between 5% and 26%). Very few consumers return unused pharmaceuticals to the pharmacy (AlAzmiet. al., 2017; Bound et al., 2006; Fenech et. al., 2013). According to the World Health Organization, the vast majority (85%) of waste generated by healthcare activities falls under the category of general, non-hazardous waste, similar to household waste. The

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

remaining small portion (15%) is deemed hazardous and may pose risks such as being infectious, chemical, or radioactive.

Meanwhile, over 75% of unused and expired medicine is disposed of through the normal waste bins which end up in landfills or dump sites. Previously, pharmaceuticals, both expired and unused, were disposed of by flushing them down toilets or pouring them down sink or floor drains, which was a method that went into the sewer lines. However, this practice has been made illegal by the Environmental Protection Agency (EPA) in 2019. Based on the study by Michael et al.(2019), a concerning majority (54.5%) of participants failed to follow guidelines for disposing of expired drugs. On the other hand, only 23.4% of respondents fully complied with these guidelines, while 22.1% only partially followed them. The issue of pharmaceutical waste becomes worse by the limited options to medication disposal (Ampadu et al., 2021). In some areas, the lack of convenient and easily accessible disposal methods for expired or unused medications can result in individuals keeping these drugs for longer or disposing of them inappropriately. Moreover, It not only contaminates water sources, jeopardizing human health and ecosystems, but it can also contribute to medication misuse, with potentially dire consequences, especially among vulnerable groups like pregnant women, newborns, and children.

In the field of pharmaceutical science and technology, the researchers' study holds a distinctive position as they delve into the development and evaluation of a modernized binbot specifically designed for the management of expired and unused medicines, utilizing Arduino Uno technology. While the field of pharmaceutical science and technology has seen extensive research in drug development and clinical trials, the systematic disposal of such medications remains overlooked. Conventional pharmaceutical waste disposal methods often lack efficiency and environmental awareness, posing risks to ecology and health.

This study addresses this gap by introducing a novel approach—a modernized Binbot using Arduino Uno—to autonomously identify and sort expired and unused solid medicines (capsules, tablets). This merging of pharmaceutical expertise with advanced engineering offers a pioneering solution that aligns with sustainable healthcare practices. This research not only enhances pharmaceutical waste management but also contributes to the larger discussion of the intersection between pharmaceutical sciences and innovative technologies.

METHODS

Study Design

This study addresses this gap by introducing a novel approach—a modernized Binbot using Arduino Uno—to autonomously identify and sort expired and unused solid medicines (capsules, tablets). This merging of pharmaceutical expertise with advanced engineering offers a pioneering solution that aligns with sustainable healthcare practices. This research not only enhances pharmaceutical waste management but also contributes to the larger discussion of the intersection between pharmaceutical sciences and innovative technologies.

The researcher adopted a mixed-method approach, specifically an exploratory sequential approach, as outlined by Johnson et al. (2007). The qualitative phase involved the examination of a modernized Binbot for the disposal of expired and unused medicines, utilizing open-ended questionnaires and key informant interviews with community pharmacists. This phase aimed to gather detailed insights and recommendations from the participants regarding the prototype. Subsequently, the study transitioned to the quantitative evaluation phase, employing a five-point Likert scale for statistical analysis and generalizability. Respondents expressed their agreement or disagreement with statements derived from various sources, including the Binbot user's manual, the System Usability Scale (SUS), and the Post-Study System Usability Questionnaire (PSSUQ). These sources are well-established tools for assessing the usability and user experience of systems or products.

Population and SamplingTechnique

The researchers used purposive sampling in conducting the study. While there were a total of 85 pharmacy establishments in Koronadal City, South Cotabato, as of 2023, the researchers intentionally selected ten (10) participants who were either readily accessible or willing to participate in the study, and initiated the participant selection process with predefined characteristics aligned with their inclusion and exclusion criteria.

The researchers established specific requirements for the inclusion criteria for participants. Firstly, they had to be licensed community pharmacists practicing in their respective jurisdictions. Additionally, their age had to fall within the range of 18 to 40 years old. Moreover, they needed to have experience in dispensing or advising on the disposal of expired or unused medicines. Lastly, it was necessary for the community pharmacists to willingly and knowingly consent to participate in the study.

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

Exclusion criteria were applied to select appropriate subjects for the study. Community pharmacists currently involved in another research study were excluded, as well as those below 18 years old or over 45 years old. Pharmacists with a known allergy or sensitivity to any components of the automated waste disposal system were also excluded. In addition, pharmacists who did not regularly handle the dispensing and disposal of expired or unused medicines were excluded. Finally, individuals who were unable or unwilling to dedicate the necessary time and resources needed for participation in the study were also excluded.

Research Instrument

Two integral components were employed, open-ended questions for qualitative phase and Likert scale for the quantitative phase. Throughout the qualitative phase, participantswere engaged through open-ended questions in conjunction with key informant interviews (KIIs).The application of open-ended questions afforded participants the opportunity to articulate their thoughts, ideas, and opinions freely, particularly concerning the design and implementation of the modernized Binbot aimed at addressing challenges related to the disposal of expired and unused medicines. The responses were meticulously captured thrivoice recordings on researchers' mobile devices to ensure accuracy.

In the quantitative phase, participants were tasked with responding to a 20-item questionnaire categorized into four main topics. The objective was to assess their evaluation of the modernized Binbot. Respondents utilized a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree), to express their levels of agreement with each statement.

Data Collection

The researchers conducted a comprehensive three-phase study to enhance pharmaceutical services in Koronadal City, South Cotabato. In Phase I, they secured clearances, obtained permissions, and collaborated with community pharmacies and St. Alexius College's Pharmacy Department. Upholding participant rights, they ensured informed consent and distributed questionnaires during surveys. Phase II focused on product development, where the team, including an engineer, acquired necessary materials, assembled components, and programmed the modernized Binbot. Thorough testing, adjustments, and validations were carried out, culminating in a functional prototype. To assess effectiveness, a custom questionnaire was validated by experts and presented to participants through a video demonstration to protect the equipment. Phase III centered on evaluation, utilizing a survey questionnaire to gather insights from respondents about the prototype's effectiveness in addressing challenges related to the disposal of expired and unused medicine. The findings guided informed decisions for the future development and implementation of the modernized Binbot.

Data Analysis

The qualitative phase employed thematic analysis, utilizing Braun and Clarke's (2006) method to explore participant responses on the modernized Binbot's design. Emphasizing diverse viewpoints, the process involved data familiarization, initial code generation, theme identification, and refinement based on community pharmacists' suggestions. In the quantitative phase, demographic variables and Binbot effectiveness were assessed using descriptive statistics and a Likert scale, with mean and standard deviation interpreted in accordance withManyange et al. (2015).

RESULTS AND DISCUSSION

A. Profile of the Participants

TABLE 1.1 PROFILE OF THE RESPONDENTS (n = 10)

Age of Respondents	Frequency	Percentage (%) Distribution
1= 25-35 years	8	80.0
2= 36-45 years	2	20.0
3= 46-55 years	0	0.0
4= Over 55 years	0	0.0
Years of Practice		
1= Less than 1 year	0	0.0
2= 1-2 years	1	10.0

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

3= 3-5 years	4	40.0
4= 6-10 years	2	20.0
5= more than 10 years	3	30.0

Table 1.1 revealed the demographic profile of the 10 respondents who were asked to participate in answering the key informant interview guide to better understand their knowledge in terms of proper disposing of expired and unused medicines. The demographic characteristics of the respondents indicated that the majority (80.0%) of community pharmacists were within the age range of 25 – 35 years old (Table 1).

Individuals within this range were more inclined to engage in studies due to their technological familiarity, environmental concern, health awareness, and interest in innovative solutions for healthcare waste management. The table also indicated the various duration of pharmacy practice among the respondents, which are: 40.0% have practiced between 3 – 5 years, 30.0% have practiced more than 10 years, 20.0% have practiced between 6 – 10 years, and 10.0% have practiced between 1 – 2 years.

B. **Level of Knowledge of Community Pharmacists in Disposal Methods of Expired and Unused Medicines**

TABLE 1.2 LEVEL OF KNOWLEDGE OF COMMUNITY PHARMACISTS IN DISPOSAL METHODS OF EXPIRED AND UNUSED MEDICINES

A. Disposal methods	**Responses**	
	f	**%**
Knowledge on Disposal of Expired Medicine	7	70.0
Patients Education on Disposal of Expired Medicine	0	0.00
B. Types of Disposal Methods (Solids)		
Return Policy	4	40.0
Monitoring	2	20.0
Segregation	4	40.0
C. Types of Disposal Methods (Liquids)		
Return Policy	6	60.0
Monitoring	0	0.0
Segregation	4	40.0
D. Disposal of Unused Medicines		
Return Policy	4	40.0
Monitoring	2	20.0
Segregation	4	40.0
E. Types of Disposal Methods (Semi-Liquids)		
Return Policy	3	30.0

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

Monitoring	3	30.0
Segregation	4	40.0
F. Storage of Expired and Unused Medicines		
3 months before expiry	4	40.0
2 months before expiry	3	30.0
Within the month of expiry	1	10.0
4 months before expiry	2	20.0
G. Should drug wholesalers or distributors take the initiative to collect their expired products?		
Yes	8	80.0
No	2	20.0
H. How do community pharmacists ensure the proper separation and storage of expired drugs?		
FIFO	1	10.0
Storage Box should be made available	9	90.0

Table 1.2 illustrated the level of knowledge among community pharmacists regarding the disposal methods of expired and unused medicines within the community pharmacy. The survey results revealed that 70.0% of community pharmacists demonstrated knowledge about proper methods for handling expired medicines. However, when it came to patient education on the disposal of expired medicines, the survey indicated a concerning 0.0%, suggesting that patients did not receive information on the correct disposal of expired and unused medicines.

In terms of specific disposal methods for solid dosage forms, community pharmacists reported using the following approaches: return policy with the supplier, proper segregation (40.0%), and rigid in-house monitoring (20.0%). For liquid dosage forms, the methods employed were return policy with the supplier (60.0%) and proper segregation (40.0%). Semi-liquid dosage forms were typically managed through proper segregation (40.0%), return policy with the supplier (30.0%), and rigid in-house monitoring (30.0%).

Regarding the timing of disposal, it was found that the majority (40.0%) of community pharmacists begin disposing of expired and unused medicines three months before their expiry date. Around 30.0% begin disposal two months before expiry, while a smaller portion (20.0%) start disposing of medications four months in advance. Only 10.0% of respondents reported discarding medicines within the month of their expiry. Furthermore, the responsibility for expired product collection, opinions varied. Some pharmacists (80.0%) believed that wholesalers or distributors should establish mechanisms for collecting expired products, potentially reducing the occurrence of medicines expiring within community pharmacies. Conversely, 20.0% of respondents disagreed with this proposition.

B. Thematic Analysis

Table 1.3. Suggestion of the Participants on the Design and Development of Modernized Binbot

Essential Themes	Core Ideas
Operational Efficiency	Increase efficiency and ease in the workflow Make work easier and more efficient Make monitoring faster
Robust System Functionality	High level of accuracy 100 percent performance Efficient inventory

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

	User-friendly accessibility features
Inventory Management	Automated sorting of expired medications Provide precise identification of expired items Notify of approaching product expirations Facilitate efficient management and disposal of expired medications
Medication Identification	Identification of medications

Participants were asked to share as widely as possible about their suggestions on the design and features for the development of modernized Binbot of expired and unused medicines. From the various themes that were developed, the researchers chose the significant and prominent ones that align with the study's problem statement.

C.1. Operational Efficiency

Workload overload can result in poor performance, increased errors, and employee burnout. Traditional systems frequently rely on manual labor, subjecting employees to repeated and labor-intensive tasks that may reduce productivity and overall organizational effectiveness (Nahrgang*et al*., 2020).

Pharmacy that integratedBinBot into their operations can use its capabilities to streamline processes, increase productivity, and gain a substantial competitive advantage.

The following statements were divided into sub-themes that aligned with the theme. These sub-themes identified the participant's insights about the efficiency of the modernized Binbot in improving the workload of the community pharmacists.

C.1.1. Improve Operational Efficiency

Some of the participants stated their insights regarding the potential impact of the product on workflow efficiency. Some of the participants expressed their beliefs that the proposed product would significantly ease the workflow. They highlighted the challenges they currently face, such as manual data input.

"Well, if your Binbot is successful, I assume that it would make our work-flow easier. It would make our disposal or keeping of the expired medications more easily. It would be less hassle. Because, currently it's manual. So, what we do, we write the details, then the supplier, dates of expiry, how many pieces. So, if you have the binbot, since it's technology-based, perhaps it will be easier because you will just encode." - ***P2***

Participant 2 reported that if the proposed Binbot, designed for managing expired medications, was successfully implemented, it would have a positive impact on their workflow. The participant 2 anticipated that the Binbot would make the storage of expired medications easier and less of a hassle compared to the current manual process. Furthermore, P7 and P8 resembled to the statement of P2.

"The work flow will become easier. Also, the expiry here is manual, we write it down. It's not automated." - ***P7***

"For me, if this Binbot exists, maybe it will make the life of any pharmacist easier." - ***P8***

According to Afolabi and Oyebisi (2007), the automation attempts to increase staff productivity and allow pharmacists to focus on providing pharmaceutical treatment by replacing several repetitive and labor-intensive operations now performed by pharmacy professionals. The workload on pharmacy workers greatly decreased by introducing automation technology such as robotics or advanced software systems. This not only streamlines processes but also allows pharmacists to devote more time and attention to patient care, thereby boosting the quality of pharmaceutical services given. Thus, automation is being investigated as a technique of improving operational efficiency (Tan *et al.,* 2009).

C.1.2. Creates Work Efficiency

One of the participants expressed that the Binbot has the potential to reduce the workload and provide a hassle-free experience for pharmacy assistants (PA's).

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

"It will make the work of [any] PA easier. [As you may know] in pharmacies, work is assigned or designated. So if [your project is] approved, it would mean lesser work and hassle-free for the PAs." - ***P5***

The participant believed that approving the project would greatly improve the work of pharmacy assistants (PAs). It would reduce their workload, simplify tasks, enhance efficiency, and eliminate potential challenges, resulting in a hassle-free experience for PAs. The study finding demonstrated by Perinni,*et al.,*(2017) that automated management system offered the potential to achieve a combination of increased efficiency and reduced risk of errors within the pharmacy setting.

Pharmacists can benefit from a detailed understanding of the available systems, as it enables them to make informed decisions and select a system that best meets their specific needs. With the implementation of an automated system in the pharmacy, productivity increased and pharmacists were able to complete fewer technical tasks (Angelo *et al.,* 2005).

C.2. Robust System Functionality

In any system, whether it is a technological system, organizational infrastructure, or operational process, robust functionality is essential for ensuring successful operation and desired outcome. A robust system is one that can consistently, efficiently, and accurately perform its intended functions, even in difficult or complex circumstances.

The following statements were divided into sub-themes that align with the theme. These sub-themes will identify the participants' responses for the overall functionality of the modernized Binbot.

C.2.1. Robust System Functionality

Several participants shared their thoughts regarding the accuracy and performance of the proposed Binbot. Their responses emphasized the importance of accuracy, performance, ease of use, and adaptability to unfamiliar technology.

"On its accuracy, it will be using a barcode." – **P1**

Participant 1 highlighted the use of barcodes as a means to ensure accuracy in the Binbot system. This indicated their expectation for reliable identification and tracking of items within the system. Furthermore, using a barcode can help improve accuracy in several ways. For example, bar-coding technology, which had an error rate of about 1 in 10 million, shows significant potential in reducing medication errors (Cina*et al.,* 2006). Successful technologies have the ability to minimize human error by automating tasks that require high levels of accuracy and repetition (Kuiper *et al.,* 2007). However, considering the novelty of this technology, P2 acknowledged the possibility of initial flaws but expressed optimism for improvements over time:

"In terms of speed, reliability, and accuracies, since it's the first time, there would be flaws. As we go along, as we use the product, we can still change it." - **P2**

In addition, another participant stressed their expectation for the Binbot to perform swiftly and accurately, ensuring efficient daily operations. Specifically, they highlighted the importance of the Binbot's ability to locate near-expiry stocks with precision.

"It should be fast [for] everyday [use] so that it's easier to locate the near expiry stocks. It should also be accurate." – **P10**

Moreover, P5 provided insights into the desired performance level, stating,

"With respect to performance, it's better if on the scale of 1-10 [10 being the highest], the level is 8. It depends on the Binbot's performance." – **P5**

With this, the participants' desires for a system with great accuracy and efficiency, as well as a performance rating near to the top level, which was similar to the statement of P8 who expressed a strong expectation for the Binbot to deliver 100 percent performance.

"So, if in case the Binbot is here, it should be 100 percent." – **P8**

Participant 9, on the other hand, expressed its expectation that the system should be intuitive and easy to adapt to, considering their prior experience with manual systems.

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

"We're used to manual [system] here, so my expectation is that it would be easier for us once we use the Binbot. But since we have no prior experience, I'm sure there'd be adjustment in learning how to use it." – P9

In a study conducted by Kumaret al., (2016), it was demonstrated that a system did not need to be excessively technologically complex. Instead, it should prioritize user-friendliness to ensure proper utilization. While technological advancements can be advantageous, it is crucial to also consider the user experience and usability of the system. If a system is overly complicated or difficult for users to use and understand, its efficacy and adoption may suffer.

Correspondingly, participant 6 mentioned the desire for a high level of accuracy.

"Maybe 99% in accuracy. We don't know [yet if it will perform well], but we'll still double check it." – P6

This understanding of the significance of accuracy demonstrates the participants' awareness of the importance of verification methods to ensure the dependability of the Binbot system. It suggested that the participants were willing to implement additional quality control methods to uphold and preserve accuracy within the system. Their willingness to engage in such measures highlights their commitment to ensuring a reliable and robust system functionality.

C.2.2. Efficient and Accurate Data Entry

Some participants stated a desire to use automated scanning and barcode technologies to improve data entry efficiency and accuracy. They believed that by integrating automated scanning and barcode systems, data input procedures can be simplified, minimizing the risk of errors and improving overall accuracy.

"Level of automation? What do you mean? With respect to our inventory [system], it is still manual so it's not that accurate. But with the [automated] system, the result of the inventory would be more accurate. Thus, it will be faster and the accuracy [is better]." ***– P7***

"Of course, for faster monitoring it should be the automated scanning. It would lessen human error too." - ***P10***

Respondents 7 and 10 expressed the potential for significantly improved accuracy by implementing an automated system. They believed that automating the inventory process would not only enhance accuracy but also expedite monitoring. Similarly, Banjar et al. (2022) discovered that several software programs have emerged to streamline medicine disposal management.

Additionally, one of participants specifically highlighted the preference for utilizing barcode technology for automated scanning.

"If it will be using a barcode, it can be automated. That makes it more easier."-P1

P1 stated that utilizing barcodes would enable automation, making the process easier.

According to Boyd & Chaffee (2019), there was compelling evidence that supported the benefits of using barcode technology in pharmacy settings. In hospitals, barcodes have been used to code supplies such as blood containers, roentgenogram jackets, medical records, and capital equipment. They have the potential to manage inventory, ensure accurate dispensing for both inpatients and outpatients, and keep records for drug product expiration or disposal in hospital pharmacies. Thus, bar-code technology is effective when collecting data and allows health-care workers to improve their work productivity and the accuracy of data entry into automated systems (Barchard& Pace, 2008; Nold& William, 2013).

Based on these major and sub-themes, the participants' responses highlighted the significance of having a system that performs effectively and reliably. This included maintaining proper data entry methods and assuring the system's strength, efficiency, and accuracy in fulfilling its intended functions. A well-functioning system contributed to the overall success and efficiency of the system.

C.3. Inventory Management

Effective management of medicine inventory is crucial in healthcare systems to prevent both stock-outs and overstocking. Inadequate inventory systems have the potential to escalate costs and reduce the availability of medical supplies (Fernie*et al.,* 2019).

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

The following statements were divided under sub-themes that represent this theme, which will identify the advantage of the community pharmacists in using BinBot.

C.3.1. Efficient Inventory Management System

Some of participants stated that the impact of implementing the proposed automated Binbot would be more significant on their inventory management.

*"With respect to our inventory [system], it is still manual so it's not that accurate. But with the [automated] system, the result of the inventory would be more accurate."- **P7***

The participant highlighted that the current manual inventory system lacks accuracy, but P7 emphasized that implementing an automated system would significantly improve the accuracy of inventory results. Furthermore, P7 resembled to the statement of P8.

*"Like, it can differentiate the expired from not. It will automatically deduct from the system. We don't have to manually count."- **P8***

According to Barton (2023), more pharmacies are relying on it to optimize inventory management and product flow through the pharmacy. However, identifying inventory that needs to be returned might be difficult. Utilizing software systems that provide alerts to pharmacists when stock reaches critical levels or nears expiration dates can also help mitigate risks. Implementing these practices can enhance patient safety and ensure the availability of quality medications (Ali, 2011). The theme coincided with the study of Awayaet. al (2015), improved inventory management system. This system enabled faster and easier inventory functions in real time. Furthermore, the automated system has created new opportunities for pharmacists to provide clinical services. With the workload reduction in inventory management, pharmacists can now take on additional responsibilities and dedicate more time to patient care. Thus, the adoption of automated systems can minimize the occurrence of errors, increase efficiency and reduce the time required to have validated medication (Bagattini et al.,2022).

C.3.2. System Automation

Some participants have shown keen interest in integrating human intellect and intuition with the precision offered by automated systems to track the expiration of medicines. They emphasized the importance of accurately identifying expired medicines and receiving timely notifications regarding approaching product expirations.

"[It will impact more] in our inventory because you can immediately see it. Unlike the manual [system] that you may missed something. Like that." – **P7**

Additionally, P7 also resembled the statement of P10

"It would be helpful if it can notify the pharmacy staff that a product [for example] will expire on a certain month. It would be easier for us to return the items to the vendor or decide not to put it on sale" – **P10**

Continuing with this theme, the study of Mohialden*et al.* (2022) had developed a software system that enabled pharmacists to effectively monitor the validity of drugs stored at their establishments. This system allowed pharmacists to track the expiration dates of medications, ensuring that they are properly utilized before becoming expired. By utilizing this software, pharmacists efficiently manage their inventory, reduce the risk of dispensing expired drugs, and enhance patient safety. The software provides a convenient and reliable tool for maintaining accurate records and promoting efficient management of medication stock.

The system is compatible with common computer PC devices in pharmacies, ensuring optimal functionality. It promptly alerts the pharmacy manager on their mobile device when a medication's expiration date has passed, facilitating timely notification. Furthermore, a notification system and email are used to effectively distribute warnings about expired drugs, enabling efficient communication and prompt actions to address them.

C.4. Medication Identification

Identifying medication non-persistence is vital for health plans, clinicians, and researchers. An automated algorithm that detects non-persistence in real-time from electronic pharmacy databases would be a valuable tool for healthcare providers, enabling them to

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

prioritize patient outreach and follow-up. Additionally, it would greatly benefit adherence research by identifying non-persistence as a critical outcome and facilitating the monitoring of medication follow-up (Bauer *et al*., 2015).

The following statement is divided under sub-theme that represented this theme, which will identify the recommendations of the community pharmacists in using BinBot:

C.4.1 Accessible Medication Identification

Participants in the study expressed a strong preference for automated scanning and identification as a means to reduce human error and improve efficiency in identifying medicines. They believed that adopting this advanced technology would enhance accuracy and reliability in the monitoring processes, ultimately leading to faster and more precise results.

*"Of course, for faster monitoring it should be the automated scanning … "– **P10***

Respondent 10 emphasized the need for improved identification of medicines through automation. They also highlighted the benefits of automating the inventory process that expedites monitoring procedures. Grace (2015) identified the emergence of software programs aimed at streamlining medicine disposal management, indicating ongoing efforts to optimize identification and tracking in this field.

Aligned with this theme, Sagdoldanova&Atymtayeva (2016) discussed system for medication data storage and retrieval. An inference engine managed the expert system's decision-making process, while a knowledge base provides disposal guidelines. Researchers also recognized the usefulness of chatbots in healthcare, with several similar systems serving the clinical field. Moreover, according to Marami*et al*. (2017), artificial intelligence techniques have been applied to the classification of drug recovery processes in an effort to discern potentially harmful drugs from benign ones based solely on visual characteristics. Therefore, this project offered an environmentally focused solution by utilizing a classification model that automatically identifies the proper medication based on specific medication details, addressing the issue and protecting the environment Banjar *et al.* (2022).

C. Quantitative Analysis

Level of Accuracy

The level of accuracyof modernized Binbot of expired and unused medicine using Arduino Uno was determined based on its terms, withdrawal verification system, accurate counting system for pulled – out medicine cap/tab, efficiency inventory management system, and sorting of expired medicines and estimated through using a five – point likert scale questions. Overall data is shown in table 1.4.

Table 1.4. Overall Mean Level of Accuracy Modernized Binbot of Expired and Unused Medicine Using Arduino Uno

Withdrawal Verification System	Mean	Description
1. The Binbot's withdrawal verification system was easy to use.	4.60	Very high
2. The Binbot accurately detected whether a medicine capsule/tablet was pulled out.	4.60	Very high
3. The Binbot performed reliably without error.	3.60	High

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

4. The Binbot provided timely and clear feedback on the withdrawal status.	4.90	Very high
5. The Binbot helped ensure the correct identification of pulled-out medicines.	4.50	Very high
Overall mean	**4.44**	Very high
SD	**0.49**	
Accurate Counting System for pulled-out medicine cap/tab		
1. The Binbot effectively tracked and counted the pulled-out medicine capsules/tablets.	**4.60**	Very high
2. The Binbot provided real-time updates on the quantity of pulled-out medicine.	**4.70**	Very high
3. The Binbot demonstrated a high level of precision in tracking the number of medicine capsules/tablets used.	**4.70**	Very high
4. The Binbot enhanced the overall management of medication stocks.	**4.50**	Very high
5. The Binbot met your expectations in terms of accuracy.	**4.10**	**High**
Overall mean	**4.52**	Very high
SD	**0.25**	
Efficiency Inventory Management System		
1. The Binbot allowed the user to add/remove/edit expired medicine in the database.	**4.30**	Very high
2. The Binbot reduces the need for manual data entry or paper work.	**4.80**	Very high
3. The Binbot had sufficient storage capacity for keeping expired medication.	**4.80**	Very high
4. The Binbot was user-friendly and intuitive.	**4.50**	Very high

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

5. The Binbot made monitoring for nearly expired/expired medicine easier.	**4.70**	Very high
Overall mean	**4.62**	Very high
SD	**0.22**	
Sorting of Expired Medicines		
1. The Binbot accurately identified expired tablets and capsules based on its barcode.	**4.80**	Very high
2. The Binbot effectively sorted tablets and capsules into a separate compartment.	**4.70**	Very high
3. The Binbot helped reduce human error in identifying expired tablets or capsules.	**4.70**	Very high
4. The Binbot was reliable and consistent in its performance for sorting expired medicines.	**4.30**	Very high
5. The Binbot contributed to the overall efficiency of the disposal process.	**4.70**	Very high
Overall mean	**4.64**	Very high
SD	**0.19**	

The test results revealed that the modernized Binbot, designed for the disposal of expired and unused medicines, exhibited a very high level of accuracy in its withdrawal verification system, with an overall mean of 4.44. This indicates a consistent and precise execution of functions related to withdrawal verification, enhancing the reliability of the medication dispensing process in community pharmacies. The system's user-friendly interface and accurate detection capabilities contribute to preventing errors, aligning with the commitment to patient well-being and safety. The timely feedback mechanism facilitates quick resolution of discrepancies, promoting efficient operations and benefiting both the pharmacy and its customers. Automated systems, like the Binbot, have significant potential to reduce drug errors, improve safety, efficiency, and accuracy in pharmacy settings (Owens &Baergen, 2021; Gupta & Chaudhary, 2021).

In terms of the accurate counting system for pulled-out medicine caps/tabs, the results indicated a very high level of accuracy, with an overall mean of 4.52. This reflects the Binbot's capacity to enhance the accuracy and speed of pill-counting, addressing the limitations of traditional counting methods. The system efficiently monitors and counts medications in real-time, providing transparency and authenticity to the procedure. The accuracy in documenting the quantity of withdrawn drugs showcases the Binbot's cutting-edge technology and meticulous engineering, contributing to optimized stock management, reduced wastage, and enhanced operational efficiency within the pharmacy. Meeting pharmacists' accuracy expectations positions the Binbot as a transformative solution in healthcare and pharmacy (Krezanoski et al., 2019; Sembiring et al., 2019). Regarding the efficiency of the inventory management

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

system, the modernized Binbot demonstrated a very high level of accuracy, with a mean value of 3.79. This indicates the system's precision in improving accuracy and productivity within the inventory management process. The adoption of automated systems, as supported by Yusuf et al. (2021), has the potential to decrease staff workload, save time, and enhance overall productivity in pharmacy operations. Embracing technological advancements speeds up the validation process, improving the reliability and accuracy of drug management systems. The study emphasizes the potential of the Binbot to contribute to a more efficient and prompt medication validation process, aligning with the evolving landscape of healthcare technology and enhancing pharmacy practices (Bagattini, 2022).

E. Data Integration

Data Integration of Qualitative and Quantitative Findings on the Performance of Binbot

Aspect of Point	Quantitative Findings	Qualitative Findings	Nature of Integration
Withdrawal Verification System	Table 1.4 shows the ease of access of the Binbot withdrawal system is very high with a mean of 4.60	Table 1.3 on the Core Ideas and Themes on the suggestions of the community pharmacists on the design and development of modernized Binbot, highlights the following core ideas:	
		-The work-flow became much easier and more efficient as the disposal of expired medicines and tracking of good medicines are up to track.	Merging-Converging (Expansion)
	Table 1.4 shows the accuracy of determining whether a medicine capsule/tablet was pulled out is very high with a mean of 4.60	- Automate the expiry tracking to reduce the risk of dispensing it and enhance the safety of patients.	Merging-Converging (Expansion)
	Table 1.4 shows the Binbot performed reliability without error with a high mean of 3.60	-Not all parts of the process are automated but it will increase the work-flow still	Merging-Converging (Expansion)
	Table 1.4 shows the Binbot provided timely and clear feedback on the withdrawal status with a very high mean of 4.90	- With its notification system, it enables quick actions upon disposal and prompt remedial disposal	Merging-Converging (Expansion)
	Table 1.4 shows the Binbot helped ensure the correct identification of pulled-out medicines with a very high mean of 4.50	- The medication identification ensures faster monitoring and greatly enhance the accuracy and reliability of the monitoring process	Merging-Converging (Confirmation)

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

	The overall withdrawal verification system showed a very high mean of 4.50	-The Binbot improves the work life of a pharmacist as it reduces the hassles of the work system.	Merging-Converging (Confirmation)
Accurate Data Entry	Table 1.4 showed the Binbot effectively tracked and counted the pulled-out medicine capsules/tablets at a very high mean of 4.60	Table 1.3 on the Core Ideas and Themes on the suggestions of the community pharmacists on the design and development of modernized Binbot, highlights the following core ideas: -With the automated system, the inventory system would show quicker and more accurate output	Merging-Converging (Confirmation)
	Table 1.4 showed the Binbot provided real-time updates on the quantity of pulled-out medicine at a very high mean of 4.70.	-The automated system ensures precise inventory management, offering immediate and reliable information	Merging-Converging (Confirmation)
	Table 1.4 showed the Binbot demonstrated a high level of precision in tracking the number of medicine capsules/tablets used with a very high mean of 4.70	- The automated system will reduce the amount of human error in the process	Merging-Converging (Confirmation)
	Table 1.4 showed the Binbot enhanced the overall management of medication stocks with a very high mean of 4.50	-Automated system speed up the process of monitoring and minimize the risk of medical errors	Merging-Converging (Confirmation)
	Table 1.4 showed the Binbot met your expectations in terms of accuracy with a high mean of 4.10	- Users' satisfaction with the Binbot's accuracy in data entry, resulted in increased productivity and a smoother workflow	Merging-Converging (Confirmation)
	The results of the Data entry accuracy showed a very high mean of 4.44 overall.	- The data entrymitigates the likelihood of inaccuracies and errors within a system, contributing to enhanced efficiency and overall smooth operation	Merging-Converging (Confirmation)
Efficiency of Inventory Management	Table 1.4 shows the Binbot reduces the need for manual data entry or paper work with a very high mean of 4.80	Table 1.3 on the Core Ideas and Themes on the suggestions of the community pharmacists on the design and development of modernized	

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

		Binbot, highlights the following core ideas: - Automated system would simplify and reduce the workload of pharmacists	Merging-Converging (Expansion)
	Table 1.4 showed the Binbot made monitoring for nearly expired/expired medicine easier with a very high mean of 4.70 The overall efficiency of the Inventory Management System had a very high mean of 4.62	-With the increase in accuracy of inventory management, it is efficient in terms of getting less errors	Merging-Converging (Confirmation)
		-The efficiency mainly stems from the time saved from manually counting the medicines	Merging-Converging (Confirmation)
Medication Identification	Table 1.4 showed the Binbot accurately identified expired tablets and capsules based on its barcode with a very high mean of 4.80	Table 1.3 on the Core Ideas and Themes on the suggestions of the community pharmacists on the design and development of modernized Binbot, highlights the following core ideas: -The fast-monitoring system makes the whole process efficient	Merging-Converging (Expansion)
	Table 1.4 showed the Binbot effectively sorted tablets and capsules into a separate compartment with a very high mean of 4.70 The Medication Identification of the study had a very high overall mean of 4.60	- Sorts of medication accurately and effectively	Merging-Converging (Expansion)
		-The barcodes which automated the process showed a high capability of separating the medications.	Merging-Converging (Expansion)

Withdrawal Verification System

The withdrawal verification system showed high performance in terms of ease of access, accuracy, low accuracy error, precise identification, and increased the work-flow overall ease within the inventory system. It is important to note that the Binbot did not fully automate the whole process of the Inventory system as some factors such as logging of expiration dates are manual but nevertheless, the system significantly reduces the amount of work hassles within the inventory aspect.

Accurate Data Entry

Both the quantitative and qualitative data supports the fact that the Binbot had high capabilities and accuracy performance in terms of medication pull-outs, real-time updates, precision tracking, and overall monitoring performance showing a quicker and more

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

accurate performance level compared to the previous process where a significant amount of human error was needed to be considered.

Efficiency of Inventory Management

Both data findings shown the ease of inventory that Binbot was able to provide to pharmacists as the Binbot had high efficiency reports of management efficiency with the accumulation of less errors given the lack of presence of human error as well as the quick sorting process due to the speed of sorting of the Binbot.

Medication Identification

In terms of the Binbot's Medication Identification performance, it showed high levels of accuracy of sorting medicines that are expired as well as continuous monitoring of the medication supply which made the whole process efficient as the automation aspect reduced a significant portion of the workload where human error often disrupts the process.

Conclusion,

This study sheds light on the practices, attitudes, and potential uses of a modernized Binbot, an automated system for sorting expired medications, aimed to assist community pharmacists. The study highlighted a gap in patient education on proper disposal methods and varied timing preferences for medication disposal among pharmacists. Furthermore, emphasizing the Binbot'simmenseability for enhancing healthcare by improving medicine safety, and streamlining dispensing activities.The Binbot, well-received for its potential in enhancing efficiency, inventory management, and medication identification, demonstrated high accuracy and participant satisfaction. In addition, this also proposed potential applications of artificial intelligence in drug identification, emphasizing the transformative impact on community pharmacy operations and advocating for continued research and development in this field.

Acknowledgement

The authors gratefully acknowledge all participants of the study and St. Alexius College for allowing us to do our study. The following people are acknowledged: Tuburan, J.,Badong, V., Silva, S., Surmion, K., and Faller, E.

References

[1] Mohammed, S. A., Kahissay, M. H., &Hailu, A. D. (2021). Pharmaceuticals wastage and pharmaceuticals waste management in public health facilities of Dessie town, North East Ethiopia. PloS one, 16(10), e0259160. Retrieved on November 2023 from https://doi.org/10.1371/journal.pone.0259160W.-K. Chen, *Linear Networks and Systems.* Belmont, Calif.: Wadsworth, pp. 123-135, 1993. (Book style)

[2] AlAzmi, A., AlHamdan, H., Abualezz, R., Bahadig, F., Abonofal, N., Osman, M., 2017. Patients' knowledge andattitude toward the disposal of medications. Journal of Pharmaceutics. https://www.hindawi.com/journals/jphar/2017/8516741/

[3] Bound, J.P., Kitsou, K., Voulvoulis, N., 2006. Household disposal of pharmaceuticals and perception of risk to theenvironment. Environmental Toxicology and Pharmacology 21, 301e307.

[4] Fenech, C., Rock, L., Nolan, K., Morrissey, A., 2013. Attitudes towards the use and disposal of unused medications in two European countries. Waste Management 33, 259e261.

[5] Daughton, C. G. (2003). Cradle-to-cradle stewardship of drugs for minimizing their environmental disposition while promoting human health. I. Rationale for and avenues toward a green pharmacy. Environmental Health Perspectives, 111(5), 757–774. Retrieved on November 2023 from https://doi.org/10.1289/ehp.5947.

[6] Sasu, S., Kümmerer, K., &Kranert, M. (2011). Assessment of pharmaceutical waste management at selected hospitals and homes in Ghana. Waste Management & Research, 30(6), 625–630. Retrieved on November 2023 from https://doi.org/10.1177/0734242x11423286.

[7] Michael, I., Ogbonna, B., Nduka, S. O., Anetoh, M. U., & Matthew, O. (2019). Assessment of disposal practices of expired and unused medications among community pharmacies in Anambra State southeast Nigeria: a mixed study design. Journal of Pharmaceutical Policy and Practice, 12(1). Retrieved on November 2023 from https://doi.org/10.1186/s40545-019-0174-1.

[8] Ampadu, I., Morones, R., Tsatoke, A., Ampadu, L., Stephens, M. L., Crump, W. C., & Bales, D. (2021). Community-based medication disposal pilot initiative in southwest tribal communities. Injury Epidemiology, 8(S2). Retrieved on November 2023 from https://doi.org/10.1186/s40621-021-00360-8

GSJ: Volume 12, Issue 2, February 2024

ISSN 2320-9186

[9] Afolabi, M. O., &Oyebisi, T. (2007). Pharmacists' perceptions of barriers to automation in selected hospital pharmacies in Nigeria. Journal of Pharmacy Practice, 20(1), 64–71. https://doi.org/10.1177/0897190007302894

[10] Angelo, L. B., Christensen, D. B., &Ferreri, S. P. (2005). Impact of community pharmacy automation on workflow, workload, and patient interaction. Journal of the American Pharmacists Association, 45(2), 138–144. https://doi.org/10.1331/1544345053623537

[11] Cina, J. L., Fanikos, J., Mitton, P., McCrea, M., & Churchill, W. W. (2006). Medication errors in a pharmacy-based bar-code-repackaging center. Am J Health Syst Pharm, 63(2), 165–168. https://doi.org/10.2146/ajhp050207

[12] Kumar, A., Cariappa, M., Marwaha, V., Sharma, M., & Arora, M. (2016). Improving medical stores management through automation and effective communication. Medical Journal, Armed Forces India, 72(1), 61–66. https://doi.org/10.1016/j.mjafi.2015.01.011

[13] Banjar, H., Alrowithi, R., Alhadrami, S., Magrabi, E., Munshi, R., &Alrige, M. (2022). An Intelligent System for Proper Management and Disposal of Unused and Expired Medications. International journal of environmental research and public health, 19(5), 2875.https://doi.org/10.3390/ijerph19052875

[14] Boyd, A. R., & Chaffee, B. W. (2018). Critical Evaluation of Pharmacy Automation and Robotic Systems: a call to action. Hospital Pharmacy, 54(1), 4–11. https://doi.org/10.1177/0018578718786942

[15] Barchard, K. A., & Pace, L. A. (2008). Meeting the challenge of high quality data entry: a free double-entry system. International Journal of Services and Standards, 4(4), 359. https://doi.org/10.1504/ijss.2008.020053

[16] In the coming years more retail pharmacy brands will adopt technology to gain a competitive edge. (2023, January 30). Drug Store News. https://drugstorenews.com/coming-years-more-retail-pharmacy-brands-will-adopt-technology-gain-competitive-edge

[17] Bagattini, Â. M., Borges, J. L. A., Riera, R., & De Carvalho, D. C. M. F. (2022). Automation of a tertiary hospital pharmacy drug dispensing system in a lower-middle-income country: A case study and preliminary results. Exploratory Research in Clinical and Social Pharmacy, 6, 100151.https://doi.org/10.1016/j.rcsop.2022.100151

[18] Mohialden, Y. M., Hussien, N. M., Jabbar, Q. a. Z., Mohammed, M. A., &Sutikno, T. (2022). An internet of things-based medication validity monitoring system. Indonesian Journal of Electrical Engineering and Computer Science, 26(2), 932. https://doi.org/10.11591/ijeecs.v26.i2.pp932-938

[19] Sagdoldanova, A., &Atymtayeva, L. (2016, April). Expert system for pharmacy. In Proceedings of the 14th International Scientific Conference Information Technologies and Managment, Riga, Latvia (pp. 14-15).

[20] Banjar, H., Alrowithi, R., Alhadrami, S., Magrabi, E., Munshi, R. M., &Alrige, M. (2022b). An intelligent system for proper management and disposal of unused and expired medications. International Journal of Environmental Research and Public Health, 19(5), 2875.https://doi.org/10.3390/ijerph19052875

[21] Owens CT, Baergen R. Pharmacy Practice in High-Volume Community Settings: Barriers and Ethical Responsibilities. Pharmacy (Basel). 2021 Apr 3;9(2):74. doi: 10.3390/pharmacy9020074. PMID: 33916737; PMCID: PMC8167746.

[22] Gupta, H., & Chaudhary, N. (2021). The practice of automated drug dispensing technology on the reduction of medication errors in the medication process. International Journal of Pharmaceutical Sciences Review and Research, 70(2). https://doi.org/10.47583/ijpsrr.2021.v70i02.002

[23] Krezanoski, P. J., Krezanoski, J. D., Nxumalo, N., Gabert, R., Comfort, A., Khumalo, P., &Matshotyana, K. (2019). Comparison of traditional methods versus SAFEcount for filling prescriptions: A pilot study of an innovative pill counting solution in eSwatini. PLOS ONE, 14(12), e0224323. https://doi.org/10.1371/journal.pone.0224323

[24] Sembiring, A. C., Tampubolon, J., Sitanggang, D., Turnip, M., &Subash. (2019). Improvement of Inventory System Using First In First Out (FIFO) Method. Journal of Physics, 1361(1), 012070. https://doi.org/10.1088/1742-6596/1361/1/012070

[25] Yusuf, S., Aliyu, A. Y., Ifeyinwa, M., Abdullahi, S., Yusuf, A. A., &Abubakar, A. Y. (2021).Automation of Pharmaceutical Inventory Control System. African Scholars Journal of Pure and Applied Science (JPAS-9), 22, No. 9(2278–1897). https://www.africanscholarpublications.com/wp-content/uploads/2021/12/AJPAS_Vol22_No9_September2021-12.pdf

[26] Bagattini, Â. M., Borges, J. L. A., Riera, R., & De Carvalho, D. C. M. F. (2022). Automation of a tertiary hospital pharmacy drug dispensing system in a lower-middle-income country: A case study and preliminary results. Exploratory Research in Clinical and Social Pharmacy, 6, 100151.https://doi.org/10.1016/j.rcsop.2022.100151

[27] Alshehri, D., & Banjar, H. (2022). Increasing awareness of proper disposal of unused andexpired medication using a Knowledge-Based Disposal Management System. Journal ofEnvironmental and Public Health, 2022, 1–10. https://doi.org/10.1155/2022/1797440

[28] Marami B., Royaee A.R. Automatic Detection and Classification of Waste Consumer Medications for Proper Management and Disposal. arXiv. 20202007.13903