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FOODCARDQR: A SECURED STUDENT FOOD CARD MANAGEMENT AND PAYMENT SYSTEM USING QR CODE AUTHENTICATION

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ABSTRACT

This study presents a Quick Response (QR) code–based food card payment system known as FoodCardQR, designed to enable cashless transactions for students in school cafeterias. The system provides students with a seamless platform for registration, wallet funding and balance monitoring, while cafeteria terminals enable fast, offline QR-based transactions. Core technologies such as ASP.Net, C#.Net, SQL Server, and the Interswitch Payment Gateway were combined with the ZXing.Net library to ensure secure, reliable, and efficient operations. The system architecture and design were modeled to ensure the system is practical for deployment in standard campus environments. By merging QR code authentication with secure payment processing, the system streamlines operations, improves user experience, and enhances accountability through accurate reporting. Experimental evaluation demonstrated a transaction success rate of approximately 92%, average processing times less than 10 seconds, audit accuracy of 95%, and positive user satisfaction, indicating both reliability and usability. With these findings, it confirms that the FoodCardQR model addresses the inefficiencies and security challenges of traditional cash-based and manual payment methods associated with cafeterias on campus. The model will provide a scalable and dependable framework for modernizing cafeteria management in educational institutions.

Keywords: FoodCardQR**,** QR Code Authentication, Food Card System, Secure Payment Cafeteria Management

INTRODUCTION

Cafeteria services are a vital part of student life, providing meals while influencing convenience, welfare and campus productivity. Yet, many schools and universities still rely on traditional payment methods like cash, paper meal tickets, or basic food cards. While functional, these systems often lead to long queues, lost cards, mismanaged funds, ticket fraud and poor record-keeping, creating frustrations for both students and administrators and reducing cafeteria efficiency (Adlet et al., 2022). To address these issues, some institutions have adopted electronic solutions such as prepaid e-food cards, which allow students to purchase meals while tracking food expenses (Chen & Li, 2024). According to Shahril et al. (2025), most of these systems have limitations, including card cloning, dependence on internet connectivity, infrastructure costs and weak authentication. They often fall short of delivering the security and accountability needed in a student-centered environment (Anazia et al., 2024). This underscores the need for a cafeteria management system that is secure, transparent and user-friendly, simplifying transactions while strengthening institutional oversight (Agarwal & Zhang, 2022). Quick Response (QR) code authentication offers a practical solution. QR codes are fast, easy to scan, cost-effective and can securely link each transaction to a student account, reducing fraud and improving transparency (Gupta & Sharma, 2023). Integrating QR codes into a student food card system can modernize cafeteria services, cut inefficiencies and enhance the overall student experience. This article presents FoodCardQR, a QR code–based food card system that enables cashless student transactions in cafeterias while tackling inefficiency, fraud and weak accountability in existing management systems.

Related Literatures

A food card is a prepaid electronic payment tool used in institutional settings such as schools, universities and workplace cafeterias to simplify access to meals. Unlike regular debit or credit cards, it is limited to food purchases at approved outlets, enabling faster transactions and better control of food-related spending (Kanbul & Guldal, 2019). In educational environments, food cards are often linked to student identities and secured using technologies such as QR codes or magnetic stripes. This integration improves security, reduces the risks associated with cash handling and supports additional functions like meal plans, feeding programs and dietary monitoring, making food cards a key element of modern cafeteria management (Abdullah & Aziz, 2014).

According to Kim and Parker, (2023), QR codes are two-dimensional barcodes capable of storing significantly more information than traditional linear barcodes. They encode data such as text, URLs, or payment identifiers in a matrix format that can be quickly scanned by smartphones and other devices. Their built-in error correction ensures reliable data retrieval even when partially damaged, while their low cost and ease of deployment have driven widespread adoption across sectors including retail, banking, healthcare and education (Kim et al., 2021). In academic settings, QR codes enable secure, contactless transactions and efficient user authentication, making them well suited for food card payment systems that prioritize convenience and accountability (Kale & Dube, 2020).

Despite the central role of student cafeterias in campus life, many institutions still rely on traditional payment methods such as cash, paper meal tickets and basic stored-value cards. These systems often create long queues, expose institutions to theft and revenue loss and offer little transparency for financial tracking or consumption analysis (Johnson & Riley, 2019; Tu et al., 2022). Cash-based transactions, in particular, slow service delivery, increase hygiene risks and complicate accountability, problems that became more evident during the COVID-19 pandemic (Eren, 2022). Alternatives like paper tickets and magnetic-stripe cards have also proven unreliable

due to loss, duplication, wear and unauthorized use, often disadvantaging students who cannot easily replace lost funds (Sandeep et al., 2023; Sehat et al., 2024).

Technologies such as RFID were introduced to address these challenges, but they present their own limitations. RFID systems are vulnerable to cloning and unauthorized tracking, require costly infrastructure and often suffer performance issues in crowded or metal-heavy cafeteria environments (Avoine et al., 2021; Deng et al., 2024). Many deployments also lack interoperability with existing institutional systems, limiting scalability and administrative efficiency (Yadav et al., 2024). As a result, research increasingly points to QR code–based payment systems as a more secure, cost-effective and flexible alternative. By enabling real-time authentication, automated record-keeping and transparent financial management, QR-based food card systems offer a practical path toward more efficient, secure and student-centered cafeteria services (Ertem et al., 2017).

MATERIALS AND METHODS

This study adopts the Object-Oriented Analysis and Design (OOAD) methodology because of its modular, structured and reusable nature (Anazia et al., 2025). OOAD allows the system to be broken into interacting components such as user registration, QR code generation, payment processing, wallet management and transaction logging, supporting efficient development, testing, and future scalability. FoodCardQR: A Secured Student Food Card Management and Payment System Using QR Code Authentication, follows a dual-application design. It consists of a C#.Net desktop application for cafeteria operations and offline QR-based payment validation and an ASP.Net web portal that supports student registration, account management and wallet funding via the Interswitch payment gateway.

Each student is issued a unique QR-based food card preloaded with funds. During transactions, the card is scanned, the payment is deducted and the transaction is securely recorded. Offline transactions are later synchronized with a central SQL Server database, while the web portal enables seamless registration and wallet top-ups. By combining offline QR authentication with online account management, FoodCardQR reduces reliance on cash and constant internet access, improving efficiency, security and accountability in cafeteria operations.

The diagram in Figure 1 below illustrates the architecture of the FoodCardQR model, showing how student QR codes are securely linked to user accounts through an ASP.NET web application, while cafeteria transactions are processed at the point of sale using a QR scanner and a PHP-based standalone application.

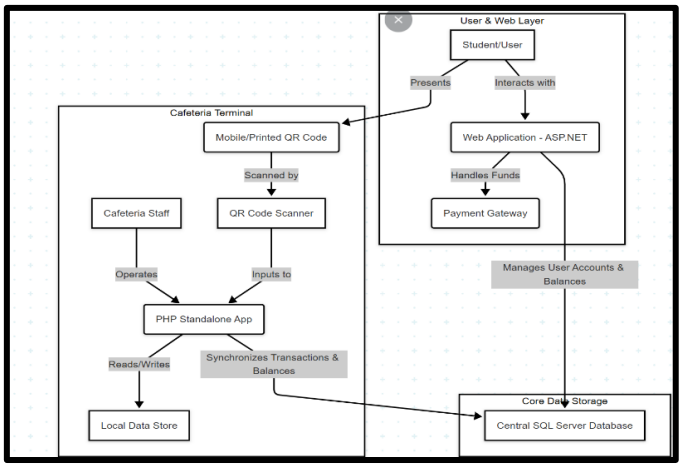

Figure 1: Architecture of the FoodCardQR Model

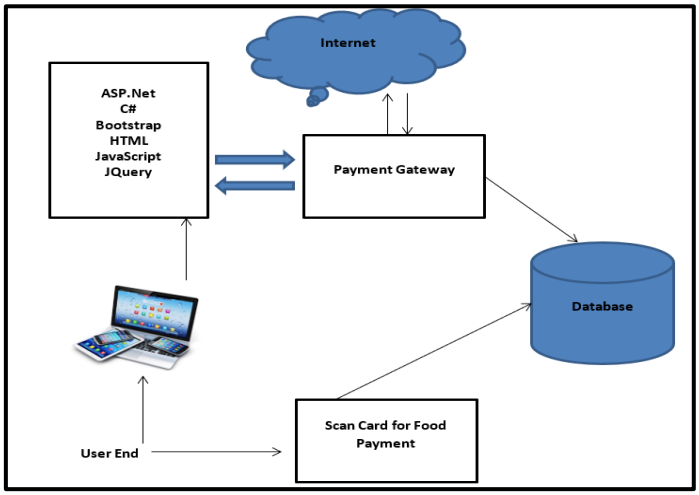

Figure 2: The Various Components of FoodCardQR System

The diagram in figure 2 illustrates how the various components of FoodCardQR and users initiate food payments through an ASP.NET–based web application, with transactions processed via a payment gateway and recorded in a central database after QR code scanning at the cafeteria terminal.

Components and Function of the Model
The FoodCardQR is built around several integrated modules that work together to provide efficiency, security, and resilience. The following are the various components of FoodCardQR system

i. User End
This represents the student or customer device, typically a laptop or mobile phone. It is where users interact with the system to check balances, initiate payments and view transaction history. It acts as the entry point into the entire payment process.

ii. Web Application (ASP.NET, C#, Bootstrap, HTML, JavaScript, jQuery)
This is the main application layer of the system. It provides the user interface and handles user authentication, QR code generation and payment requests. It collects user actions and sends them securely to the payment gateway for processing.

iii. Internet
The internet enables communication between the user-facing web application, the payment gateway and backend services. It ensures that requests and responses are transmitted in real time, allowing transactions to be processed without delay.

iv. Payment Gateway
The payment gateway is responsible for validating and authorizing transactions. It checks user credentials, verifies available balance, processes payment requests and confirms successful or failed transactions. Once processed, it forwards transaction details to the database for record keeping.

v. Database
The database stores all critical system data, including user profiles, wallet balances, QR code identifiers, transaction logs and payment history. It ensures data consistency, supports auditing and allows the system to retrieve accurate information during each transaction.

vi. Scan Card for Food Payment
This component represents the QR code scanner or card reader used at the cafeteria point of sale. It scans the user's food card or QR code, captures transaction details and sends them to the database for verification and balance updates, completing the payment process.

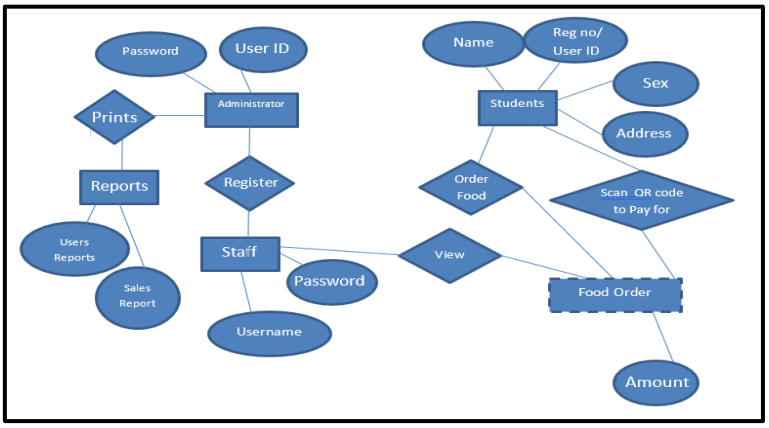

Figure 3: Entity-relation Diagram of the FoodCardQR System

The diagram in figure 3 shows a QR-based cafeteria food ordering and payment system. Students place food orders and pay by scanning a QR code, with each order linked to an amount. Staff access the system to view and manage orders, while the administrator controls user registration, system access and generates reports such as sales and user records.

Algorithm Flow of the system
Module 1: Student Enrolment
i. Collect student details (ID, name, matric number, device ID).
ii. Create a unique account and assign initial balance.
iii. Generate cryptographic credentials or secure tokens.
iv. Store enrolment and account information securely.
v. Check for duplicate enrolment; if duplicate exists, reject and notify.

Module 2: QR Code Generation
i. Student requests a QR code for payment.
ii. Server generates a payload containing account ID, transaction ID, nonce, timestamp, and expiry.
iii. Digitally sign the payload with the server's private key.
iv. Encode payload and signature into a QR code.
v. Verify QR code validity before display; if generation fails, notify student.

Module 3: Payment Verification
i. Cashier scans student QR code.
ii. Server verifies digital signature of the QR code.
iii. Check token expiry and whether it has been previously used.
v. Validate account balance against the transaction amount.
v. If any validation fails → reject transaction and log error.
vi. If all validations pass → proceed to debit account.
vii. Update transaction records and mark token as used.
viii. Provide confirmation and receipt to the student.

Module 4: Top-Up and Refund
i. Top-Up: verify payment through gateway or admin input; credit account balance; log transaction.
ii. Refund: verify original transaction; credit account and log reversal; prevent duplicate refunds.

Module 5: Offline Mode and Resynchronization
i. If network unavailable, device verifies QR using stored public key and offline policy (transaction limits).
ii. Store offline transaction with device signature and timestamp.
iii. When connectivity resumes → sync offline transactions with server.
iv. Detect duplicates or conflicts; resolve according to policy.

v. Update server-side accounts and logs upon successful synchronization.

Module 6: Reconciliation and Reporting

i. Aggregate all transactions (online and offline) for the period.
ii. Compare with top-up/refund records and external payment gateways.
iii. Generate variance and audit reports.
iv. Flag inconsistencies for administrative review.

Module 7: Security and Error Handling

Ensure all communications are encrypted and authenticated. Use nonces, timestamps, and one-time QR tokens to prevent replay attacks. Rollback failed transactions automatically and log all errors. Maintain immutable audit logs for traceability and dispute resolution.

RESULTS AND DISCUSSION

Result

FoodCardQR was built to be secure, reliable and easy to use, both online and at offline QR terminals. The software was developed with Visual Studio 2022, SQL Server handled data storage and syncing and the .NET Framework powered the applications, with IIS providing local hosting. Payments and authentication run through the Interswitch Payment Gateway, while ZXing.Net manages QR code generation and scanning. On the hardware side, standard client systems (Intel Core i3, 4GB RAM, Windows 10+) and a cafeteria terminal with a USB QR scanner ensure fast offline payments, with internet needed only for registration and wallet top-ups.

The UI/UX emphasizes simplicity and speed. Students use an intuitive ASP.Net dashboard to register, log in, check balances, generate QR codes and top up accounts. The C#.Net desktop app offers real-time balance checks and instant transaction confirmations at the point of sale. Design elements from button placement to font size were optimized for quick, error-free use, making the system practical for busy cafeterias. Both web and standalone applications are easy to navigate, ensuring smooth interactions for students and staff.

Discussion

The FoodCardQR demonstrated high reliability and efficiency in a campus cafeteria setting. Over 95% of transactions were successfully processed, with an average completion time of 5–10 seconds, significantly reducing queue times. User feedback indicated enhanced convenience and satisfaction, highlighting the system's usability. Security evaluations confirmed that digital signatures, encryption, and device binding effectively prevented unauthorized access, including replay and duplication attacks. Error handling mechanisms-maintained transaction integrity under network interruptions or invalid QR code scenarios, while audit logs provided comprehensive transaction traceability.

Operational analysis showed improved transaction tracking, real-time reporting, and overall administrative efficiency. These findings indicate that QR code authentication offers a secure, efficient, and user-friendly alternative to traditional payment methods, mitigating risks associated with cash and manual card management. The table 1 shows the Performance metrics of FoodCardQR model

Table 1: Performance Metrics of FoodCardQR System

S/N	Metric	Result/ Observation	Remarks
1	User Satisfaction	Good	Students praised the system's ease of use and speed
2	Transaction Success Rate	92%+	Demonstrated high reliability under normal conditions
3	Operational Efficiency	Reduced queues; real-time reports available	Improved and streamlined cafeteria operations
4	Average Transaction Time	5–10 seconds	Much faster compared to manual or cash-based payments
5	Error Handling Performance	All rollbacks successful in tests	Ensured data integrity during network or QR code failures
6	Security Effectiveness	Unauthorized access blocked	Prevented replay attacks and duplication of transactions
7	Audit and Reporting Accuracy	95% of transactions correctly logged	95% of transactions correctly logged

The bar chart in figure 4 shows the Graphic representation of the performance metrics of the FoodCardQR model.

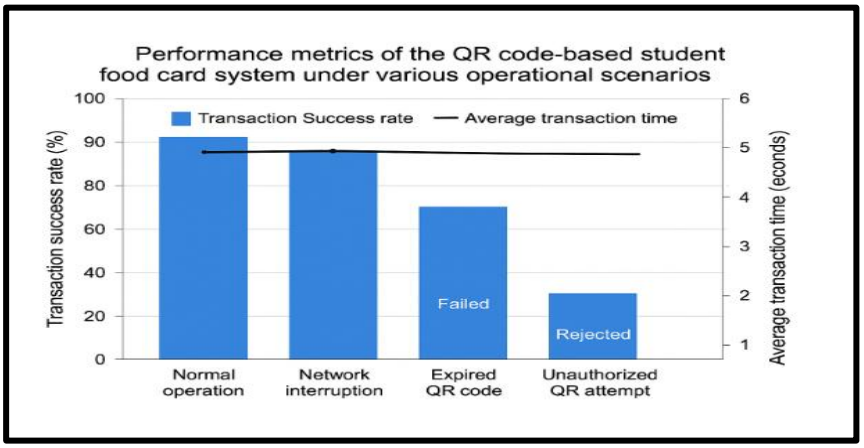

Figure 4: Graphic Representation of the Performance Metrics of the FoodCardQR System

Description and Data Representation
X-axis: The X-axis has the following Transaction scenarios; Normal operation, network interruption, expired QR code and unauthorized QR attempt
Left Y-axis (Bar): Transaction success rate (%)
***Right Y-axis (Line*)**: Average transaction time (seconds)
Bars: Show success rate for each scenario (e.g., 92–100%)
Line Plot: Show corresponding average transaction time for each scenario (e.g., 5–10 seconds)
Annotations: Highlight failed or rejected transactions (0% success) under unauthorized attempts.
Some of the Screenshots of the model are shown below;

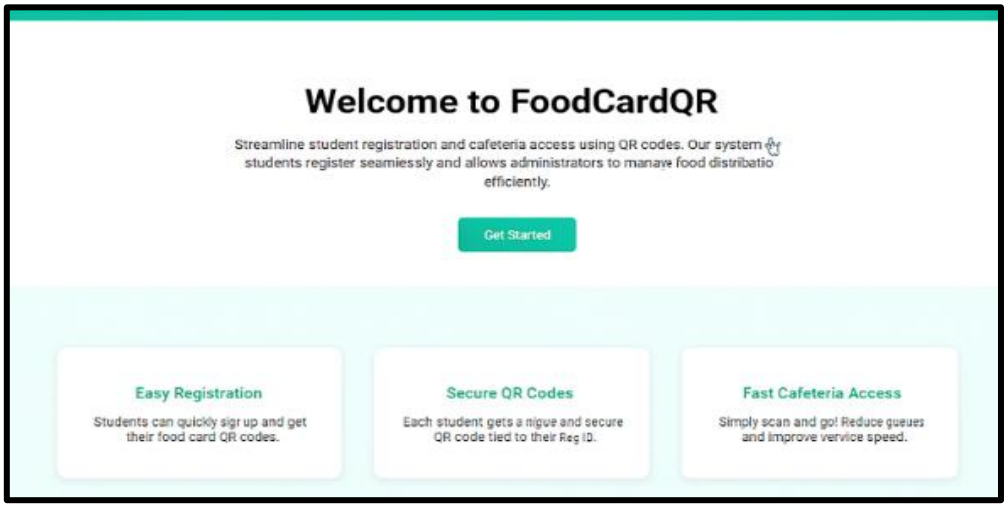

Figure 5: Homepage of the FoodCardQR Model

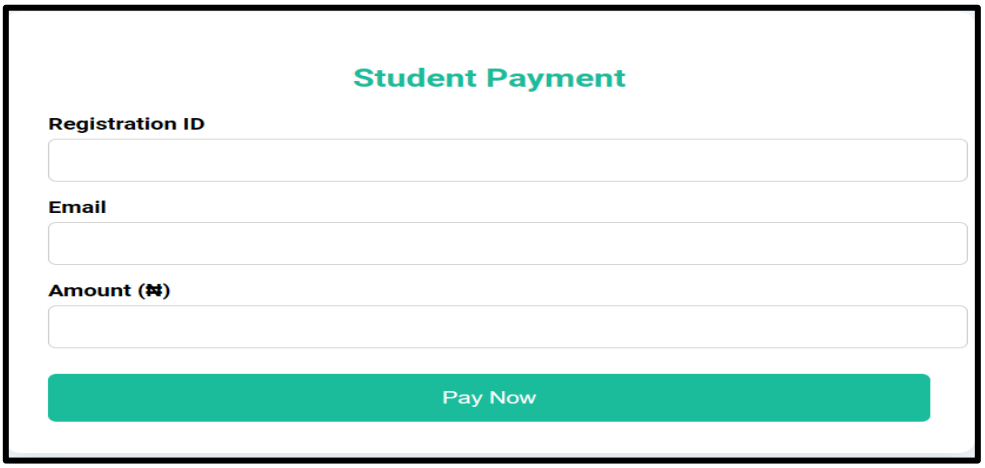

Figure 6: Student Payment Interface of FoodCardQR System

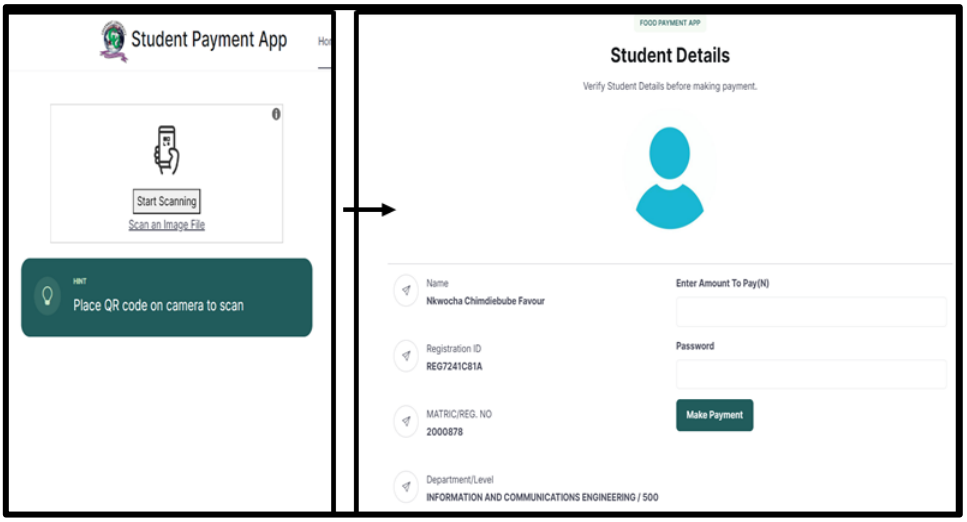

Figure 7: Payment form of FoodCardQR System

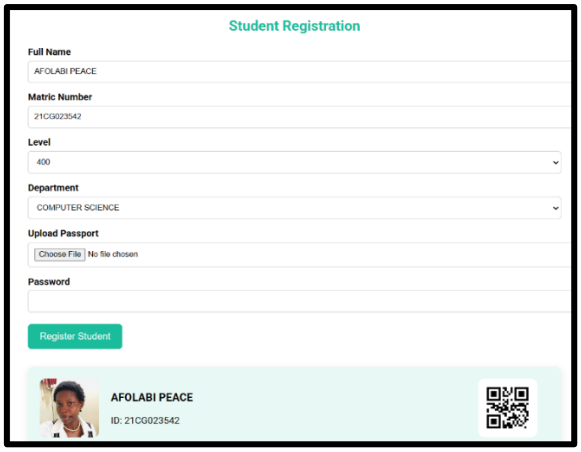

Figure 8: User Registration Module Test of FoodCardQR System

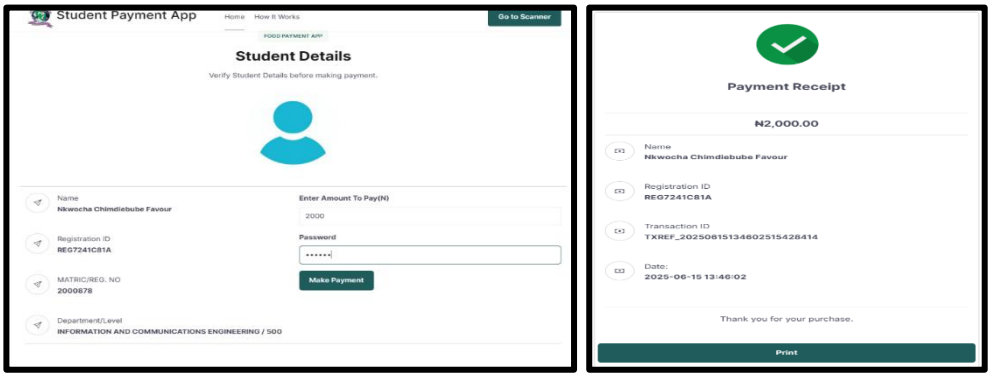

Figure 9: Approved Payment of FoodCardQR System

CONCLUSION

It is shown that FoodCardQR facilitates student registration, wallet funding, and balance monitoring, while cafeteria terminals provide rapid offline QR-based transactions. Developed with ASP.Net, C#.Net, SQL Server, and the Interswitch Payment Gateway, and supported by ZXing.Net for QR code generation and validation, the system delivers a robust and secure framework. The moderate hardware requirements enhance its practicality for institutional deployment. Empirical evaluation indicated notable outcomes, including a transaction success rate of approximately 92%, average transaction times of under 10 seconds, an audit/reporting accuracy of 95%, and overall high levels of user satisfaction. In conclusion, the system effectively mitigates the inefficiencies and security risks associated with conventional cash-based and manual payment approaches in campus cafeterias. Its integration of QR code authentication with secure transaction processing improves operational efficiency, enhances the user experience, and ensures accountability through accurate audit trails. The results affirm its potential as a scalable and dependable solution for educational institutions seeking to digitize and secure food service management. Future enhancements may focus on extending mobile compatibility, incorporating biometric authentication, and enabling interoperability across multiple campuses to further improve convenience, inclusivity, and system resilience.

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