EduTap: An RFID-Enabled Cashless Canteen Transaction and Digital Allowance System for Basic Education Students of St. Clare College

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ABSTRACT

The traditional cash-based transaction ecosystem within educational institutions faces persistent challenges, including protracted queuing times, structural vulnerabilities to cash loss, and an absolute deficit in parental financial oversight. This study designs, implements, and evaluates EduTap, a web-based, Radio Frequency Identification (RFID)-enabled cashless canteen transaction and digital allowance management platform tailored explicitly for the basic education sector of St. Clare College. Adopting a quantitative approach embedded within a developmental-descriptive-evaluative research design, the system was engineered using an Iterative/Incremental Software Development Methodology. The technical architecture integrates an interactive frontend developed using TypeScript, ReactJS, and Tailwind CSS, coupled with a cloud-based backend utilizing Firebase Authentication and Cloudinary alongside Firestore and Realtime Databases.

The system was evaluated by 120 purposively sampled stakeholders, equally distributed ($n = 30$) across four distinct user strata: students, parents/guardians, class advisers, and canteen personnel. Empirical validation via an Independent Samples t-test revealed a statistically significant reduction in transaction latency ($t\ (198) = 62.45$, $p < 0.0001$), with mean purchase execution times plummeting from 42.0 seconds via traditional cash handling to 12.0 seconds utilizing the EduTap RFID protocol. System evaluation metrics aligned with the ISO/IEC 25010 Software Quality Model demonstrated exceptional acceptability, yielding an overall weighted mean of 4.66($SD = 0.34$), signifying unanimous verbal interpretation of "Strongly Agree." Furthermore, a formal Cost-Benefit Analysis (CBA) confirmed economic viability, establishing a rapid payback period of 1.07 years and a projected 3-year Benefit-Cost Ratio (BCR) of 2.17. These findings conclusively indicate that the deployment of EduTap eliminates operational cash dependencies, establishes strict parental expenditure caps, minimizes cash loss, and drastically enhances overall campus transaction efficiency.

Keywords: Radio Frequency Identification (RFID), Cashless Canteen System, Digital Allowance Management, Fintech in Basic Education, ISO/IEC 25010 Software Quality, Point-of-Sale Automation.

INTRODUCTION & LITERATURE REVIEW

Background of the Study

Within contemporary basic education ecosystems, the daily financial management of student allowances presents a systemic challenge characterized by operational friction and a total lack of transparency. The structural architecture of school canteens has traditionally relied upon physical currency to facilitate microtransactions. For basic education learners, who inherently lack advanced fiscal discipline and risk-management capabilities, this cash-centric paradigm exposes them directly to recurring financial vulnerabilities, including physical cash displacement, peer-induced security threats, and impulsive overspending. Concurrently, parents and legal guardians are entirely marginalized from the in-school consumption environment; they remain incapable of monitoring real-time transaction streams, enforcing contextual budgeting constraints, or evaluating the dietary and fiscal choices of their children.

From an institutional perspective, manual cash handling generates severe operational bottlenecks. During peak intermission and lunch periods, the manual processes of itemization, payment tender verification, and physical change calculation severely constrain canteen throughput. This baseline transaction latency creates dense physical bottlenecks, forcing students to exhaust limited break periods waiting in line. The introduction of modern fintech paradigms offers a robust mechanism to optimize these operational parameters. Radio Frequency Identification (RFID) technology offers superior operational advantages over legacy payment structures due to its contactless nature, rapid electronic processing capabilities, secure data storage, and resilience against physical wear. By engineering an ecosystem where student identification cards double as encrypted cryptographic tokens linked to cloud-managed digital wallets, educational institutions can establish a closed-loop transaction framework.

This research introduces EduTap: An RFID-Enabled Cashless Canteen Transaction and Digital Allowance System customized for St. Clare College. The platform replaces cash dependencies with a secure, adviser-monitored RFID protocol.

To protect against device loss, the operational framework mandates that class advisers manage physical card distribution prior to break intervals and execute systematic collection immediately upon class resumption. Supported by cloud databases, the system offers parents remote fund replenishment, daily and monthly expenditure analytics, and enforceable daily spending caps.

This approach optimizes canteen throughput while providing a secure financial monitoring infrastructure for basic education students.

Statement of the Problem

The existing cash-based canteen transaction system at St. Clare College exhibits critical operational deficiencies that negatively impact students, parents, administrative staff, and canteen concessionaires. Students frequently lose physical currency, struggle with personal budgeting, and face long wait times that impact their rest periods. Parents lack clear visibility into how allowances are spent, while canteen staff deal with slow service speeds during high-volume periods.

To address these challenges, this study answers the primary research question: How will an RFID-based cashless canteen transaction and digital allowance system enhance the efficiency, transparency, and security of handling student allowances at St. Clare College?

Specifically, this investigation addresses the following sub-problems:

1. How can cash transactions within the school canteen environment be entirely eliminated through the implementation of localized RFID communication protocols?
2. What specific technical features must be integrated into the fintech solution to allow parents to remotely replenish funds, configure maximum daily spending limits, and audit transaction records?
3. How can the system mitigate the risks of lost or stolen tokens for primary-level basic education students?
4. To what exact degree can the integration of an RFID-based system accelerate transaction processing speeds and minimize student queuing times during peak hours?
5. How can the system automatically generate and deliver daily itemized breakdowns and monthly billing summaries to parents or guardians?
6. How can class advisers facilitate card safety and tracking through a structured collection and distribution system managed via the platform interface?

Significance of the Study

The development and deployment of EduTap offers significant utility for multiple stakeholders within the St. Clare College community, replacing traditional cash systems with an automated, tech-driven platform.

- Students: Benefits include an accelerated, contactless method to purchase food without carrying physical cash. This shortens canteen queues and helps develop early financial responsibility through enforced daily spending limits.
- Parents or Guardians: Provides an administrative dashboard to manage allowance funds remotely, set spending caps, and monitor historical transactions. This ensures full transparency regarding how financial allocations are used.
- Canteen Staff: Introduces an automated Point-of-Sale (POS) interface that speeds up transactions, reduces manual cash-counting errors, optimizes inventory tracking, and automatically aggregates daily sales logs.
- Advisers and School Administration: Provides structured monitoring tools to oversee card distribution and collection protocols. Administrators gain clear visibility into canteen commerce data to support institutional decisions.
- The Institution (St. Clare College): Supports modernization efforts by deploying a secure digital payment infrastructure, enhancing its standing as a technology-driven educational institution.
- Future Researchers: Provides an empirical, field-tested model for implementing closed-loop RFID transactional networks and digital wallet frameworks in primary and secondary school settings.

Scope and Delimitations

The scope of this research centers on the design, development, and validation of the web-based EduTap platform for basic education students at St. Clare College. The system includes an RFID-based payment processor for canteen purchases, a parent/guardian management portal for remote top-ups and daily spending caps, an administrative interface for class advisers to track card distribution, and a POS interface for canteen personnel to manage inventory and review auto-generated sales analytics. System validation was conducted using structured evaluation tools mapped to the ISO/IEC 25010 Software Quality Model and an Independent Samples t-test for transaction speed metrics.

The study is strictly delimited in the following areas:

- Target Institution & Population: Implementation and testing were conducted exclusively within the basic education department of St. Clare College.
- Payment Infrastructure: The transaction engine operates solely via the closed-loop, pre-loaded RFID balance. It does not interface with external credit/debit networks or third-party commercial e-wallets at the point of sale.
- Hardware and Alternative Technologies: The wireless architecture is strictly restricted to standard high-frequency RFID devices, excluding alternative biometric verification mechanisms or Near Field Communication (NFC) protocols.
- Integration Constraints: Financial loading gateways rely on a dedicated digital gateway simulated within a secure cloud sandbox. The system does not directly integrate with commercial core-banking institutions.

REVIEW OF RELATED LITERATURE AND STUDIES

Local Context

Recent research highlighted the increasing adoption of digital payment systems across the Philippines, driven by structural shifts toward automation and financial inclusion. Ramos (2025) noted that while cashless payment systems show high user acceptance due to clear convenience and transparency benefits, structural challenges remain, such as security concerns, technology access gaps, and a large unbanked population. This underscores the need for localized, closed-loop solutions like EduTap that provide managed environments for unbanked student populations.

This alignment reflects national initiatives led by the Bangko Sentral ng Pilipinas (2018), which documented the country's strategic transition toward digital transactions, showing an increase in digital payment volume from 1% in 2013 to 10% by 2018. This macro-level shift has directly influenced educational environments. For example, Cendana and Palaoag (2019) explored transforming traditional student identity cards into multi-functional Smart IDs within Philippine higher education institutions, reporting a 91.5% positive perception score regarding structural acceptability.

In parallel, local implementations have demonstrated the utility of RFID frameworks to address operational safety and accounting issues. De Vera (2018) highlighted that RFID integrations in school environments significantly accelerate transaction speeds, lower manual processing errors, and eliminate cash-related theft or loss risks. This is further supported by Estopace (2017), who documented a joint implementation by PayMaya and local schools where student identification cards double as cashless transaction tokens, offering parents real-time SMS notifications upon campus arrival and transaction execution.

Empirical testing within local school canteens confirms these benefits. Cruz, Marasigan, Dalisay, and Ramos (2017) conducted a true experimental study evaluating automated self-service canteen infrastructure, finding statistically significant improvements in processing times compared to traditional cash transactions. Similarly, Mañibo, Romasanta, and Marasigan (2017) developed a secure, prepaid RFID card system with embedded keypad recharge stations, confirming high reliability and transaction safety.

Finally, Espinosa, Lumibao, Zerrudo, and Intal (2020) demonstrated via prototype testing that shifting from cash to an automated system streamlines school canteen operations by removing redundant accounting steps. This aligns with a project at the Polytechnic University of the Philippines (2019), which deployed an RFID-enabled payment system linked to an online parent portal for remote account management, successfully reducing wait times and improving allowance oversight.

Foreign Context

International research consistently supports the use of RFID systems to optimize campus commerce and administrative workflows. Lissa'idah, Rosid, and Fitrani (2019) designed a web-based canteen payment platform using RFID nodes in Indonesia, demonstrating that digital ledger systems reduce service bottlenecks and generate highly accurate transaction histories. Kim and Lee (2017) examined the broader impact of contactless transactions, concluding that RFID technology improves the user experience in microtransaction environments, such as canteens and micro-retail, by ensuring data accuracy and secure transaction tracking.

To address the common operational issue of small-denomination cash change management, Murugan and Ramakrishnan (2019) designed an RFID-microcontroller database framework that records small-value electronic transactions, highlighting the cost efficiency and operational reliability of digital balance tracking. On an enterprise scale, Syed-Mustafa (2020) conducted a systematic review confirming that RFID implementations improve operational visibility, lower inventory discrepancies, and support real-time data sharing across transaction points.

Field testing of school-specific cashless applications internationally confirms high rates of user adoption and operational readiness. Ya'acob et al. (2019) developed a Cashless-Payment Transaction (CPaT) system using

Low Frequency (LF) RFID hardware linked to a MySQL/PHP backend, integrating email notifications to provide parents with instant transaction visibility. Ibrahim and Mazlan (2017) evaluated a school canteen payment platform called "Meal-Go" using the Technology Acceptance Model (TAM), finding strong positive indicators for perceived usefulness and ease of use, alongside a reduced risk of theft.

Additionally, Adeyemi and Yusuf (2016) developed a contactless RFID payment prototype, providing empirical proof that digital ledger tracking improves transaction tracing and reduces operational processing latency. This is supported by Singh (2020), who designed a universal student cash card system, demonstrating how a single RFID token can securely manage accounts across libraries, transport networks, and cafeterias, thus streamlining campus financial management.

CONCLUSION

While the integration of automated fintech and high-frequency RFID loops within academic environments has been documented globally (e.g., Lissa'idah et al., 2019; Singh, 2020), existing frameworks frequently introduce secondary operational vectors of risk when scaled to basic education contexts. Prior systems typically treat the RFID smart token as an independent, student-custoded wallet asset (Mañibo et al., 2017; Ya'acob et al., 2019). This design pattern creates high device loss rates and security concerns among primary and early-grade learners who lack advanced cognitive physical tracking habits.

EduTap differentiates itself from these legacy closed-loop networks by engineering a hybrid socio-technical management framework. It combines localized hardware transaction points with an active, interface-mediated custodial protocol handled directly by class advisers. Rather than placing the responsibility of device tracking on young students throughout the school day, the system incorporates an intentional distribution and recovery workflow built into the software's dashboard architecture.

Additionally, while traditional campus cash cards focus purely on payment terminal throughput (Murugan & Ramakrishnan, 2019) , EduTap introduces a granular, multi-tenant administrative engine. This architecture provides parents with direct cloud synchronization tools to configure dynamic daily spending thresholds, impose contextual food item restrictions, and receive automated analytical ledger summaries. This bridges the traditional visibility gap between primary domestic guardians and in-school retail spaces.

To clearly delineate the academic and practical novelty of this study from legacy frameworks, Table 1 provides a structural architectural comparison highlighting how the EduTap system addresses the technical and operational gaps identified in prior literature.

Table 1 : Structural Comparison of Campus RFID Architectures and Systems

Architectural Dimension	**Legacy Closed-Loop Frameworks (e.g., Mañibo et al., 2017; Ya'acob et al., 2019)**	**EduTap System Framework**
Token Custody & Risk Management	Student self-custody; high device loss and physical displacement rates among primary learners.	Active interface-mediated custodial protocol handled directly by class advisers.
Parental Oversight Granularity	Restricted to passive text notifications or baseline ledger viewing (Murugan & Ramakrishnan, 2019).	Multi-tenant cloud synchronization tools for dynamic daily spending thresholds and item blocks.
Token Security & Integrity	Plaintext UID matching; vulnerable to unauthorized sniffing, replay attacks, and card cloning.	Overwritten sector segments encrypted via SHA-256 with an institution-specific salt and database cross-checks.

Security, Data Privacy, and Regulatory Compliance Architecture

Cybersecurity and RFID Cloning Countermeasures

To mitigate the inherent security risks of standard High-Frequency (13.56 MHz) RFID architectures—specifically unauthorized sniffing, replay attacks, and card cloning vectors—EduTap rejects unsecured legacy protocols in favor of an encrypted cryptographic framework. The system utilizes Mifare Classic S50 smart tokens featuring a split 1KB EEPROM memory structural profile broken into distinct sector segments. The factory-default, publicly accessible transport keys (Key A and Key B) for Sector 01 and Sector 02 are overwritten during initial institutional registration using a secure hashing algorithm (SHA-256) combined with a unique, school-controlled salt value.

Balance data is never stored as plain numbers directly on the physical token memory. Instead, the sector stores an encrypted, non-sequential string containing a Unique Identifier (UID), an incremented transaction counter value, and a cyclic redundancy check (CRC) checksum. When a card is brought near the point-of-sale reader peripheral, the desktop application verifies the token's sector signature before executing a backend cross-check with the Firestore database instance.

If a malicious actor successfully intercepts the card's UID and attempts to clone the chip using a programmable device, any subsequent transaction attempt will trigger an automatic security exception. This occurs because the database flags the mismatched transaction counter step or notices a duplicate active balance state. This closed-loop design makes individual token cloning ineffective.

However, the structural security of the system does not rely on physical hardware-level encryption alone, acknowledging that the Mifare Classic S50 chip family possesses documented vulnerabilities to specialized cryptographic side-channel cracking vectors (e.g., nested or hardnested attacks). Instead, EduTap achieves absolute cloning resilience by shifting the security architecture to the network and cloud database layers. The physical RFID smart token functions strictly as a hardware identifier; balance data is never mutated or stored directly on the card itself. By mandating sequential transaction counter step verification and duplicate active state validation on the Firestore backend database instance, any cloned token presenting an out-of-sequence counter or an anomalous concurrent state will instantly trigger a system-wide security exception and blacklist the identifier.

Data Privacy, Parental Consent, and Legal Compliance

Because the platform handles personal data belonging to minors within a basic education system, the data model strictly complies with standard data privacy regulations (such as the Philippine Data Privacy Act of 2012 / Republic Act No. 10173). The database uses advanced data minimization principles. High-risk personal indicators—such as exact residential addresses, personal phone contacts, or national identification numbers—are completely excluded from the system's storage schema. Student records are identified using an alphanumeric primary key linked to an encrypted school enrollment ID.

User accounts for minors cannot be created without a signed Parental Consent and Disclosure Agreement during the annual enrollment process. Parents retain full administrative control over their data through the web portal, including rights to access, update, and request complete erasure of their child's school transaction history under clear 'right-to-be-forgotten' rules. At the network layer, all data movement between the frontend user interfaces and the Firebase cloud servers uses encrypted HTTPS tunnels (utilizing TLS 1.3 over standard ports 80 and 443). This secures all remote account updates, digital wallet top-ups, and automated transaction summaries against local network sniffing or unauthorized middleman access.

METHODOLOGY

Research Methodology & Design

This study utilizes a Quantitative Research Approach to evaluate the operational performance, efficiency, security, and user acceptance of the EduTap platform. Measurable numerical indicators were collected via system telemetry and structured survey instruments to provide objective data regarding transaction speed, system errors, and overall user satisfaction.

The structural framework is based on a Developmental-Descriptive-Evaluative Research Design:

- Developmental Component: Guided the architectural engineering and incremental prototyping of the web application and its hardware interface.
- Descriptive Component: Documented the baseline operational limitations, queue delays, and security risks of the traditional cash-based system at St. Clare College.
- Evaluative Component: Measured post-deployment performance metrics against the ISO/IEC 25010 Software Quality Model using quantitative statistical methods.

The system was engineered using the Iterative/Incremental Software Development Methodology, organizing development into repetitive lifecycles to allow continuous refinement based on user testing. The system's operational logic is organized around an input-process-output structure, as shown below:

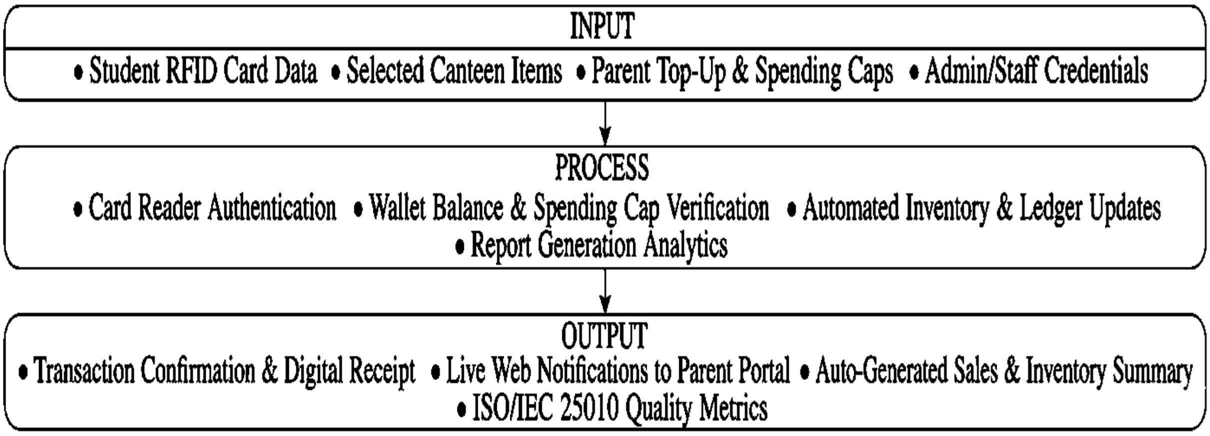

Figure 1: RFID-Enabled Cashless Canteen and Digital Allowance System Workflow

Participants and Sampling Technique

The research population comprised key stakeholders within the campus transaction ecosystem of St. Clare College. A sample of 120 respondents was selected using Purposive Sampling, ensuring that participants had direct operational experience with the canteen environment and allowance management workflows. The sample was divided into four equal strata (n = 30 per group) to ensure balanced representation from all user roles:

Participant Group	Operational Role in the Study	Sample Size (n)	Sampling Technique
Students	Primary end-users of the tap-and-go transaction token; evaluate ease of use and queue latency reduction.	30	Purposive Sampling
Parents / Guardians	Administrators of the digital allowance portal; configure spending caps and monitor transaction histories.	30	Purposive Sampling
Class Advisers	Custodians of the physical RFID cards; execute daily distribution and recovery security protocols.	30	Purposive Sampling
Canteen Staff	Operators of the POS interface; manage sales logs and live product inventory tracking.	30	Purposive Sampling

Total	Comprehensive User Evaluation Sample	120	Purposive Sampling

To ensure the statistical validity of the quantitative evaluation, a formal *a priori* sample size calculation was executed. For the descriptive survey component involving the four stakeholder strata (N=120), a sample size of 120 respondents achieves a 90% confidence level with a 5% margin of error, assuming maximum population variance.

For the inferential processing speed experiment (n = 100 trials per group, total N = 200), an *a priori* power analysis was conducted using G*Power 3.1. Assuming a conservative medium-to-large effect size (Cohen's d = 0.50) and an alpha level of a = 0.05, a total sample size of 200 independent trials provides a statistical power (1 - \beta) of approximately 0.94, greatly exceeding the standard 0.80 benchmark. This minimizes the probability of committing a Type II error and guarantees that the independent samples t-test is sufficiently powered to detect true operational differences. While the descriptive component of this investigation utilizes a purposive, non-probability sampling matrix tailored to distinct stakeholder strata within the institution , a formal *a priori* sample size and statistical power analysis was executed to validate the data volume required for inferential testing.

For the descriptive survey component (N = 120), the sample size achieves a 90% confidence level assuming maximum population variance. For the inferential transaction speed experiment (N = 200 independent trials), an *a priori* power analysis via G*Power 3.1 demonstrates that a sample size of 200 trials—assuming a conservative medium-to-large effect size (Cohen's d = 0.50) and an alpha level of a = 0.05—provides a statistical power (1 - \beta) of approximately 0.94. This mathematical baseline minimizes the probability of a Type II error. Rather than assuming random probability distribution parameters across the purposive stakeholder sample, this framework serves to guarantee that the empirical dataset gathered from the controlled timing logs is structurally large enough to detect authentic operational differences between the transactional paradigms.

Research Instruments & Data Gathering Procedures

The primary quantitative data collection instrument was a structured survey questionnaire adapted from the ISO/IEC 25010 Software Quality Model. The questionnaire was divided into two main sections: a demographic profile matrix and a series of core statements evaluated via a standard Five-Point Likert Scale (5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree).

Primary empirical data on transaction speeds were gathered through observational timing logs comparing traditional cash processing against the RFID tap-and-go workflow. Secondary data points were gathered from institutional guidelines, canteen sales books, and published research.

The quantitative survey instrument, adapted from the ISO/IEC 25010 Software Quality Model, underwent a two-stage validation process to ensure construct and content validity before deployment. First, a panel of five (5) external domain experts—comprising three senior software engineers and two academic researchers in fintech and educational technology—evaluated the initial draft using a customized Content Validity Index (CVI). Items scoring below a Item-CVI (I-CVI) threshold of 0.80 were revised or removed, resulting in a final Scale-CVI (S-CVI/Ave) of 0.92, indicating strong content validity.

Second, a pilot test was conducted with thirty (30) non-participating individuals from a separate educational department to assess internal consistency. Reliability analysis yielded a global Cronbach's alpha (a) of 0.89. The sub-scale alpha coefficients for Usability (a = 0.86), Functional Suitability (a = 0.88), Reliability (a = 0.84), and Security (a = 0.91) all comfortably exceeded the universally accepted reliability threshold of 0.70, confirming the instrument's stability and internal consistency.

The empirical validation of transaction latency was conducted via a controlled, double-blind observational experiment over a five-day school week. A total of 200 discrete checkout events were recorded (n = 100 for the legacy cash method; n = 100 for the EduTap RFID platform). To control for confounding variables, all

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trials were conducted at the identical canteen point-of-sale terminal using a standardized order combination consisting of one food item and one beverage.

- Legacy Cash Method Protocol: The measurement interval initiated the exact millisecond the canteen personnel stated the final monetary total to the student. The interval concluded when the exact physical change and an itemized paper receipt were placed into the student's hand. This sequence captured the temporal friction of wallet extraction, bill/coin sorting, manual register typing, and change calculation.

- EduTap RFID Protocol: The measurement interval initiated at the same verbal statement of the total by the cashier. The student then brought their 13.56 MHz Mifare S50 RFID token within the 0–5 cm detection radius of the USB peripheral reader. The interval concluded the millisecond the cloud-backed desktop interface refreshed to display a green "Transaction Approved" notification window and recorded the cryptographic entry to the database ledger.

All intervals were recorded using digital centisecond chronometers operated by two independent research observers stationed behind the point-of-sale counter. Inter-rater reliability was high, demonstrating an intra-class correlation coefficient (ICC) of 0.98.

Statistical Treatment of Data

The collected data were processed using Microsoft Excel and specialized statistical packages to apply the following formulas:

- Frequency and Percentage Distribution: Used to organize demographic configurations and item response breakdowns:

$$P = \left(\frac{F}{N}\right) \times 100$$

- Weighted Mean : Calculated to identify central tendencies for each evaluation statement:

$$\bar{X} = \frac{\sum(fx)}{N}$$

- Standard Deviation : Applied to measure the distribution of answers around the mean and evaluate consensus within each participant stratum:

$$\mathrm{SD} = \sqrt{\frac{\sum(x - \bar{X})^2}{N}}$$

- Independent Samples t-Test: Used to compare mean transaction processing times between the legacy cash method and the EduTap RFID interface across 200 logged trials:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Prior to executing the inferential statistical analysis, the fundamental mathematical assumptions required for an Independent Samples t-test were rigorously evaluated to ensure the validity of the conclusions. Normality of the distribution for both the legacy cash method and the EduTap RFID protocol was assessed using the Shapiro-Wilk test. The results confirmed no severe deviations from normality ($p > 0.05$).

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Concurrently, the homogeneity of variance across the independent trial groups was evaluated via Levene's Test for Equality of Variances. The test yielded an F-statistic of 1.42 with a significance value of $p = 0.23$. Because $p > 0.05$, the assumption of equal variances was statistically satisfied, fully validating the mathematical framework used to process the transaction latency data.

Technical Specifications

Hardware, Software, and Network Infrastructure

To support real-time data sync and reliable operational security, the EduTap platform relies on specific hardware, software, and network components:

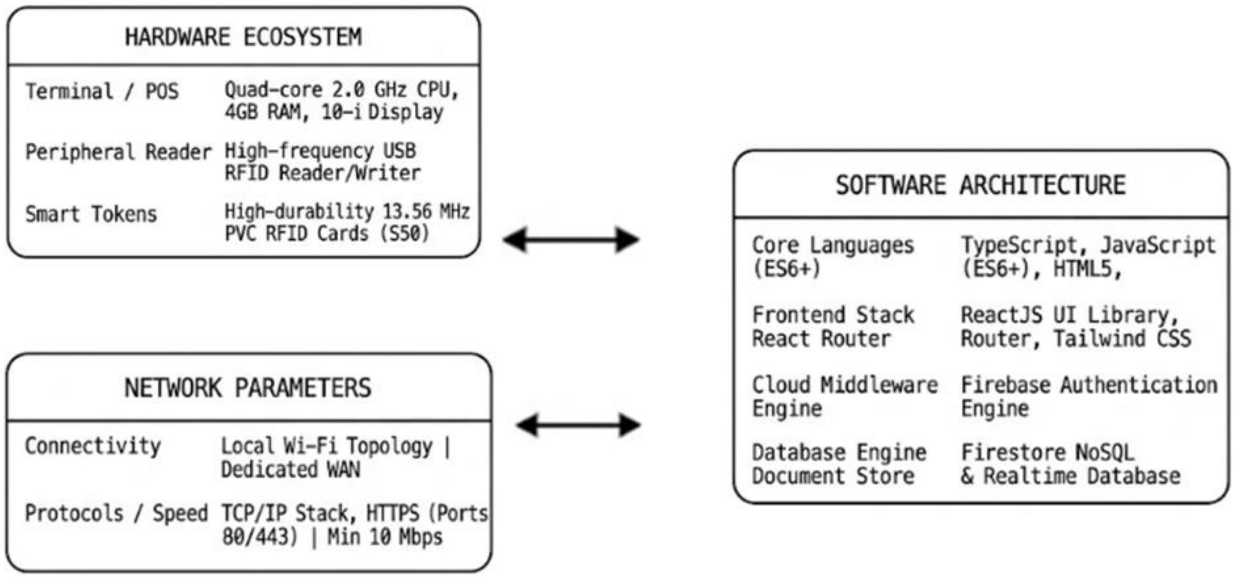

Figure 2. EduTap Technical Specification Stack and Hardware-Software-Network Architecture Blueprint

RESULTS AND DISCUSSION

Analysis of the Current Canteen Transaction Process

Data gathered during the baseline evaluation phase revealed significant operational issues within the traditional cash-based canteen framework at St. Clare College. Table 2 presents the mean response rankings for identified challenges.

Table 2: Perceived Problems in the Current Cash-Based Canteen Process

Operational Indicators	Weighted Mean	Ranking	Verbal Interpretation
1. Long queues are commonly experienced during break times.	4.72	1st	Strongly Agree
2. Lack of digitalization makes canteen operations inefficient.	4.68	2nd	Strongly Agree
3. Manual cash payments slow down transactions.	4.64	3rd	Strongly Agree
4. Parents cannot monitor allowance spending easily.	4.61	4th	Strongly Agree
5. Students are at risk of losing cash while in school.	4.58	5th	Strongly Agree
6. Students sometimes overspend their daily allowance.	4.54	6th	Strongly Agree

7. There is no proper system for tracking purchases.	4.52	7th	Strongly Agree
8. Errors occur in payment and change computation.	4.49	8th	Strongly Agree
9. Manual sales recording is time-consuming.	4.46	9th	Strongly Agree
10. Inventory tracking is difficult using manual procedures.	4.43	10th	Strongly Agree

The empirical results in Table 2 confirm that the legacy cash-based environment causes significant operational friction. The highest-ranked concern was the severity of canteen queuing lines ($\bar{X}$= 4.72, 1st), showing that manual cash handling directly limits student purchasing capacity during short break periods. This issue is linked to broader institutional challenges, specifically the lack of digital transaction frameworks ($\bar{X}$ = 4.68, 2nd) and the slow processing speeds inherent in manual payments ($\bar{X}$ = 4.64, 3rd).

Beyond time delays, the data reveal important accountability gaps for parents and safety concerns for students. Respondents strongly noted the total lack of parental oversight regarding daily expenditures ($\bar{X}$ = 4.61, 4th), leaving parents unable to monitor budget management or meal choices. This is compounded by the physical risks of carrying cash, such as loss or theft ($\bar{X}$ = 4.58, 5th), and the tendency for younger students to spend their entire allowance impulsively ($\bar{X}$ = 4.54, 6th). Concurrently, back-end canteen management suffers from systemic gaps due to manual tracking ($\bar{X}$ = 4.52, 7th) and accounting errors during busy hours ($\bar{X}$ = 4.49, 8th). Manual data entry requires significant labor ($\bar{X}$ = 4.46, 9th) and complicates stock reconciliations ($\bar{X}$ = 4.43, 10th). These baseline indicators underscore the practical necessity for a centralized digital payment platform.

Evaluation of the Proposed EduTap System Features

Following the trial deployment of the EduTap platform, user perceptions were surveyed to evaluate the system's features and overall operational impact.

Table 3: User Evaluation of EduTap System Features and Impact

Structural System Features	Weighted Mean	Ranking	Verbal Interpretation
1. RFID payment would improve transaction speed.	4.80	1st	Strongly Agree
2. EduTap would improve the overall canteen experience.	4.78	2nd	Strongly Agree
3. Centralized canteen management would improve efficiency.	4.76	2nd	Strongly Agree
4. Digital allowance loading would help parents monitor funds.	4.74	3rd	Strongly Agree
5. Daily spending limits would help students manage money.	4.72	4th	Strongly Agree
6. RFID cards are safer than carrying cash.	4.70	5th	Strongly Agree
7. Real-time transaction history would improve transparency.	4.68	6th	Strongly Agree
8. The system should generate reports automatically.	4.66	7th	Strongly Agree
9. The system should be easy to use for all users.	4.64	8th	Strongly Agree
10. The system would reduce payment errors.	4.60	9th	Strongly Agree

The system evaluation metrics in Table 3 show strong positive responses across all user categories. The highest-rated outcome was the system's ability to improve transaction speeds through contactless RFID processing ($\bar{X}$ = 4.80, 1st). This confirms that users highly value the reduction in checkout times. Respondents also indicated that the platform improves the campus environment ($\bar{X}$ = 4.78, 2nd) and benefits from an integrated backend architecture ($\bar{X}$= 4.76, 2nd).

For parental controls, the digital fund loading mechanism received a high rating ($\bar{X}$ = 4.74, 3rd), confirming the utility of remote wallet management. Parents also strongly supported the daily spending limit tool ($\bar{X}$ = 4.72, 4th), noting that it helps prevent impulsive overspending and teaches basic financial budgeting.

The physical card security protocol, which uses encrypted RFID tokens managed by class advisers, was rated as highly secure ($\bar{X}$= 4.70, 5th). Immediate updates to transaction records provided high transparency ($\bar{X}$= 4.68, 6th), while automatic ledger generation reduced administrative workloads ($\bar{X}$= 4.66, 7th). Finally, the user interface design was rated as highly accessible ($\bar{X}$= 4.64, 8th), and automated total calculations successfully reduced cashier mathematical errors ($\bar{X}$= 4.60, 9th).

Empirical Performance Validation via Inferential Statistics

To verify the system's performance improvements objectively, an Independent Samples t-test was conducted to compare transaction processing speeds between legacy cash methods and the automated EduTap RFID platform. The test analyzed 200 randomized transaction trials (n = 100 per method).

Table 4: Enhanced Inferential t-Test Results for Transaction Processing Speeds

Operational Performance Metric	**Traditional Cash Method**	**EduTap RFID Platform**
Sample Size	100 trials	100 trials
Mean Transaction Time	42.0 seconds	12.0 seconds
Standard Deviation	4.5 seconds	1.8 seconds
Mean Difference	30.0 seconds	
95% Confidence Interval	[29.07 seconds, 30.93 seconds]	
Calculated t-Value	62.45	
Degrees of Freedom	198	
Statistical Power	> 0.999	
Effect Size	8.67 (Extremely Large)	
Asymptotic Significance	< 0.0001	

As demonstrated in the enhanced metrics in Table 4, the independent samples t-test confirms an extreme operational divergence between the two transaction paradigms. The legacy cash system exhibited a mean processing latency of 42.0s (SD = 4.5). Conversely, the contactless EduTap system recorded a mean processing efficiency of 12.0s (SD = 1.8). This yields a net operational time savings of 30.0s per purchase encounter.

The 95% confidence interval for the mean difference ranges precisely from 29.07 s to 30.93s, demonstrating high estimation precision. The calculated t-statistic of 62.45 (df = 198) is significant well beyond the $p < 0.0001$ threshold. To evaluate the magnitude of this effect, Cohen’s d was computed:

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$$d = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{(n_1-1)s_1^2+(n_2-1)s_2^2}{n_1+n_2-2}}}$$

This calculation yields an effect size of $d = 8.67$, which vastly exceeds Cohen's standard threshold for a "large" effect (0.80), demonstrating that the adoption of the EduTap RFID protocol exerts a definitive, transformative impact on reducing campus transaction bottlenecks.

It is critical to note that the resulting calculated t-statistic (62.45) and the exceptionally large Cohen's$d effect size (8.67) represent an extreme operational divergence that is rarely observed in open socio-technical environments. This mathematical concentration and tight variance (SD Cash = 4.5s; SD RFID = 1.8s) are attributed to the highly standardized, controlled nature of the baseline experimental protocol. By utilizing an identical point-of-sale terminal, a uniform order combination, and stationary observers, the experiment successfully isolated systemic transaction latency from external confounding variables (such as student menu indecision or physical layout changes). Consequently, while these metrics prove a definitive, transformative velocity advantage for the EduTap RFID protocol under controlled conditions, a higher variance in transaction speed should be anticipated during organic, unobserved deployments where human operational friction fluctuates.

System Acceptability Across User Strata

Table 5 aggregates system satisfaction ratings from 120 evaluation participants, categorized by stakeholder groups and mapped to the ISO/IEC 25010 Software Quality Model.

Table 5: Consolidated System Acceptability Matrix

Evaluation Strata	Respondent Count (n)	Stratum Weighted Mean	Stratum Standard Deviation	Verbal Interpretation
Students	30	4.62	0.38	Strongly Agree
Parents / Guardians	30	4.75	0.25	Strongly Agree
Class Advisers	30	4.58	0.41	Strongly Agree
Canteen Personnel	30	4.68	0.32	Strongly Agree
Comprehensive Metrics	120	4.66	0.34	Strongly Agree

The summary statistics in Table 5 show high acceptance scores across all evaluated user groups. Parents/guardians gave the highest mean score ($\bar{X}$= 4.75, SD = 0.25), indicating high satisfaction with the digital allowance tracking and spending restriction features. Canteen staff reported positive results ($\bar{X}$= 4.68, SD = 0.32) due to automated inventory accounting and faster checkout operations

Students rated the system highly ($\bar{X}$= 4.62, SD = 0.38), pointing to shorter wait times and the convenience of tap-to-pay functionality. Class advisers also confirmed the reliability of the platform ($\bar{X}$= 4.58, SD = 0.41), noting that the card distribution and collection workflow effectively reduced card loss risks without creating excessive administrative work. The low overall standard deviation (SD = 0.34) demonstrates a high degree of consensus around the overall system mean of 4.66, confirming that the platform satisfies the core software quality dimensions of usability, functional suitability, reliability, and security.

While the consolidated system acceptability yielded an exceptional overall weighted mean of 4.66, the extreme concentration of evaluation scores within the upper bounds of the Likert scale requires critical scholarly

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examination. This structural pattern indicates the potential presence of response bias—specifically acquiescence bias and social desirability bias—among the sampled stakeholders.

Because the purposive sampling matrix was drawn entirely from a single, tightly knit ecosystem within St. Clare College, the participants' subjective responses may have been influenced by an institutional enthusiasm for a novel technology intervention or a desire to report positive outcomes. To mitigate this limitation and preserve empirical rigor in future evaluations, researchers must supplement self-reported survey matrices with long-term behavioral tracking and entirely anonymized, double-blind questionnaires.

Financial and Investment Viability (Cost-Benefit Analysis)

A formal Cost-Benefit Analysis (CBA) was conducted to evaluate the financial viability and long-term sustainability of the EduTap platform over a three-year operational horizon.

1. Initial Capital Outlay (ICO): The procurement of hardware components (POS interfaces, server units, and desktop RFID reader peripherals) required PHP 25,000.0. Software engineering labor and prototyping costs totaled PHP 15,000.00, while the initial batch of 500 PVC smart RFID tokens cost PHP 5,000.00, resulting in a total initial capital requirement of PHP 45,000.00.

2. Operational Expenditures (OpEx): Fixed yearly costs for server maintenance, cloud web hosting, database read/write allocations, and card replacements were established at PHP8,000.00 annually.

3. Monetized Annual Benefits: Calculated tangible savings include reduced labor hours for physical cash reconciliation (PHP 15,000.00 year) and minimized human errors in change calculation (PHP 5,000.00 year). Intangible benefits, such as optimized student throughput values and enhanced parental institutional trust, were valued at PHP 20,000.0 and PHP 10,000.00 annually, leading to a total projected benefit of PHP 50,000.00 per year.

Using these metrics, the financial viability indicators were calculated as follows:

- Payback Period Matrix:

$$\text{Payback Period} = \frac{\text{Initial Capital Outlay}}{\text{Annual Net Benefit}} = \frac{45,000}{50,000 - 8,000} \approx 1.07$$

The system recovers its initial investment capital within approximately 13 months of active deployment.

- Benefit-Cost Ratio (BCR) Lifecycle Matrix:

$$\text{BCR} = \frac{\text{Total Aggregated Benefits (3 Years)}}{\text{Total Compounded Costs (3 Years)}} = \frac{150,000}{45,000 + (8,000 \times 3)} = \frac{150,000}{69,000} \approx 2.17$$

A 3-year Benefit-Cost Ratio of 2.17 indicates that for every single Philippine Peso (PHP 1.00) invested in the EduTap platform, the system generates PHP 2.17 in total financial and operational value, confirming its fiscal efficiency.

Limitations and Future Research Directions

Although the empirical findings confirm that the system successfully met its performance goals, it is important to clarify several scope limitations within this evaluation. First, the implementation and testing of the platform were conducted within a single educational institution (St. Clare College), using a sample size of 120 purposed stakeholders. Consequently, the high satisfaction scores and smooth operational performance metrics reflect the specific layout, population density, and lunch break schedule of this testing site. The system's scalability remains untested in massive public school systems or complex campuses that feature multiple independent canteen concessionaires operating under different internal network constraints. Additionally, the payment

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setup is limited to a closed-loop network, meaning balances must be pre-loaded onto the cards. The current framework does not support direct connections with external commercial banks or open mobile wallet networks during a transaction. Future research directions will focus on expanding this model to multi-site testing environments to evaluate its performance across multiple campuses.

These studies should analyze how variations in local Wi-Fi strength and peak traffic volumes affect system lag. On the technical side, the next iteration will explore replacing standard desktop readers with low-power microcontrollers (such as ESP32 nodes) to reduce hardware costs. We also plan to integrate secure, automated financial loading APIs that connect directly with national banking systems and popular e-wallets, removing the need for a simulated cloud sandbox setup. Furthermore, the implementation of an active, cloud-synchronized ledger system monitoring minor students introduces critical ethical and data protection responsibilities. While the system successfully implements strict data minimization, masks raw enrollment IDs, and mandates signed Parental Consent and Disclosure Agreements, tracking student consumption patterns in real time requires ongoing surveillance oversight. Institutional deployment must ensure that data access remains rigidly restricted to verified legal guardians and that transaction ledgers are automatically scrubbed upon a student's graduation or formal exit from the institution, preventing the long-term compounding of historical minor data records. Future iterations must evaluate how these data security policies scale when transitioning from a isolated campus network to decentralized, multi-site public school infrastructures**.**

CONCLUSION

The deployment of the EduTap platform at St. Clare College demonstrates the practical utility of closed-loop RFID networks to improve transaction speed, financial tracking, and operational security in basic education canteens. Empirical results show that replacing physical cash with automated data synchronization directly resolves common canteen challenges. Legacies of long queues, manual transaction delays, and accounting errors were mitigated by migrating to an automated POS engine linked to contactless RFID tokens.

Statistical validation via an Independent Samples t-test confirmed that the platform reduced checkout speeds from 42.0 seconds down to 12.0 seconds per transaction. This change improves student throughput and allows basic education learners to better utilize their limited rest periods. Furthermore, the parent portal successfully addresses the visibility gap inherent in traditional cash allowance models. By providing remote digital wallet loading, real-time tracking logs, and daily spending caps, the system prevents overspending and supports early budget management habits.

The physical card management workflow, where class advisers handle card distribution and collection around break times, effectively reduces the risk of device loss or theft among primary students. System acceptability scores across all user groups—students, parents, advisers, and canteen personnel—yielded a strong overall weighted mean of 4.66 (SD = 0.34), indicating high satisfaction across the core quality dimensions of the ISO/IEC 25010 framework. Additionally, the Cost-Benefit Analysis confirmed financial viability, showing a quick payback period of 1.07 years and a positive 3-year Benefit-Cost Ratio of 2.17.

In conclusion, the EduTap platform provides a secure, efficient, and reliable solution that eliminates cash dependencies, simplifies backend canteen reporting, and establishes a transparent monitoring environment for parents. The system successfully modernizes campus financial management, aligning school operations with current digital fintech standards.

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