Tapdrop: A Gcash-Enabled Water Vending Machine

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ABSTRACT*——- *Access to clean drinking water remains a critical need, especially in urban areas where coin-operated water vending machines are common. However, reliance on cash limits convenience in a society rapidly shifting to digital payments. This study presents TAPDROP, a prototype vending machine that supports both GCash and coin payments. The system employs an ESP32 microcontroller, Firebase for transaction logging, and MacroDroid to detect GCash transactions. Testing confirmed reliable water dispensing (approx. 200 mL per ₱1), minimal response delay, and positive user feedback. While limitations include internet dependence and reliance on third-party automation, results show that integrating mobile wallets into public utilities is both technically viable and socially beneficial. The project aligns with national goals for digital inclusion and service modernization.

***Keywords*—Gcash, Coin Macrodroid, Microcontroller, Esp32, Firebase, Water Vending Machine,**

I. Introduction

A. Background of the Study

Access to drinking water remains a challenge in many urban areas of the Philippines. While coin-operated Water Vending Machines (WVMs) offer affordable access to purified water, their reliance on physical currency is increasingly inconvenient in today's digital society. In 2023, digital transactions accounted for 52.8% of all payments, surpassing the Bangko Sentral ng Pilipinas' 50% target [10]. The rise of mobile wallets like GCash—used by over 94 million Filipinos by late 2024 [12]—highlights the nation's shift toward digital payments, driven by smartphone penetration and post-pandemic behavior changes [11]. Despite this, most WVMs remain cash-only. Integrating GCash into these machines would eliminate the need for exact change and align with the government's push for a cash-lite economy [3].

B. Statement of the Problem

Traditional water vending machines (WVMs), which serve many communities, primarily rely on coin-based payments. This creates inconvenience for users who must carry exact change and physically handle cash. Operators also miss out on the benefits of cashless systems, such as faster transactions, reduced downtime, and higher revenue [13]. Despite widespread adoption of platforms like GCash, integration with WVMs remains limited, revealing a gap in service modernization. This study addresses that gap by developing a GCash-enabled WVM to align with evolving payment behaviors and improve user convenience.

C. Objective of the Study

This study aims to develop a GCash-enabled Water Vending Machine to enhance user accessibility and convenience. The objectives are to design and build a machine that accepts GCash payments, eliminating the need for cash or coins; integrate security measures to protect payment transactions; and test the overall system functionality.

D. Scope and Limitation of the Study

The study is limited to the development and testing of a GCash-enabled water vending machine prototype at selected sites within the University of Science and Technology of the Philippines, without plans for mass production or wider deployment. Results may not generalize to regions with different infrastructure or socio-economic conditions. The system relies on stable internet connectivity and continuous availability of the GCash platform. Only GCash is supported as the payment method, excluding other digital payment options.

E. Significance of the Study

This study benefits key stakeholders in multiple ways. Consumers, such as students and commuters, gain convenient, cashless access to clean drinking water. Vending machine operators can improve sales, reduce cash-handling costs, and enhance operations through real-time IoT monitoring. Policymakers support digital financial inclusion and public health goals aligned with the Philippines' cash-lite economy initiatives. Researchers and developers receive a practical framework for integrating secure digital payments with IoT, informing future smart vending innovations.

II. LITERATURE REVIEW

A. Digital Payment Transformation in the Philippines: From Cash to GCash

Susilo and Dizon analyzed the Philippines' shift from cash-based to digital payments, emphasizing the rapid adoption of GCash due to rising smartphone use, government-led initiatives, and pandemic-driven demand for contactless transactions [11]. They also noted ongoing challenges, including infrastructure gaps and digital literacy barriers, which contribute to a persistent digital divide. Their findings support the relevance of GCash-enabled vending machines while underscoring the need to address accessibility in deployment.

B. Factors Influencing E-Wallet Adoption Among Generation Z and Millennials in the Philippines

Belmonte et al. examined E-wallet adoption among Generation Z and Millennials in the Philippines using an extended Technology Acceptance Model (TAM). Based on a survey of 500 respondents, key adoption drivers included ease of use, usefulness, trust, security, and social influence—where trust emerged as more influential than perceived value [2]. These findings are directly relevant to this project, as younger users are likely the primary adopters. A secure, user-friendly interface and peer-driven promotion strategies are essential for enhancing adoption of GCash-enabled vending machines.

C. GCash: Revolutionizing Digital Payments in the Philippines and Beyond

Afable [1] examined the evolution of GCash from a mobile wallet to a nationwide digital payment platform promoting financial inclusion through services like bill payments, transfers, and mobile commerce. Strategic partnerships and regulatory support have positioned GCash as a trusted and widely adopted solution, especially during the COVID-19 pandemic. This supports its integration into the vending machine system, as aligning with a well-established platform can boost user confidence, reliability, and adoption in public settings.

D. User Perception of a Developed GCash Cash-In and Cash-Out Machine in the Philippines

User acceptance is key to the success of cashless systems. Enojas et al. [4] developed a GCash cash-in/cash-out kiosk and evaluated it with 50 users. Results showed strong approval: 94% rated the deposit function as "excellent," 92% confirmed accurate cash handling, and all users found it convenient and user-friendly. These findings suggest that well-designed GCash-enabled machines can achieve high user acceptance in the Philippines, supporting the feasibility of integrating cashless modules into public vending systems.

E. Automated Smart Water Vending Machine

Engineering studies on vending machines offer useful design insights. Yadav developed an automated water vending machine in India that accepted multiple coin denominations and dispensed mineral water in response to validated payments. The system included phased development—requirement analysis, component selection, and coin-recognition programming [13]. Its multi-denomination detection and microcontroller-based control provide relevant concepts for designing the currency-handling logic of a GCash-enabled vending system.

F. Smart Water Vending Machine

Karalgikar and Kumar developed a smart water vending machine using an Arduino Uno and RFID cards to enable cashless transactions. Each tap of the RFID card dispensed a fixed volume of water and deducted credit from the card's balance. [6] The system also integrated automation features, including water-level, overflow, and pH sensors. Their work demonstrates how contactless payment and environmental sensing can modernize water dispensers—principles relevant to the design of a GCash-enabled vending system.

G. IoT-Based Smart Vending Machine

Hashi et al. developed an IoT-based vending machine in Somalia that operates 24/7 and integrates with the EVC-Plus mobile payment platform. The system enables real-time monitoring and control, enhancing accessibility in areas with limited infrastructure [5]. This study supports the feasibility of integrating mobile payments and IoT in vending machines, paralleling the goals of the GCash-enabled system. It also suggests that such machines can be effectively deployed in diverse public settings using real-time data for improved efficiency.

I. RFID-Based Cashless Drink Vending

Okafor et al reviewed the transition from coin-operated to RFID-based cashless vending machines, proposing a prototype drink dispenser using RFID cards for contactless payment. Their microcontroller-controlled system improved transaction efficiency and sales tracking compared to traditional machines [8]. Although their study focuses on RFID rather than smartphone payments, it highlights how digital payment integration enhances vending machine reliability, user convenience, and operational data monitoring.

I. QR/ESP32 Snack Vending with Firebase

Maulana et al. developed a snack vending prototype using an ESP32 microcontroller integrated with an Android QR-payment app backed by Firebase. Users select snacks via keypad and pay by scanning a QR code. The ESP32 verifies payment from Firebase before dispensing the snack with a servo. Testing showed reliable hardware performance and accurate transaction recording [7]. This study demonstrates how low-cost IoT hardware combined with cloud/mobile services enables a fully integrated cashless vending system, applicable beyond snacks to other dispensers.

III. METHODOLOGY

A. Component list and its Function

TABLE I
COMPONENTS AND FUNCTIONS

Component	Function
Water Gallon	Primary storage of pre-filtered drinking water.
12 V Adapter	Converts AC mains to 12 V DC, supplying the pump, relay coil, and any other 12 V peripherals with stable power.
Power Module	Regulates and converts input voltage to stable 5V and 3.3V outputs for powering the ESP32, relay, and sensors.
ESP32 Module	Central microcontroller
1-Channel Relay	Electrically isolates the ESP32 from the 12 V pump circuit. When triggered by the ESP32, it closes its contacts to power the pump.
Coin Sensor	Detects and counts pulses as coins pass through. Outputs signals proportional to inserted denominations (used only if cash payments are accepted).
12V Water Pump	Draws water from the reservoir and pushes it through the dispensing hose. Pump run-time is controlled to meter out precise volumes.
Dispensing Hose	Food-grade tubing that carries water from the pump to the outlet. Hygienic, flexible, and easy to replace.

B. Circuit Diagram Flow

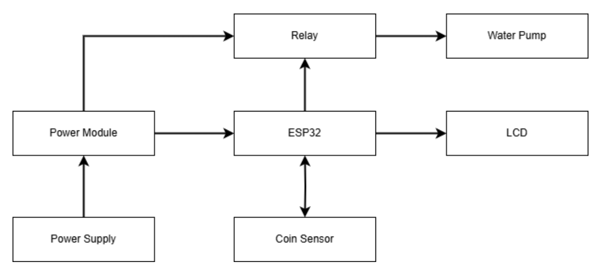

Figure 1: Circuit Diagram Flow

Figure 1 illustrates the power and signal flow among the system's core hardware. The main power source feeds a power management module that regulates voltage to 5V and 3.3V for the ESP32 microcontroller and relay module. The ESP32 controls the system, receiving input signals from a coin sensor it also powers. Upon valid coin detection, the ESP32 activates the relay, which switches power to the water pump to start dispensing. This setup ensures the pump operates only after a confirmed transaction, enhancing efficiency and safety. External elements like the GCash app and Firebase database are not shown in the diagram.

C. Flowchart

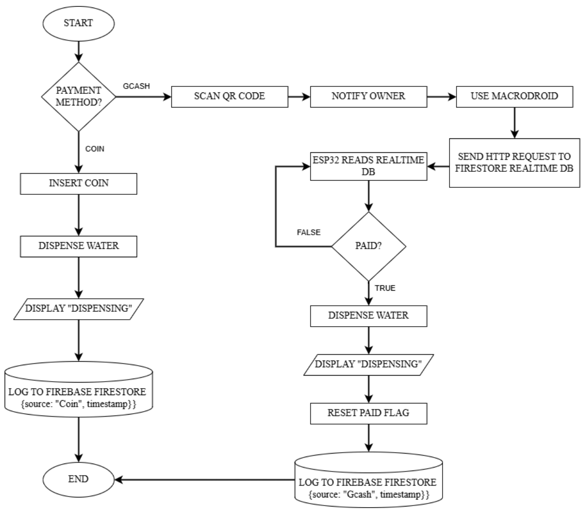

Figure 2: Flowchart

Figure 2 shows the vending machine's flowchart for coin and GCash payments. After selecting a payment method, if Coin is chosen, the user inserts a coin, the machine dispenses water, displays a "Dispensing water..." message, and logs the transaction as "coin." If GCash is selected, the user scans a QR code, notifying the owner. MacroDroid monitors payment notifications and updates a Firebase Realtime Database flag. The ESP32 continuously polls this flag; when set to true, it dispenses water, resets the flag, and logs the transaction as "gcash." The process ends after successful dispensing and logging.

D. Schematic Diagram

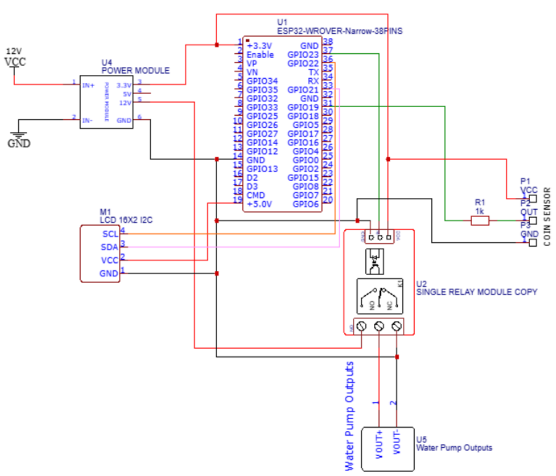

Figure 3: Schematic Diagram

Figure 3 shows the system's schematic with key hardware and connections. The ESP32-WROVER microcontroller (U1) serves as the main controller, powered by a module (U4) converting 12V to regulated 5V and 3.3V for safe operation of components. A coin sensor connects to the ESP32 GPIO pins to detect coin insertion. Upon validation, the ESP32 triggers a relay module (U2) that controls power to the water pump. A 16x2 I2C LCD display (M1) provides user feedback via the ESP32's I2C lines. Output terminals (U3, U5) handle pump connections, while proper distribution of ground and power lines ensures circuit stability.

D. System Architecture

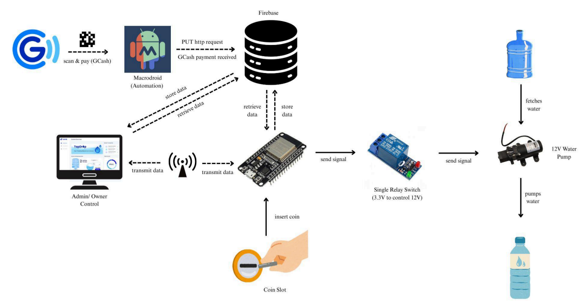

Figure 4: System Architecture

Figure 4 illustrates the system architecture for a contactless, user-friendly purified water dispenser. The ESP32 microcontroller manages inputs, data exchange, and controls dispensing. Payment options include coin insertion and GCash QR code scanning. For GCash, MacroDroid on an Android device detects payments and updates the Firebase real-time database. For coins, the sensor sends signals directly to the ESP32. After verifying payment, the ESP32 triggers a relay that powers the 12V water pump to dispense water. Firebase serves as a centralized cloud database for real-time transaction tracking and synchronization. The machine owner accesses an admin dashboard connected to Firebase for monitoring, transaction logs, and system control.

E. Prototype

The TapDrop prototype features a two-tiered enclosure with distinct functional compartments. The lower compartment is a sealed reservoir housing a standard water gallon, secured upright with tubing extending to the upper section. The upper compartment serves as the user interface area, containing a front-facing coin slot with a sensor and a 16×2 LCD display below it for user prompts. Centrally located is the water faucet outlet, which dispenses water upon payment confirmation. The top panel holds the GCash QR code at eye level for easy scanning. This stacked design integrates water storage, payment input, and user feedback into a compact and intuitive unit.

IV. Results and Discussion

A. System Overview and Testing Procedure

This study developed a prototype GCash-enabled Water Vending Machine supporting both GCash digital payments and manual coin insertion, providing flexible payment options for users. The system employs MacroDroid to detect GCash transaction notifications, which trigger a relay controlling a 12V water pump to dispense water proportional to the payment amount. A coin sensor validates specific denominations (e.g., ₱1) to activate the pump for a preset duration, dispensing the corresponding water volume. The system's effectiveness was evaluated through structured testing, including functionality testing to verify accurate transaction detection and water dispensing, performance testing to assess response time, volume accuracy, and reliability, and usability testing to gauge ease of use and user satisfaction with both payment methods.

B. Functionality Testing

The primary goal was to validate that the system reliably performs all core functions as intended, including accurate detection and response to valid GCash payments, correct activation of the water dispensing mechanism, and rejection of invalid coins or incorrect payment amounts.

TABLE II
FUNCTIONALITY RESULTS

Test Case	Expected Result	Actual Result	Pass/Fail
₱1 via GCash	Dispense 200ml	~ 200ml dispensed	Pass
₱1 coin inserted	Dispense 200ml	~ 200ml dispensed	Pass
Pump unplugged	No Output	No output	Pass
Coin slot jammed	No output	No output	Pass
LCD Text Output	Output text "Dispensing"	Outputted text "Dispensing"	Pass

This shows the functionality results of the GCash-enabled Water Vending Machine under various test conditions. It shows that the machine successfully dispensed 200ml when activated via ₱1 GCash payment or coin insertion, matching the expected outcome. In fault scenarios, such as the pump being unplugged or the coin slot being jammed, the machine correctly produced no output, indicating proper error handling. Additionally, the LCD displayed the correct message "Dispensing" during operation. All test cases passed, demonstrating that the system performs accurately and reliably under both normal and adverse conditions.

C.Performance Testing

This test aimed to measure how efficiently the system responds to inputs and completes dispensing tasks. Metrics included response time, dispensing speed, success rate, and operational stability.

TABLE III
PERFORMANCE RESULTS

Metric	Gcash Result	Coin Insertion Result
Average response time	1.5 seconds	< 1 second
Maximum response delay	< 2 seconds	< 1.5 seconds
Water dispense speed	~ 200 ml in ~3 seconds	~ 200 ml in ~3 seconds
Success rate (10 trials)	90% (A Gcash read error occurred twice, that bot results in the double dispensing of water.)	95% (1 coin read error)
Uptime over 2-hour test	No crash	No crash

This summarizes the performance results of the dispensing system using two different payment methods: GCash and coin insertion. It evaluates various metrics such as response time, dispensing speed, success rate, and system uptime. The average response time was slightly faster with coin insertion (< 1 second) compared to GCash (1.5 seconds). Both methods showed minimal maximum response delays (under 2 seconds), and the water dispense speed was consistent at 200 ml in approximately 3 seconds. In terms of success rate over 10 trials, GCash achieved 90%, with two read errors causing double dispensing, while coin insertion had a 95% success rate with one read error. Importantly, both methods showed no crashes during a 2-hour uptime test, indicating stable operation throughout.

D. Usability Testing

Usability testing assessed the ease of use and user satisfaction across both payment methods. Five participants interacted with the system, each tasked with using both GCash and coin insertion to dispense water. Observations were recorded, and participants completed a brief satisfaction survey.

TABLE IV
USABILITY RESULTS

User	Method Used	Confusion?	Satisfaction (1–5)	Comments
User 1	GCash	Minor	4	“Very modern”
User 2	Coin	None	5	"Very easy and fast."
User 3	GCash	Yes	3	"Wasn’t sure about the correct amount."
User 4	Coin	None	5	"Quick and simple."
User 5	Both	None	4	"Nice to have options."

This shows the usability testing involving five participants who used both GCash and coin insertion methods to dispense water, aiming to evaluate ease of use and user satisfaction. Results showed that most users experienced no confusion and reported high satisfaction scores, particularly with the coin method, which was described as “very easy and fast” and “quick and simple.” One participant encountered minor confusion using GCash, and another had difficulty understanding the correct payment amount, leading to a lower satisfaction score. Overall, feedback indicated that both payment options were generally effective, with some preference for simplicity and clarity.

E. Water Dispensing Volume and Calibration

An essential aspect of the automated water dispensing system is the accurate measurement and calibration of water volume dispensed per payment unit. In this study, the system is configured so that each ₱1 payment activates the water pump for 3 seconds, resulting in the delivery of approximately 6⅔ fluid ounces (oz) of water.
Using standard unit conversion:

$$1\,oz \;\simeq\; 29.5735\,ml$$

The total volume dispensed per ₱1 payment is:

$$6\frac{2}{3} \cdot 29.5735 \;\simeq\; 197.16\,ml \sim 200\,ml$$

This calibrated output ensures that users receive a measurable and fair quantity of water for every transaction. The system's runtime-to-volume ratio allows for consistent dispensing across both digital (GCash) and manual (coin) payment modes.

Maintaining this calibration is essential for long-term reliability. Variations in pump efficiency, voltage fluctuations, or environmental conditions may affect the dispensing rate over time. Therefore, routine calibration checks are recommended to ensure accurate volume delivery and uphold user trust.

E. System Limitations

The GCash-enabled Water Vending Machine prototype demonstrated reliable performance but revealed several limitations. The system cannot distinguish payments intended for multiple units since MacroDroid detects GCash notifications without identifying metadata, necessitating separate accounts per machine or integration with a GCash API for accurate transaction association. The reliance on MacroDroid, an unofficial mobile automation app, poses risks related to app updates or notification delays that may affect responsiveness. Stable internet connectivity is critical for real-time GCash payment processing, and weak Wi-Fi signals can cause transaction delays or failures, impacting user experience. Additionally, the system lacks mechanisms for error handling or refunds in case of incorrect payments, which may lead to user dissatisfaction. Finally, the 12V water pump cannot self-prime when the water source is below the pump intake, requiring careful installation to ensure proper water flow.

V. Conclusion and Recommendation

A. Conclusion

In conclusion, this research was able to reach its objective which is to come up with a working model of a Water Vending Machine that has both digital (GCash) and manual coin acceptance systems. The machine dispenses around 200 ml of purified drinking water for each ₱1 paid, correctly sensing and authenticating valid payments in both modes. During the development and testing process, the system exhibited considerable reliability, consistency, and responsiveness, especially in the coin-operated mechanism and the reproducibility of its operation in both transaction modes. Usability testing validated that the machine is largely intuitive and easy to use, with users finding the payment and dispensing procedures easy to understand. Feedback did identify, however, that there is a need for simpler instruction during the GCash transaction process, with users noting that more visual cues or step-by-step instructions would add to the ease of use. Addressing these minor usability issues will ensure that even initial users or those not familiar with digital payments can easily use the system. The integration of both GCash and coin-based payment options directly addresses the limitations of traditional water vending machines by catering to diverse user preferences and financial capabilities. By accommodating both cash-reliant and cashless users, the machine becomes a practical, modernized solution suitable for deployment in both urban and rural areas seeking convenient, secure, and automated access to drinking water. Overall, the GCash-enabled Water Vending Machine prototype has been a workable, convenient, and effective way of providing potable drinking water using automated technology. Its successful merging of secure payment recognition, proper water dispensation, and user-friendly design shows great promise for further development and practical application. With slight refinement of the digital payment interface, this system can meaningfully help solve public access to safe water while encouraging the use of innovative, cashless technologies.

A. Recommendation

To improve the GCash-enabled Water Vending Machine, it is recommended to integrate the official GCash API with webhook support for accurate payment identification across multiple units. Replacing MacroDroid with a dedicated app or direct microcontroller integration will enhance system stability. To address internet dependency, offline payment options or transaction caching should be implemented. Adding payment validation and refund mechanisms will improve user satisfaction. Finally, using a self-priming pump or providing clear installation guidelines will ensure reliable water dispensing. These measures will enhance the system's reliability, usability, and scalability.

References

[1] F. P. Afable, "GCash: Revolutionizing digital payments in the Philippines and beyond," SSRN, 2024. [Online]. Available: https://doi.org/10.2139/ssrn.4871527

[2] Z. J. A. Belmonte, Y. T. Prasetyo, M. M. L. Cahigas, R. Nadlifatin, and M. J. J. Gumasing, "Factors influencing the intention to use e-wallet among generation Z and millennials in the Philippines: An extended technology acceptance model (TAM) approach," Acta Psychologica, vol. 250, Art. no. 104526, 2024. [Online]. Available: https://doi.org/10.1016/j.actpsy.2024.104526

[3] R. C. Dela Cruz, "GCash has now over 33 million users," Philippine News Agency, Feb. 2021. [Online]. Available: https://www.pna.gov.ph/articles/1130710

[4] M. J. B. Enojas, J. E. Morgado, H. L. Bongao, R. G. Arribas, C. Damiles, K. J. Z. N. Talon, and L. M. M. Turallo, "User perception of a developed GCash cash-in and cash-out machine in the Philippines," Indonesian Journal of Electrical Engineering and Computer Science, vol. 32, no. 1, pp. 328–334, 2023. [Online]. Available: https://doi.org/10.11591/ijeecs.v32.i1.pp328-334

[5] M. N. Hashi, Y. S. Abdulle, Y. A. Kayre, A. D. Mohamud, M. A. Khalaf, and S. A. Kahie, "IoT-based smart vending machine," in Elsevier eBooks, pp. 277–286, 2024. [Online]. Available: https://doi.org/10.1016/b978-0-443-13268-1.00008-x

[6] R. Karalgikar and H. P. Kumar, "Smart water vending machine," International Journal of Research in Engineering, Science and Management, vol. 2, no. 9, pp. 225–226, 2019. [Online]. Available: https://www.ijresm.com/Vol.2_2019/Vol2_Iss9_September19/IJRESM_V2_I9_64.pdf

[7] A. J. Maulana, E. Alimudin, V. Prasetia, and M. R. Hidayat, "Snack vending machine using QR code as payment method," Jurnal Ecotipe (Electronic Control Telecommunication Information and Power Engineering), vol. 10, no. 1, pp. 1–11, 2023. [Online]. Available: https://doi.org/10.33019/jurnalecotipe.v10i1.3357

[8] P. Okafor, C. Ituma, and G. James, "Implementation of a Radio frequency identification (RFID) based cashless vending machine," International Journal of Computer Applications Technology and Research, 2023. [Online]. Available: https://doi.org/10.7753/ijcatr1208.1013

[9] M. T. Picardal, E. M. G. Rapirap, L. I. Micame, M. J. B. Tura, O. N. Barrientos, R. A. Kimilat, A. C. Sarnillo, and A. L. Porol, "Drinking water quality from water vending machines in selected public schools in Cebu City, Philippines," Environmental Science & Sustainable Development, vol. 3, no. 2, pp. 1–9, 2018. [Online]. Available: https://doi.org/10.21625/essd.v3i2.253.g144

[10] A. Samaniego, "Philippines achieves major milestone in digital payments as technology accelerates cashless adoption," Manila Bulletin, Aug. 29, 2024. [Online]. Available: https://mb.com.ph/2024/8/30/philippines-achieves-major-milestone-in-digital-payments-as-as-technology-accelerates-cashless-adoption

[11] D. Susilo and C. C. G. Dizon, "Digital payment transformation in the Philippines: From cash to GCash," SEAN Institute, Dec. 4, 2023. [Online]. Available: https://ejournal.seaninstitute.or.id/index.php/Ekonomi/article/view/3366

[12] C. Venzon, "Philippines to boost fintech oversight after top e-wallet glitch," BNN Bloomberg, Nov. 20, 2024. [Online]. Available: https://www.bnnbloomberg.ca/business/2024/11/20/philippines-to-boost-fintech-oversight-after-top-e-wallet-glitch

[13] J. S. Yadav, "Automated smart water vending machine," in INCONRIT 2017: International Conference on Digitalization: Impact on Indian Society, Mar. 2017. [Online]. Available: https://www.researchgate.net/publication/319535629_Automated_Smart_Water_Vending_Machine