Exploring the Usability of Vending Machines through Multi-Method Evaluation Techniques

***Abstract*—Usability is a key quality attribute to ensure accessibility and high user acceptance of any embedded system. While several studies have examined the usability of embedded systems, only a few have specifically addressed the usability assessment and intuitive design of systems like vending machines. Therefore, the objectives of this research are to explore the usability of existing vending machines and to propose design solutions for enhancing the usability of such embedded systems. To achieve these objectives, three unique vending machines (*Your Shop, SnacKeeper, and SPN Convenience*) were evaluated using both Heuristic Evaluation (HE) and Cognitive Walkthrough (CW) methods; and revealed a wide range of usability problems. A comparative analysis was performed between the findings of both methods and then the identified usability issues were categorized into interface accessibility, transactional design, instructional layout, and visibility & clarity. Based on the findings, a set of design recommendations was developed to address these challenges. Additionally, as an example a prototypical design was created based on the proposed recommendations. As such, the findings of this study will make a substantial contribution to the fields of embedded system design and human-computer interaction (HCI) to offer valuable insights for designing more usable and intuitive vending machines.**

***Index Terms*—Human-Computer Interaction, Usability, Heuristic Evaluation, Cognitive Walkthrough, Vending Machines.**

I. Introduction

Vending machines have become one of the most important parts of our daily lives by offering quick access to snacks, drinks, and other essentials. With time, these machines have evolved from basic coin-operated models to advanced systems. Different payment methods and various purchasing options are supported by the advanced models. As society continues to embrace automation and convenience, vending machines have adapted and transformed to meet the changing needs and preferences of consumers. However, in the present situation, the general population finds it difficult to operate the vending machine's user interface. As a result, its popularity is not very widespread. Its outcome will be fruitful when it can be used by people of all ages. Its productivity as well as its popularity will increase by making it user-friendly for individuals of all ages. Additionally, if voice instructions are added to the system, users can be able to purchase products more efficiently and quickly using vending machines.

The articles [1], [2], and [3] demonstrate several drawbacks of vending machines that have been found by the current literature review analysis. These limitations include the lack of audio instructions, the inflexibility of changing options, the lack of a categorized item selection system, and the requirement for an approachable way of choosing products. Furthermore, as mentioned in the paper [4], the literature research has brought attention to the lack of an autonomous fault detection system for mistake prevention in vending machines. Moreover, as the article [5] discusses, a gap in the current research has been found in the absence of integration of future technologies like augmented reality and touchless interfaces.

People are rarely interested in making use of vending machines due to the complex layout of the user interface. Besides, it requires considerable time to understand the payment system because of its complexity. As there are limited payment options, users may not purchase things even when they have sufficient funds on another money transfer platform. Productivity and a significant amount of revenue can be made if the vending machine's user interface is made more user-friendly. Audio instructions need to be included in vending machines so that normal users can easily access these machines.

Therefore, the objectives of this study are to evaluate the ease of use of the interfaces of the existing vending machines and propose a design solution for developing an intuitive vending machine with enhanced usability. In this research, a variety of vending machines is selected. After that, appropriate evaluators are selected to evaluate the existing vending machines. Two approaches are used for this evaluation. One is Heuristic evaluation, and the other is Cognitive Walkthrough. After the evaluation, findings are collected, and a proposed design guideline is given to overcome those findings as well as create a new design for the people.

II. Literature Review

The related works that focus on the usability analysis of vending machines are briefly presented in this section.

A. Hardware integration and performance evaluation

Qureshi [1] focused on designing and implementing a vending machine using Verilog HDL on an FPGA board that could provide four different products. An automatic beverage vending machine was proposed and implemented using Finite State Machine (FSM) technology by Krishna et al. [6]. The proposed model offers features including automatic billing, cancellation options, and product reinitialization. In another study, Murena et al. [2] showed that with the use of a gateway device, the proposed system can regulate vending procedures automatically. It also allows the system to function as a multi-payment device with high compatibility across all mobile phone kinds and easy payment methods, including card swiping. Monga [7] focused on the design of a multi-select vending machine using a finite state machine model with auto-billing features.

After that, its performance was compared with a CMOS-based machine. Pradeepa [8] developed a vending machine using Verilog HDL and implemented an efficient algorithm using an FPGA board. Plaha [9] discussed the design and development of a vending machine that accepts paper currency. Liquid products are dispensed through a solenoid valve plunger by the proposed machine. Singh [10] discussed the design and implementation of a touchscreen-based automated medical vending machine. Basic medicines and information on nearby medical facilities can be provided to people in remote areas by the implemented vending machine. Jaka [11] conducted a case study to design and implement a snack vending machine with an Android-based QR Code payment system through a real-time database feature on Firebase. Particular attention was paid by Kho [12] to the design and implementation of a multi-select state vending machine that uses a state machine, and FPGA was selected for faster response, less power consumption, and reprogrammable capacity. A web server application for vending machines was developed by Asyhari et al. [13] and after the web server was integrated with a vending machine, the client's data could be processed and stored by the system.

B. Progressive features and payment methods

The main topic of the study conducted by Sibanda et al. [3] was the design of a vending machine that can dispense many products at once. Three methods of payment were available: cash, credit card, and smartphone in the proposed design. Alam et al. [5] presented an Internet of Things-enabled vending machine system allowing for the integration of bKash payments and facilitating goods purchases via cell phones. Ratnasri [14] provided an overview of two main types of vending machines, the advantages of IoT-based vending machines, the use of credit and debit card payment methods, big data analytics tools, and NoSQL databases. In another study, Wiyanti [15] proposed the design of an automated vending machine with IoT infrastructure to use in a smart factory. This vending machine can be monitored and controlled remotely. Ramzan et al. [16] described how a cashless and secure payment system was designed, implemented, and used in vending machines using radio frequency identification technology. Again, Phade et al. [17] analyzed the design and implementation of various vending machine variations. Shoji et al. [18] presented the idea of a mesh topology network design for a community-based wireless Internet of Things infrastructure used by universal vending machines. A series of design heuristics for user interfaces were introduced by Sandnes et al. [19] concerning the THSR ticket vending machine.

C. Interface design and user experience

An experimental analysis was conducted by Sprague [4] for teaching generalized vending machine use to high school students with disabilities. A prototype of an emotionally engaging self-service ticket vending machine was developed by Siebenhandl et al. [20] using a User-Centered Design (UCD) approach. Data collection methods included observations, surveys, usability testing, etc. In another study, Vezzoli [21]] developed guidelines and checklists for the eco-efficient life cycle design of NECTA vending machines, and the outcome of this research was a handbook with guidelines and checklists incorporating the company's product development process and suggested rebuilding the interface using an activity relationship chart (ARC) to improve user experience and performance. Widyanti [22] assessed the usability of TTM, identified new problems relating to its use, and concluded that there was potential for improvement in the TTM's usefulness.

In sum, though several studies were carried out focusing on the design and development of vending machines, a few of them explicitly focused on design and usability issues by assessing the multiple vending machines. Thus, this research focuses on the evaluation and design of vending machines for the convenience of users.

III. METHODOLOGY

The following steps are sequentially performed to attain the research objectives.

(a) Select Vending Machines: Three unique vending machines (*Your Shop, SnacKeeper, and SPN Convenience*) were selected randomly for evaluation to find a wide range of usability problems. The main reason for choosing these vending machines is to explore the usability issues and the possible ways of improving their usability and user experience.

(b) Evaluators Profile: A total of six experts were recruited for this research. The evaluators' age range was between 32 and 38 years. They had 6-8 years of experience in IT-related products. They all completed HCI and interface design-related courses; they were familiar with usability evaluation methods like Heuristic Evaluation, Cognitive Walkthrough, A/B Testing, Task Analysis, etc approach. However, they conducted a Heuristic Evaluation and Cognitive Walkthrough for this research. Among six experts, three conducted a Heuristic Evaluation, and the rest conducted a Cognitive walkthrough while performing two specific tasks.

(c) Evaluate the Vending Machines: Two methods were selected for the evaluation. One was a Heuristic evaluation and the other one was Cognitive Walkthrough. The main reason for choosing the Heuristic Evaluation was to examine the design of a user interface and judge its compliance with a list of predefined heuristics [23]. These heuristics were used as a template, helping the evaluators to identify the potential problems users might encounter. Then, each problem was given a severity rating of 0-4, where 0 denotes no problem, 1 denotes cosmetic problem only, 2 denotes minor usability problem, 3 denotes major usability problem and 4 denotes a usability catastrophe [24]. On the other hand, the Cognitive Walkthrough was chosen because it would help to examine how easily new users could accomplish the tasks with the system. The cognitive walkthrough is a technique for evaluating the design of a user interface, with special attention to how well the interface supports "exploratory learning," i.e., first-time use without formal training [25]. In this evaluation, while

(a) (b) (c)

Fig. 1: Screenshots taken from (a) & (b) Your Shop and (c) SnacKeeper

conducting a cognitive walkthrough, evaluators were asked to answer the four types of questions [26], [27] where Question 1 denoted whether the user's actions were aligned with the system and real-world scenarios. Question 2 emphasized the visibility and accessibility of the controls that were necessary for performing a particular action. The clarity and intuitiveness of the relationship between controls and the actions were focused on by Question 3. Question 4 evaluated whether the system provides timely and relevant feedback to users after they act. Both evaluation techniques helped to find out the usability and user-interface-related problems.

(d) Data Analysis and Findings: The study findings were analyzed to reveal possible usability problems and categorized them according to the problem type. Based on these problems, a redesign of a vending machine is proposed.

IV. Evaluating Vending Machine

The evaluation was conducted in two phases. Before conducting this evaluation, evaluators were briefed about the purpose of this experiment and their roles in it. The written consents were also obtained from each evaluator to address all ethical issues. In the first phase, three evaluators evaluated the usability of the interfaces of the three snack vending machines based on heuristic principles. Each of them found out and listed several usability problems. Then all the problems were aggregated and categorized according to the problem types and severity ratings. Then, in the second phase, the other three evaluators were asked to try out different features of the system in the form of tasks to perform a cognitive walkthrough. Problems were identified based on the evaluators' activity and feedback. Finally, all the problems were aggregated and categorized according to the usability problems.

A. Heuristic Evaluation

Evaluators looked at the interface of the selected vending machines and determined if it complied with established usability guidelines. A few examples are discussed here to show how the Heuristic Evaluation was conducted. For '*Your shop*' vending machine, evaluators found that while purchasing a product, only online payment options are visible on the interface but no icon is shown for cash payment (see figure 1(a)). Users may think that the vending machine might not accept any banknote but the vending machine also accepted the banknote. This violates the heuristic 'H4'(consistency and standards). The average severity of this violation has been graded as 3.42 by three evaluators. Again, two evaluators pointed out that there was no clear instruction on which way they needed to swipe to see the remaining products (see figure 1(b)). It creates confusion as to whether user would need to scroll left to right or top to bottom. This is also considered as a violation of 'H4'(consistency and standard) heuristic with an average severity rating of 2.32. In *'SancKeeper'* vending machine (see figure 1(c)), there was no option like 'add to cart' for selecting multiple items at once. As a result, for purchasing multiple items evaluators had to go through the same sequence of actions multiple times. This denotes the violation of the 'H3'(User control and freedom) heuristic and was given an average severity rating of 2.48 by the evaluators. A total of 32 problems were identified from the selected interactive vending machines. Due to space limitation, the problem details are provided in [28]. Among them, eight belonged to the *'Your Shop'* vending machine, eight belonged to the *'SnacKeeper'* vending machine, and the other sixteen belonged to the *'SPN Convenience'* vending machine. Twenty unique problems were found in the vending machine and the maximum problems were found in the *SPN Convenience* vending machine in terms of the total problem (n=16) and the unique problem (n=8). The problems were analyzed and categorized into Interface Accessibility, Transactional Design, Instructional Layout, and Visibility and Clarity. As three evaluators conducted this heuristic evaluation, their Severity ratings were averaged for each problem and a particular problem type.

B. Cognitive Walkthrough

In Cognitive Walkthrough Evaluation, two assigned tasks were focused including (i) Purchasing a product using the online payment method and (ii) Purchasing a product using cash. Evaluators analyzed each action of these tasks based on the prescribed questions of cognitive walkthrough approach. For

example, to assess task-1 in '*Your Shop*' vending machine, two evaluators were confused about whether the vending machine would accept any banknote or not, as there was no notification about inserting the banknote when the product was selected (see figure 1(a)). Again, to analyze task-2 using the *'Your Shop'* and *'SnacKeeper'* vending machine, two evaluators pointed out a usability problem as the system did not provide any notification of payment confirmation like 'Your payment has been successful' or 'Thanks for choosing the vending machine'. The findings of cognitive walkthrough evaluation are available in [28]. Each problem is categorized into three problem types and the percentages of yes/no are provided for each generalized question of Cognitive Walkthrough.

V. Result Analysis

A. Findings of Heuristic Evaluation

In Heuristic Evaluation, it has been seen that the selected vending machines violated the heuristic H4 (consistency and standards) maximum times (n=10). The lowest (n=2) violated

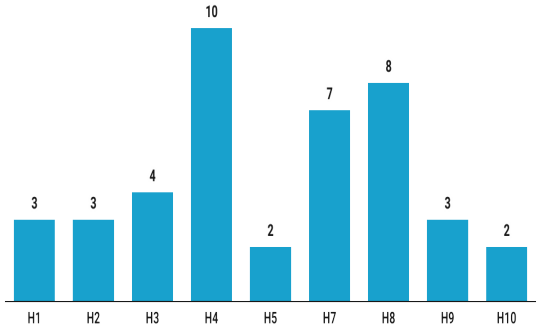

Fig. 2: Number of violations to each heuristic

heuristics were H5 and H10. Except H6, all other heuristics are violated in a range of 2-10 times. This analysis shows that while the vending machines have strengths in certain areas like visibility and help/documentation, there are significant issues with consistency and minimalistic design that need addressing.

Interface Accessibility had the highest number of heuristic violations (n=16) whereas Visibility and Clarity related problem type had the lowest violation (n=6), suggesting effective design in this area which is found by analyzing [28]. The Transactional Design-related problem type had moderate violations (n=8) but a higher severity rating, decreasing transaction efficiency. Instructional Layout-related concerns had the second-highest number of violations (n=12), indicating a lack of clear guidance and better feedback systems.

B. Findings of Cognitive Walkthrough

The Cognitive Walkthrough(CW) identified usability issues related to the purchasing process as the task was based on purchasing a product. CW emphasized Transactional Design problems, especially where users find difficulties in completing a transaction and that's why six problems (n=7) were identified in this problem type. Instructional Layout related three problems (n=3) were also identified but their impact was less prominent. During CW, the absence of Visibility and Clarity issues indicates that these aspects were not problematic when these specific tasks were evaluated.

TABLE 1: Comparison of Heuristic and Cognitive

	Interface Accessibility	**Transactional Design**	**Instructional Layout**	**Visibility and Clarity**
Problems Revealed by HE	5	5	7	3
Severity of HE	3.32	3.58	2.90	2.91
CW Procedures	4	7	3	0

C. Comparison between HE and CW

A comparison of usability problems, identified by both Heuristic Evaluation (HE) and Cognitive Walkthrough(CW) is shown in table 1. Both HE and CW found three common problem types but Visibility and Clarity-related problem type was not found in CW. In table 1, the Interface Accessibility problem type was similarly identified by both evaluation methods, with five problems (n=5) in HE and four (n=4) in CW. Instructional Layout-related problems were more prevalent in HE (n=7) compared to CW (n=3) while Transactional Design-related problems were slightly prominent in CW (n=7) compared to HE(n=5). From this, it is noticeable that HE raised issues against unclear feedback and delayed responses, whereas CW emphasized the purchasing process.

VI. Design Recommendation

Evaluators provided feedback after conducting HE and CW. Analyzing the evaluation feedback, the following design recommendations are proposed for 'Interface Accessibility': (a)The voice command system should be integrated; (b)A touch screen should be provided with all the functionalities; (c)The money insertion option should be in a downward position so that all kinds of users can use it; (d)A separate coin-paying option should be given at the vending machine; (e)A backlit should be used on the number pad; (f)Items should be categorized to enhance organization and user navigation. Considering the proposed design recommendations, a prototype of the vending machine has been designed to address usability issues with features including a touch screen interface (see figure 3(a)), a voice command system (see figure 3(b)), a backlit number pad (see figure 3(c)) and payment slots for cash and coins (see figure 3(d)).

During the evaluation, a 'Transactional Design' issue was identified, and the specific recommendations are proposed for 'Transactional Design': (a)There should be an interactable icon on the screen for retrieving the money; (b)A place should be located where returned coins can be collected; (c)The cash icon should be available and functional; (d)Online payment options should be integrated into the system; (e)The accepted type of banknote should be displayed while the payment is done in cash. According to the proposed solution, an

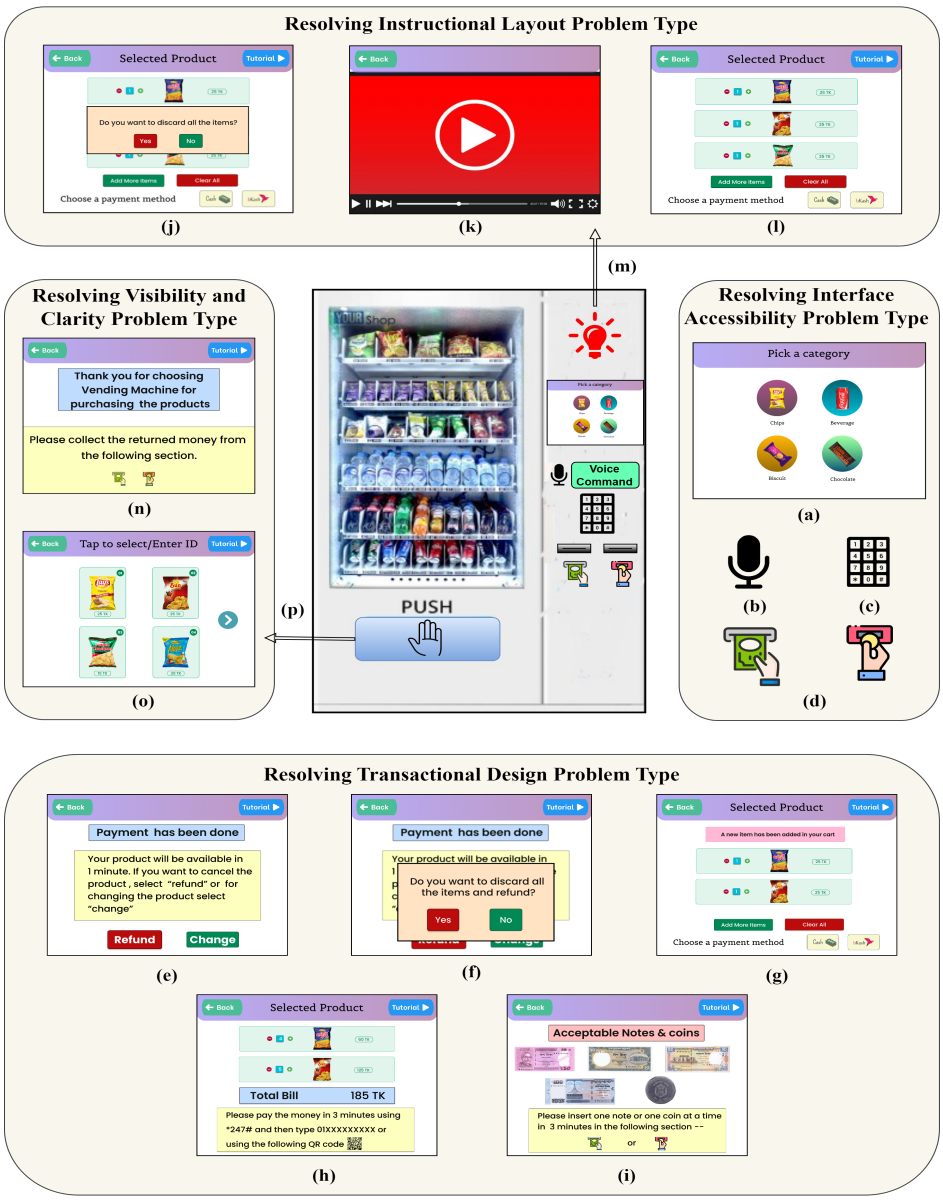

Fig. 3: Vending Machine Redesign Using Proposed Design Recommendation

interactable 'Refund' icon (see figure 3(e)), a coin collection slot (see figure 3(d)), a functional 'Cash' icon and 'Online Payment' icon (see figure 3(g)) and the accepted banknote (see figure 3(i)) that vending machine would accept have been designed.

'Visibility and Clarity' was another type of problem that was found during the evaluation. The following design recommendations are proposed for 'Visibility and Clarity': (a)The coin collection box should be upward, and a message should be displayed on the screen while returning the coin; (b) An appropriate symbol should be used so that the user can understand that the screen has to be swiped to select the product. Also, a relevant symbol should be used to denote the push sign; (c)The display should be large and clearly visible. According to the suggestion, the following prototype has been designed (see figure 3(n), 3(o) and 3(p)) to overcome these issues.

For the 'Instructional Layout', the following design recommendations are made: (a)A pop-up message should be appeared while discarding the item for confirmation; (b)An instruction should be provided for inserting the money; (c)A bulb should be lit while releasing the product; (d)The instructions should be large enough to be understood; (e)A discarded button should be available on the screen; (f)There should be an "add to cart" button on the interface; (g)A documentation-related button should be available on the screen to understand

the system. According to the proposed solutions, a pop-up message (see figure 3(j)), a documentation-related button (see figure 3(k)), an 'add more items' button and a 'clear all' button (see figure 3(l)), and a bulb (see figure 3(m)) has been introduced.

VII. Conclusions

Vending machines are relatively difficult to use for novice users, and most of the research studies have mainly focused on evaluating a single vending machine for a specific type of user. Hardly any research has been conducted to evaluate multiple vending machines regarding their usability considering the varieties of users, which was emphasized in our study. In this research, a rigorous literature survey has been conducted to define the scope of improving the user experience of vending machine technology more systematically. According to the study results, heuristic evaluation and cognitive walkthrough techniques were found to be helpful in evaluating the usability of vending machines. As an outcome, several usability problems of vending machines were revealed, as well as a user-intuitive design was recommended, including audio instructions, an easy-navigating interface, and a more efficient payment system. The study has a few limitations as well. First, the evaluation is limited to three vending machines, which restricts its generalizability. Second, the proposed design was not practically implemented, which limits understanding of the usability of the recommended solution. Future work will focus on evaluating more types of vending machines and testing the implemented design with real users to get better insights regarding usability.

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