

## SmartCloud QR: a next-gen online attendance system leveraging QR code and cloud technology

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### ABSTRACT

This study presents SmartCloud quick response (QR), a cloud-based attendance monitoring system designed to enhance efficiency, accuracy, and fraud prevention in educational institutions. Traditional paper-based attendance methods are time-consuming, error-prone, and vulnerable to proxy attendance. To address these limitations, the system was developed using a software-as-a-service architecture that integrates QR code technology with cloud computing, enabling scalable deployment without requiring dedicated institutional hardware infrastructure. The research was conducted in two phases: phase 1 involved user needs analysis to identify operational challenges in attendance management and phase 2 evaluated system effectiveness through large-scale implementation involving 27,070 participants. Statistical analyses, including independent samples t-tests and one-way analysis of variance (ANOVA), were performed to examine satisfaction differences across gender and user roles. The results demonstrated a high overall satisfaction rate (92.84%), with only minimal and practically negligible differences observed across demographic groups. The findings empirically support the technology acceptance model (TAM), indicating that perceived usefulness and ease of use are reinforced by fraud-prevention mechanisms and infrastructure-light deployment. This study contributes to the applied educational informatics literature by introducing a scalable software-as-a-service attendance framework that enhances fraud prevention, reduces institutional hardware investment, and operationalizes privacy-by-design principles in large-scale real-world implementation.

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## 1. INTRODUCTION

Effective attendance management is a critical aspect for the success of any organization, particularly within educational institutions and businesses, as it directly impacts performance and accountability [1], [2]. Traditionally, attendance tracking has relied on manual, paper-based registers or spreadsheets, methods that are inherently time-consuming and prone to human error, data loss, and inefficiency [3]–[6]. These outdated processes can consume significant instructional or working hours, affecting overall productivity and, in educational settings, potentially impacting student academic performance and leading to serious consequences for the institution's reputation and quality [7]–[9]. Issues such as the difficulty in tracking

absences over extended periods, lack of real-time updates, and limited reporting capabilities further exacerbate the challenges associated with manual systems [10]–[12].

In response to these limitations, modern online attendance management systems (OAMS) have emerged as digital solutions designed to automate and streamline the attendance process [13]. These systems leverage advancements in web technologies, mobile applications, and various identification methods, including biometric verification and quick response (QR) codes, to enhance accuracy, efficiency, and accessibility [14]. Key benefits include real-time updates, secure data recording, remote access, automated reporting, and improved accountability, which collectively reduce human error and administrative burdens [15]. QR codes, in particular, have gained significant popularity due to their ability to provide quick scanning and greater information storage compared to traditional barcodes, offering a user-friendly mechanism for attendance recording through ubiquitous mobile devices [3].

Despite the widespread adoption and documented benefits of online and QR-code-based attendance systems globally [1], [9], [16], challenges in their implementation and user acceptance persist. Existing systems have reported issues such as software bugs, application crashes, mapping errors, and difficulties in scanning QR codes [2], [17]. Concerns also remain regarding the potential for “proxy attendance” or students misusing self-attendance features, necessitating robust identity verification mechanisms [11], [18]. Furthermore, user interfaces can sometimes be perceived as “complicated,” and issues like users or administrators forgetting to log attendance or open access windows can still hinder overall effectiveness [16], [19], [20]. These observations highlight that while the underlying technology is powerful, successful implementation requires careful design to address practical challenges and ensure high user satisfaction.

In the context of Thailand, similar challenges relating to the efficiency, accuracy, and security of attendance management are prevalent in educational and organizational settings. Current solutions may not fully address the specific needs or overcome persistent issues of fraud and user dissatisfaction within the local operational environment. Therefore, there is a clear research gap for a comprehensively designed and robust online attendance system that not only incorporates advanced technologies like QR codes and cloud computing but is also meticulously tailored and evaluated for the unique operational landscape in Thailand, ensuring seamless integration and high user satisfaction.

Therefore, this study aims to develop an online attendance system that leverages QR code technology and cloud computing to address the limitations of traditional attendance tracking methods. The proposed system is designed to improve efficiency, accuracy, and security in attendance management. Additionally, it aims to provide a user-friendly interface for both administrators and users, facilitating a smooth transition from manual to automated attendance recording.

## 2. METHOD

This study adopts a design-oriented applied research approach aimed at developing a scalable, hardware-independent, and fraud-resistant OAMS deployable across educational institutions nationwide and internationally through cloud computing infrastructure. In contrast to prior QR-based or radio frequency identification (RFID)-based attendance systems that require dedicated hardware installation or institution-level infrastructure investment (e.g., RFID readers, biometric scanners, or near field communication (NFC) technology) [11]–[13], [15], [21], the primary architectural objective of SmartCloud QR is to eliminate physical infrastructure dependency. It also aims to implement a cost-minimizing software-as-a-service deployment model [22]–[24].

### 2.1. Experimental setup

To ensure alignment with the two-phase design-oriented applied research framework described in this study, the experimental implementation was structured into two phases. Phase 1 focused on system design and requirement validation. Phase 2 focused on large-scale user satisfaction and usage evaluation.

#### 2.1.1. Phase 1: system design, deployment, and requirement validation

In phase 1, the SmartCloud QR system was deployed in a university setting. This deployment aimed to validate system requirements, operational feasibility, and technical performance under real-world classroom conditions. The pilot implementation involved multiple courses across different departments to reflect diverse classroom environments and attendance patterns.

Participants, including instructors and students, were recruited through social media platforms such as Facebook and Line, the university website, and word-of-mouth communication [25]. Prior to deployment, training sessions were conducted to ensure correct system utilization. Training materials included step-by-step demonstrations on QR code generation, time-restricted activation, scanning procedures, and

photo verification mechanisms. Instructional videos were also disseminated through a dedicated YouTube channel to support asynchronous learning and user onboarding [26].

During the semester-long deployment, the system automatically recorded attendance transactions and operational logs. System log monitoring was conducted continuously to evaluate technical stability, server responsiveness, and data synchronization integrity. The collected logs enabled the identification of potential operational issues and provided empirical validation of the cloud-based infrastructure under authentic usage conditions. This phase provided practical evidence of system feasibility, deployment scalability, and operational stability in authentic classroom environments.

### **2.1.2. Phase 2: large-scale user satisfaction and usage evaluation**

Following successful deployment and technical validation in phase 1, phase 2 focused on evaluating user perceptions, system effectiveness, and satisfaction levels across a large and diverse user base. A structured survey instrument was developed and integrated directly into the SmartCloud QR system interface using Google Forms [27]. The questionnaire measured system usage experience, perceived efficiency, perceived usefulness, perceived ease of use, and overall satisfaction using a five-point Likert scale.

Participation in the survey was voluntary and accessible through the system interface. Therefore, a non-probability voluntary response sampling approach was adopted, whereby respondents self-selected to complete the questionnaire [28]. Although this sampling strategy does not guarantee random representation, it enabled the collection of large-scale real-world feedback from active system users.

A total of 27,070 valid responses were collected, reflecting authentic system usage experiences across various provinces and institutional contexts. The large sample size enhanced statistical power and supported inferential analysis conducted in this study. Data analysis involved the statistical examination of survey responses to evaluate user satisfaction and examine demographic variations across gender, user roles, and geographic locations. Descriptive statistics, including mean and standard deviation, were computed to assess overall satisfaction levels with the SmartCloud QR system.

To examine differences between two groups (male and female users), independent samples t-tests were performed. For comparisons across more than two user-role categories (teacher, student, and other), a one-way analysis of variance (ANOVA) was conducted. When statistically significant differences were identified, post hoc pairwise comparisons using the least significant difference (LSD) method were applied to determine specific group differences [29]. All satisfaction items were measured using a five-point Likert scale [30], where 5 indicates the highest level of satisfaction and 1 indicates the lowest level of satisfaction.

## **3. RESULTS AND DISCUSSION**

In alignment with the two-phase, design-oriented applied research framework described in the research method. The first phase involved data collection from users at the Mahasarakham Business School and Mahasarakham University. The second phase focused on evaluating user satisfaction with service quality through a survey conducted among voluntarily responding users through a non-probability sampling approach.

### **3.1. Phase 1: user requirement analysis**

In the initial phase, the researchers collected and analyzed the requirements for the online attendance system from different user roles.

- i) Faculty member analysis:
  - Large classrooms: in large classrooms, attendance often exceeds 30 minutes.
  - Technological barriers: faculty members expressed a desire for a fast and modern attendance system, but lacked the technical skills to develop it themselves.
  - Attendance records: calculating attendance scores relies solely on physical attendance sheets. The loss of these sheets renders the verification of individual attendance records impossible.
  - Limited annotations: because each column has a limited amount of space for annotations, notes on attendance sheets can only include basic markings for absence, leave, or tardiness.
- ii) Students' problem analysis:
  - Proxy attendance: some students can answer roll calls on behalf of their peers if the instructor does not visually verify them during attendance [18].
  - Disruptions: during attendance taking, some groups of students may talk among themselves, causing disruptions for those currently being called.
  - Long wait times: students, particularly those called later in the sequence, may become frustrated and bored due to the lengthy process of taking attendance [31].
- iii) Software development:
  - Programming languages: the system was primarily developed using PHP for backend processes

- and JavaScript for frontend interactions. PHP was selected due to its extensive support and seamless database integration, while JavaScript enabled dynamic user interactions [32].
- Database management: MySQL was used to handle data storage. A cloud-based MySQL database was set up to ensure scalability and remote accessibility [33]. The entity-relationship (ER) diagram and other relationships are shown in Figure 1. This figure illustrates the main entities and their relationships, including user management, teacher profiles, subject assignments, attendance records, and session validation tables. The relational links between these tables enable the system to effectively validate QR code scans, verify session authenticity, and store attendance data in real time. This normalized schema ensures data integrity, reduces redundancy, and enhances query efficiency when generating attendance reports.
- Cloud Platform: the system operated on a cloud computing platform, which offered flexibility in resource management and scalability. This allowed for high availability and reduced latency when handling varying loads [22], [23].
- iv) Hardware components:
  - Students and staff used mobile devices with cameras as QR code scanners. Each device needed to have a QR code scanning app installed, which could read and transmit data to the cloud server in real time [9], [34].
  - Server infrastructure: the cloud server was configured to handle requests from multiple clients simultaneously, process them, and update the attendance records in the database.
- v) QR code generation and validation: a secure algorithm dynamically generated QR codes for each class session, encoding the session details. Each QR code was valid for a specific duration, typically the duration of the class, to prevent unauthorized access after the session. This research utilizes the QuickChart API to generate QR codes. QuickChart offers a dependable and adaptable solution for QR code creation, suitable for integration into diverse applications such as educational systems and marketing campaigns. The API’s flexibility and the ability to incorporate analytics with third-party tools like Google Analytics and Mixpanel make it an ideal choice for projects requiring detailed tracking and analysis of QR code usage [35], [36]. The process involved three main steps, each illustrated in Table 1 and Figure 2:
  - Generation: upon the creation of a class session in the system, a unique QR code was generated containing encrypted data such as the session ID, timestamp, and location.
  - Scanning: students scanned the QR codes in the classroom using their mobile devices. The scanning app decoded the information and sent it to the cloud server via a secure API.
  - Verification: if the data matched, the server verified it against the current session details and recorded the attendance in the database.

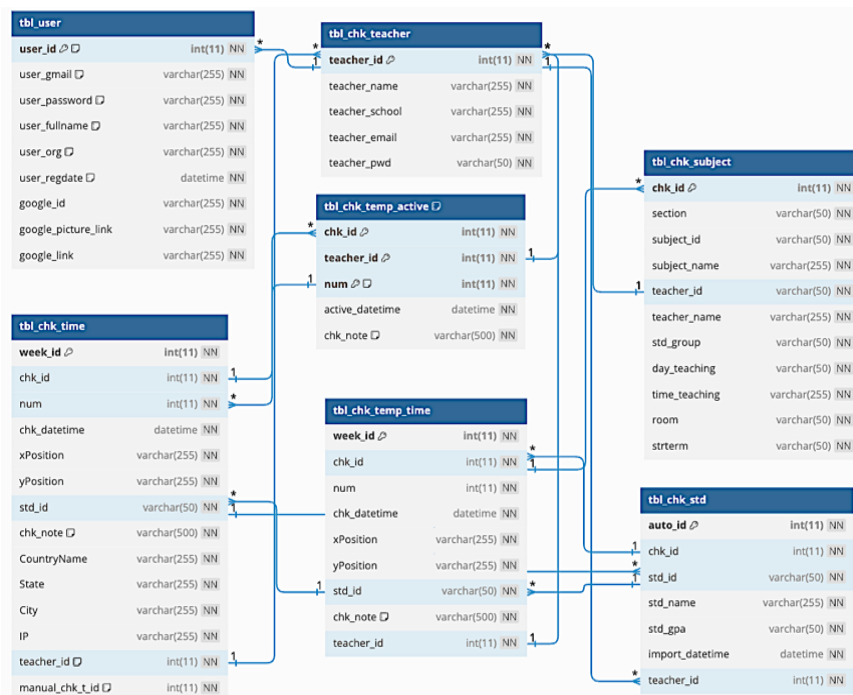


Figure 1. ER diagram of the SmartCloud QR online attendance system

Table 1. System workflow steps and stakeholder responsibilities in SmartCloud QR online attendance system

| Workflow Step | Admin/researcher   | Teacher   | Student   |
|---------------|--|---|---|
| Generation    | Configures system settings and monitors overall process. | Creates a class session and generates a QR code containing the session ID, timestamp, and location. | –   |
| Scanning      | –  | Displays the QR code to the class for attendance.   | Scans the QR code with a mobile device; transmits encrypted data to the server. |
| Verification  | Monitors system logs and validates data integrity.       | Confirms session details with server; reviews attendance records.                                   | –   |

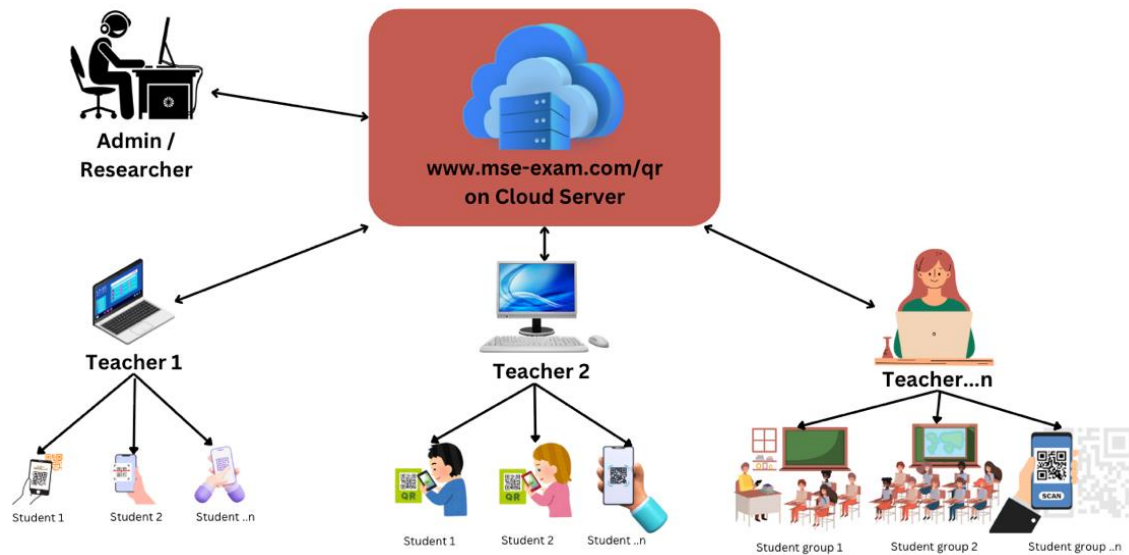


Figure 2. Infrastructure and workflow of the SmartCloud QR online attendance system

Figure 2 illustrates the overall infrastructure and workflow of the SmartCloud QR online attendance system. This figure shows the interaction between administrators, teachers, students, and the cloud server. The system operates on a cloud server [37], which connects administrators, teachers, and students nationwide. Administrators or researchers can configure and monitor the system via the cloud interface. Teachers create class sessions, and for each session, a unique QR code is generated. Students scan the code using their mobile devices, and the data are transmitted securely to the cloud server. The server verifies the scanned data against the session details and records the validated attendance into the database.

This infrastructure enables the system to be deployed as a free service for teachers across the country, requiring no specialized hardware beyond existing devices such as smartphones and computers. Teachers can manage attendance for multiple groups of students simultaneously, while administrators can analyze collected data at scale. The cloud-based architecture ensures scalability, high availability, and real-time synchronization across all stakeholders [38].

### 3.1.1. Data security and privacy

Several measures were implemented to ensure the security and privacy of the attendance data. All data transmitted between the client devices and the server was encrypted using secure sockets layer (SSL)/transport layer security (TLS) protocols, ensuring that any intercepted data could not be read by unauthorized parties [39]. Authentication mechanisms controlled access to the system, ensuring only authorized users could access or modify the attendance records, thereby maintaining data integrity [40]. Furthermore, to safeguard student identities and personal information, we anonymized data where necessary, ensuring that unauthorized access would not reveal personal information [18], [41].

The researchers, after analyzing the collected issues, developed an online attendance tracking information system for use in educational management at all levels of educational institutions in Thailand. The system uses QR code technology from cloud computing to store attendance data within educational institutions. This system significantly facilitates both instructors and students by enabling efficient tracking of attendance behavior and compiling participation scores after a semester has ended.

This system was developed using PHP for user interface creation and database queries, with MySQL as the database management system. The researchers designed the system as a software-as-a-service model [24], providing it free of charge to instructors at any institution wishing to use it. This eliminates the need for individual instructors to develop their own systems, allowing them to access the service [37]. The system is accessible via both computers and mobile devices. Figures 3 and 4 illustrate the system’s functionalities from the perspectives of both instructors and students.

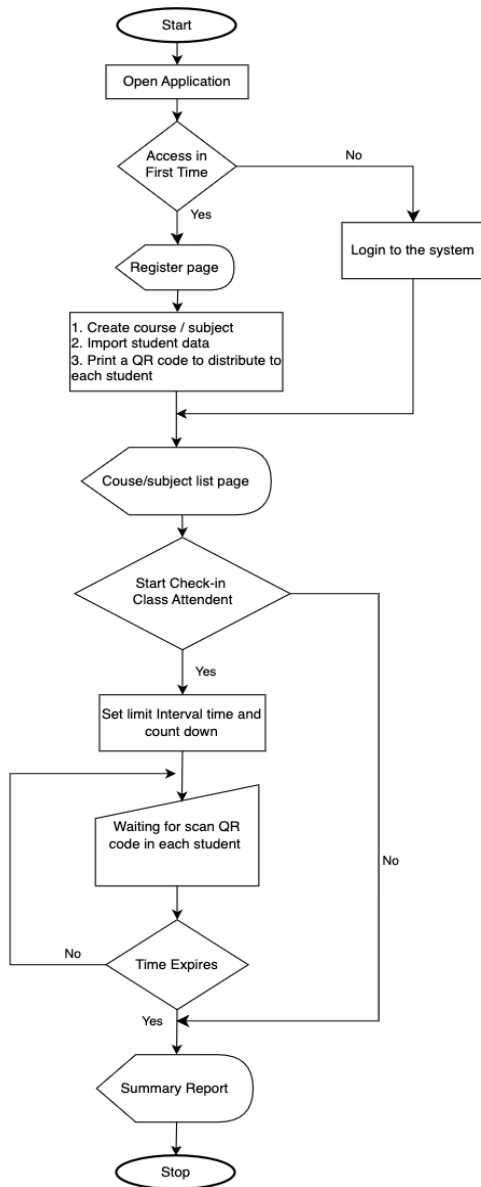


Figure 3. Teacher module flowchart

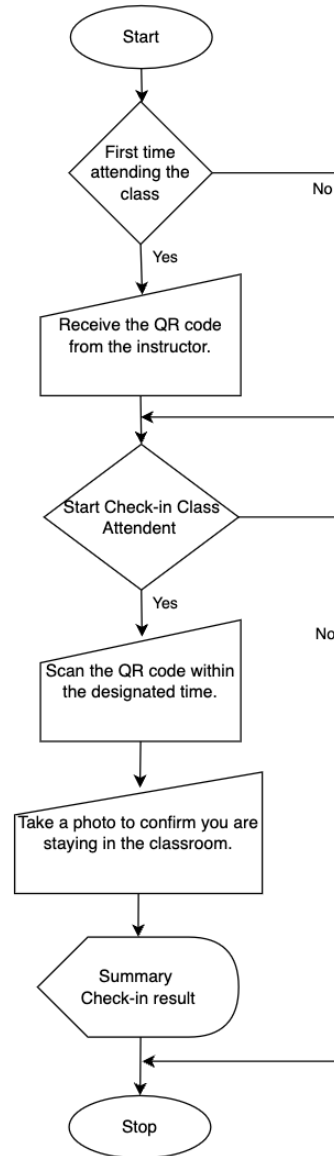


Figure 4. Student module flowchart

This system ensures a structured and efficient way to take attendance using QR codes. Compared to traditional methods, implementing a digital method reduces the time and effort required. The initial setup involves registering courses and importing student data, which streamlines the subsequent attendance-taking process. The use of a time-limited window for QR code scanning helps to manage the process efficiently and generate timely reports for the instructor. The system's workflow was designed to seamlessly handle both new and returning users, making it user-friendly and adaptable to various classroom settings. This approach not only improves the accuracy of attendance records but also enhances the overall efficiency of classroom management.

Although formal benchmarking metrics such as latency, throughput, and stress-testing performance were not systematically evaluated under controlled laboratory conditions, continuous system log monitoring during the semester-long deployment did not indicate critical server downtime, prolonged service interruptions, or data synchronization failures. These operational observations provide indirect yet practical evidence of system stability and scalability under real-world educational usage conditions. Future research may incorporate structured load-testing experiments and quantitative performance benchmarking to further validate system robustness under peak usage scenarios.

Figure 3 shows the teacher module flowchart. When accessing the application for the first time, teachers are required to register by creating courses or subjects, importing student data, and printing the corresponding QR codes to distribute to students. Once courses are registered, teachers can access the course/subject list page, initiate the attendance session, and configure the time limit for QR code scanning. The system then enters a waiting state, allowing students to scan the QR codes within the designated time interval. Once the time expires, the system automatically generates a summary report, providing the instructor with accurate attendance data. This module highlights the flexibility and control available to instructors, enabling them to manage multiple classes and groups simultaneously with minimal manual effort.

Figure 4 illustrates the student module flow chart. Students begin by receiving the QR code from their instructor. During the attendance session, each student is required to scan the QR code within the specified time limit using their mobile device. To ensure authenticity and prevent proxy attendance, the system also requires students to take a photo confirming their presence in the classroom. After the check-in process, the system summarizes the attendance status, which is then synchronized with the cloud database. This workflow ensures fairness, minimizes disruptions during attendance, and provides a transparent record of individual student participation.

Together, these two modules demonstrate the seamless interaction between instructors and students within the SmartCloud QR system. By automating the attendance-taking process, the system significantly reduces classroom disruptions and manual workload while enhancing accuracy, security, and user satisfaction. User roles between teachers and students are compared in Table 2.

Table 2. Comparison of input, process, and output functionalities between teacher and student modules in the SmartCloud QR system

| Aspect  | Teacher module   | Student module                                |
|---------|--|---|
| Input   | – Course/subject information                             | – QR code provided by instructor              |
|         | – Student enrollment data                                | – Student's mobile device with scanning app   |
|         | – Session configuration (time limit, date, and location) | – Photo capture for presence verification     |
| Process | – Register/log in to the system                          | – Scan QR code within specified time window   |
|         | – Create/manage course sessions                          | – Transmit data to server via secure API      |
|         | – Generate and distribute QR codes                       | – Capture photo to confirm classroom presence |
|         | – Set time interval for attendance                       | – Wait for system validation                  |
|         | – Monitor QR code scanning in real time                  |   |
| Output  | – Attendance logs are stored in the database             | – Attendance status confirmation              |
|         | – Automatic summary reports of attendance                | – Transparent record of participation         |
|         | – Improved accuracy and reduced manual effort            | – Real-time synchronization with database     |

### 3.2. Phase 2: user satisfaction evaluation

An evaluation of the online attendance tracking system using QR codes was conducted in the second phase. As of May 2025, there were a total of 8,753 instructors utilizing the system, and the number continues to increase. The system recorded approximately 256,770 students' attendance. Feedback was obtained through questionnaires from 27,070 participants, of which 38.40% were male and 61.60% were female. The highest user role comes from student users (86.5%), followed by the teacher group (12.70%) and another group (0.70%). Moreover, the highest proportion of respondents came from Bangkok (16.98%), followed by Ubon Ratchathani (8.90%) and Maha Sarakham (7.47%). Table 3 presents the detailed characteristics of the respondents.

User satisfaction scores were measured across three dimensions of the attendance system's quality of service. Firstly, the system's ability to meet user needs scored an average of 4.29. Secondly, the system's effectiveness in facilitating work efficiency scored an average of 4.31. Lastly, the system's capability to reduce the time required for tasks also scored an average of 4.31. All scores are based on a maximum of 5, as shown in Table 4. Overall, respondents overwhelmingly agreed that the attendance system is highly effective and beneficial for educational management, with a satisfaction rate of 92.84%.

Table 3. Demographic characteristics

| Property  | Item group          | Frequency | Percentage |
|-----------|---------------------|-----------|------------|
| Gender    | Male                | 10,366    | 38.40      |
|           | Female              | 16,661    | 61.60      |
|           | Total               | 27,070    | 100.00     |
| User role | Teacher             | 3,444     | 12.70      |
|           | Student             | 23,390    | 86.50      |
|           | Other               | 193       | 0.70       |
|           | Total               | 27,070    | 100.00     |
| Province  | Bangkok             | 4,596     | 16.98      |
|           | Ubon Ratchathani    | 2,408     | 8.89       |
|           | Maha Sarakham       | 2,022     | 7.47       |
|           | Chiang Mai          | 1,840     | 6.80       |
|           | Prathumthani        | 1,342     | 4.96       |
|           | Songkhla            | 1,278     | 4.72       |
|           | Chonburi            | 934       | 3.45       |
|           | Phisanulok          | 859       | 3.17       |
|           | Nakhon Si Thammarat | 774       | 2.86       |
|           | Chiang Rai          | 755       | 2.79       |
|           | Nakhon Ratchasima   | 658       | 2.43       |
|           | Other Provinces     | 9,604     | 35.48      |
|           | Total               | 27,070    | 100.00     |

Table 4. User satisfaction evaluation and effective score

| Indicators of satisfaction with the attendance system         | Mean | S.D. | Satisfaction |
|---|------|------|--------------|
| The system's ability to meet user needs                       | 4.29 | 0.81 | Highly       |
| The system's effectiveness in facilitating work efficiency    | 4.31 | 0.80 | Highly       |
| The system's capability to reduce the time required for tasks | 4.31 | 0.81 | Highly       |
| Average user satisfaction with the quality of system service. | 4.30 | 0.81 | Highly       |

Note: \*N =27,070 sampling

Figure 5 illustrates the overall acceptance of the SmartCloud QR online attendance system among surveyed respondents. Out of a total of 27,070 participants, an overwhelming majority of 92.84% (N =25,131) agreed that the system significantly enhances attendance tracking efficiency. Only 7.16% (N =1,939) of respondents indicated that the system did not provide any benefits. This high acceptance rate reflects both the perceived usefulness and ease of adoption of the system among its users. The results suggest that most faculty members and students recognize the advantages of QR code-based attendance compared to traditional manual methods, particularly in terms of speed, accuracy, and convenience. While the overall response was overwhelmingly positive, a small proportion of participants reported limited perceived benefits, which may be associated with technological constraints, resistance to change, or contextual implementation factors within certain classroom environments. To better understand these minority perceptions, qualitative feedback from respondents who indicated limited benefits was further examined. Although the overall acceptance rate of the SmartCloud QR system remained high (92.84%), this subgroup provides valuable insights into potential adoption barriers. A thematic analysis of these responses identified four primary concerns: infrastructural limitations, perceived procedural complexity, technical usability issues, and resistance to change.

First, several respondents reported unstable or insufficient internet connectivity, which affected real-time QR code scanning and photo verification processes. In cloud-based systems, reliable network infrastructure is a critical external variable influencing system performance. Limited connectivity may reduce perceived usefulness, particularly in environments where digital infrastructure is inconsistent. This finding highlights the importance of contextual technological readiness in applied informatics implementations [42].

Second, some users perceived the attendance procedure as more complex compared to traditional roll-call methods. The requirement to scan QR codes within a time-limited window and upload photo verification was viewed by certain respondents as an additional procedural burden. From the perspective of the technology acceptance model (TAM), this reflects challenges related to perceived ease of use. When users perceive increased procedural effort, their attitude toward system adoption may be negatively affected despite objective efficiency gains [43].

Third, technical usability issues were identified. These included difficulties in uploading images or compatibility limitations with certain devices. Although these issues were not widespread, they underscore the need for continuous system optimization and user-centered interface refinement.

Finally, a small proportion of respondents expressed preference for traditional attendance methods, suggesting elements of resistance to change. Such responses are consistent with adoption literature indicating that familiarity with legacy systems can influence user attitudes. This occurs even when new systems

demonstrate measurable advantages. Overall, these findings do not undermine the system’s effectiveness but rather provide valuable insights for future system enhancement. Addressing infrastructure variability, simplifying user workflows, and strengthening user training strategies may further improve adoption outcomes and long-term sustainability in diverse educational contexts.

The results presented in Table 5 indicate that gender-based differences in satisfaction were generally minimal. Independent samples t-tests revealed no statistically significant differences between male and female users in most satisfaction dimensions, including the ability to meet user needs ( $t = -0.576, p = 0.565$ ), perceived time reduction ( $t = -1.735, p = 0.083$ ), and overall satisfaction ( $t = -1.702, p = 0.089$ ). A statistically significant difference was observed only in the dimension of work facilitation efficiency ( $t = -2.422, p = 0.015$ ). However, the associated effect size was extremely small (Cohen’s  $d = -0.03$ ), indicating a negligible practical difference between male and female users. Given the large sample size ( $N = 27,070$ ), even trivial mean differences may reach statistical significance. Therefore, although one dimension achieved statistical significance at the 0.05 level, the magnitude of the observed gender differences is not practically meaningful. These findings suggest that the SmartCloud QR system is perceived similarly across genders, demonstrating equitable usability and acceptance among male and female users.

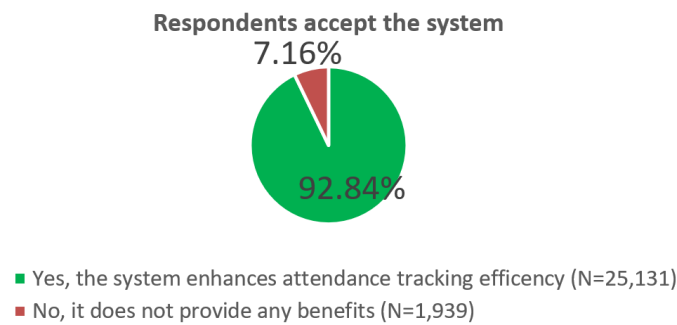


Figure 5. Overall acceptance of high effectiveness and benefits

Table 5. Independent samples t-test results comparing gender differences in satisfaction dimensions

| Satisfaction with the SmartCloud QR                            | Male |      | Female |      | t      | P-value | Cohen’s d |
|--|------|------|--------|------|--------|---------|-----------|
|  | Mean | S.D. | Mean   | S.D. |        |         |           |
| The system’s ability to meet user needs.                       | 4.34 | 0.68 | 4.35   | 0.67 | -0.576 | 0.565   | -0.007    |
| The system’s effectiveness in facilitating work efficiency.    | 4.30 | 0.70 | 4.34   | 0.68 | -2.422 | 0.015*  | -0.030    |
| The system’s capability to reduce the time required for tasks. | 4.33 | 0.69 | 4.35   | 0.68 | -1.735 | 0.083   | -0.022    |
| Average user satisfaction with the quality of system service.  | 4.32 | 0.68 | 4.34   | 0.67 | -1.702 | 0.089   | -0.021    |

\*Significance level at  $p < 0.05$

Table 6 reports the results of the one-way ANOVA conducted to examine satisfaction differences among three user role groups (teacher, student, and other). The analysis revealed a statistically significant difference in satisfaction across the groups ( $F = 6.233, p = 0.002$ ). This indicates that the role of the user has a measurable effect on how satisfaction with the system is perceived.

Table 6. One-way ANOVA results for differences in satisfaction across three groups in user role

| Source of variation | Sum of squares (SS) | df     | Mean square (MS) | F-value | P-value |
|---------------------|---------------------|--------|------------------|---------|---------|
| Between groups      | 5.857               | 2      | 2.928            | 6.233   | 0.002*  |
| Within groups       | 12,696.54           | 27,024 | 0.470            |         |         |
| Total               | 12,702.39           | 27,026 |                  |         |         |

\*Significance level at  $p < 0.01$

To further explore these differences, Table 7 presents the results of the LSD post hoc test. Pairwise comparisons indicate that the satisfaction level of teachers differed significantly from that of students (mean difference = 0.041,  $p = 0.005$ ). However, no statistically significant differences were observed between teachers and other users ( $p = 0.142$ ) or between students and other users ( $p = 0.491$ ). These findings

suggest that teachers, as primary system operators, expressed slightly higher levels of satisfaction compared to students, while the “other group” showed no significant difference from either of the main user groups.

Table 7. Post hoc test (LSD) for pairwise comparisons of the satisfaction among three groups in user role

| Group (I) | Group (J)   | Mean difference (I-J) | Std. Error | P-value | Interpretation  |
|-----------|-------------|-----------------------|------------|---------|-----------------|
| Teacher   | Student     | 0.041                 | 0.125      | 0.005*  | Significant     |
| Teacher   | Other group | 0.101                 | 0.051      | 0.142   | Not significant |
| Student   | Other group | 0.059                 | 0.495      | 0.491   | Not significant |

\*Significance level at  $p < 0.01$ , using the LSD post hoc test

As shown in Table 8, a robustness independent samples t-test was conducted to compare overall satisfaction between teachers and students. The results indicated a statistically significant difference,  $t$  statistic = 3.285,  $p = .001$ , mean difference = 0.05, 95% CI [0.02, 0.08], with teachers reporting slightly higher satisfaction (mean = 4.36, S.D. = 0.67) than students (mean = 4.31, S.D. = 0.68). However, the effect size was very small (Cohen's  $d = 0.06$ ), suggesting that although the difference reached statistical significance due to the large sample size, its practical magnitude is minimal. Overall, the statistical analyses confirm that gender and user role both influence user satisfaction with the SmartCloud QR system. While the differences are not large in magnitude, they are significant and highlight the importance of considering demographic and role-based factors when designing and implementing attendance management systems.

Table 8. Robustness test: independent samples t-test comparing teachers and students across satisfaction dimensions

| Satisfaction compares with user roles                          | Teacher |      | Student |      | $t$   | P-value | Cohen's $d$ |
|--|---------|------|---------|------|-------|---------|-------------|
|  | Mean    | S.D. | Mean    | S.D. |       |         |             |
| The system's ability to meet user needs.                       | 4.33    | 0.81 | 4.28    | 0.81 | 3.449 | 0.001*  | 0.063       |
| The system's effectiveness in facilitating work efficiency.    | 4.36    | 0.79 | 4.29    | 0.80 | 4.852 | <0.001* | 0.089       |
| The system's capability to reduce the time required for tasks. | 4.37    | 0.81 | 4.30    | 0.80 | 4.819 | <0.001* | 0.088       |
| Average user satisfaction with the quality of system service.  | 4.36    | 0.67 | 4.31    | 0.68 | 3.285 | 0.001*  | 0.060       |

\*Significance level at  $p < 0.01$ .

Moreover, the findings highlight the system's effectiveness in addressing long-standing problems of manual attendance tracking, providing significant improvements in accuracy and fraud prevention compared to prior QR-based attendance systems. Table 9 shows a comparative analysis between the smart attendance system proposed by Nuhi *et al.* [44] and the SmartCloud QR developed in this study. The comparison highlights key technological, architectural, and functional differences that demonstrate the enhanced effectiveness and scalability of the SmartCloud QR system.

In terms of core technology, while Nuhi *et al.*'s system relied solely on QR codes, SmartCloud QR integrates both QR codes and cloud computing. This integration allows for greater scalability, remote accessibility, and seamless synchronization across devices. Regarding the system architecture, Nuhi *et al.*'s model [44] was a conventional web-based system designed to be responsive across devices. By contrast, SmartCloud QR is implemented as a software-as-a-service model, enabling institutions to access the system without additional installation or maintenance costs. This model reduces technical barriers and ensures widespread usability. For hardware management, the earlier system required installation of camera-connected devices in classrooms to read QR codes, which limited flexibility and increased setup costs. SmartCloud QR, however, requires no additional hardware beyond commonly available smartphones and computers, making it more practical and cost-effective.

A significant distinction is observed in anti-fraud and accuracy mechanisms. Nuhi *et al.*'s system improved security by generating unique QR codes for professors and students, but SmartCloud QR goes further by requiring students to take a photo to confirm their physical presence in the classroom. This additional verification prevents proxy attendance and strengthens the authenticity of attendance records. In terms of pilot implementation and scope, Nuhi *et al.*'s study was limited to a case study at the University of Tetova in North Macedonia. By comparison, SmartCloud QR has been tested at Maharakham Business School and subsequently adopted by more than 1,000 educational institutions and private organizations, including international adoption in China and Laos. This demonstrates its cross-cultural applicability and global scalability. With regard to evaluation and satisfaction, Nuhi *et al.*'s system primarily focused on replacing manual monitoring to speed up the process, without providing extensive user evaluation results.

SmartCloud QR, on the other hand, achieved a high user satisfaction rate of 92.84% based on 27,070 survey responses, confirming its effectiveness and acceptance among users.

Finally, the backend development of Nuhi *et al.*'s system was not explicitly described beyond using the Instascan JS library for QR code reading. In contrast, SmartCloud QR was developed with robust backend processes using PHP and a cloud-based MySQL database, ensuring scalability, reliability, and secure data management. Taken together, these comparative insights demonstrate that SmartCloud QR provides substantial improvements over prior systems by leveraging cloud-based architecture, requiring no specialized hardware, enhancing anti-fraud mechanisms, and proving its large-scale applicability through extensive adoption and high user satisfaction rates.

Table 9. Comparative table of QR code-based attendance systems

| Comparison aspect       | Smart attendance system (Nuhi <i>et al.</i> [44])   | SmartCloud QR (This research)  |
|-------------------------|---|--|
| Project/research title  | Smart attendance system using QR codes.   | SmartCloud QR: a next-gen online attendance system leveraging QR code and cloud technology   |
| Core technology         | QR code   | QR code and cloud technology (cloud computing)   |
| Architecture/model      | Web-based system that is fully responsive to mobile phones, tablets, and various computer systems.                  | Software-as-a-service model.   |
| Hardware management     | Requires installation of a device connected to a camera device and the internet in each classroom to read QR codes. | Requires no specialized hardware beyond existing devices such as smartphones and computers.  |
| Anti-fraud/accuracy     | Improved security over traditional methods by using a unique QR code for each professor and student.                | Requires students to take a photo confirming their presence in the classroom to ensure authenticity and prevent proxy attendance.  |
| Pilot location/scope    | A case study was conducted at the University of Tetova—North Macedonia.   | A preliminary investigation was conducted at Mahasarakham Business School (Thailand). The system is adopted by over 1,000 educational institutions and private groups, including institutions from China and Laos. |
| Evaluation/satisfaction | Focuses on replacing the current system of manual monitoring and recording; it aims to speed up the process.        | Achieved an overall user satisfaction rate of 92.84% based on 27,070 survey responses.   |
| Backend development     | Not explicitly specified (system uses the Instascan JS library for QR code reading).                                | Developed using PHP for backend processes and MySQL for data storage. Utilizes a cloud-based MySQL database.   |

Table 10 presents a cross-technology comparative analysis of prevailing attendance management systems, including RFID, face detection via CCTV, NFC-based systems, biometric fingerprint scanning, and the SmartCloud QR platform developed in this study. The comparison encompasses core technology, architectural models, hardware requirements, fraud prevention mechanisms, implementation contexts, and user satisfaction outcomes. RFID-based systems rely on radio frequency communication between tags and readers to enable rapid data transmission. While such systems are capable of processing large volumes of attendance data efficiently, they require substantial initial hardware investments, including RFID readers and identification cards. Moreover, RFID implementations remain susceptible to proxy attendance (commonly referred to as “buddy punching”) and potential signal collision when multiple tags are scanned simultaneously [13], [45].

Face detection systems, typically utilizing AI-driven image recognition models such as convolutional neural networks, offer fully contactless attendance verification and continuous monitoring capabilities. These systems demonstrate high accuracy under optimal environmental conditions and effectively reduce proxy attendance. However, their performance is highly dependent on camera quality, lighting conditions, and computational resources. Additionally, privacy concerns and high processing demands may limit large-scale deployment in resource-constrained institutions [11], [21].

NFC-based attendance systems provide enhanced proximity-based authentication, requiring students to be physically close to scanning devices. This short-range communication increases security compared to Bluetooth-based approaches. Nevertheless, implementation is constrained by smartphone compatibility, as not all devices support NFC functionality, potentially affecting inclusivity [12].

Biometric fingerprint systems ensure identity verification through unique physiological traits, offering strong anti-fraud protection. Despite their high reliability, such systems may create operational bottlenecks in large classes, resulting in queuing delays. Furthermore, scanner sensitivity issues (e.g., wet or damaged fingers) and hygiene concerns associated with shared physical contact represent practical limitations [15], [17], [46], [47].

Table 10. Comparative analysis of SmartCloud QR and alternative attendance system technologies

| Criteria                | RFID and IoT [13], [45]  | Face detection (CCTV/Webcam) [11], [21]   | NFC [12]   | Biometrics (fingerprint scanner) [15], [17], [46], [47]  | SmartCloud QR (this research)  |
|-------------------------|--|---|--|--|--|
| Core technology         | Radio frequency waves (RFID tags/readers) and IoT (e.g., ESP32)  | Facial recognition utilizing AI/deep learning (e.g., ResNet-50, YOLO, and Haar Cascade)   | Short-range wireless communication (NFC)   | Physical characteristic recognition (Fingerprint scanning).  | QR code integrated with cloud computing.   |
| Architecture/model      | Hardware devices connected to the internet to transmit data to a database                                | Real-time detection models monitoring the entire class duration or capturing images at specific intervals                                 | Client-server architecture via mobile application  | Standalone systems or network-connected to a central database.   | Software-as-a-service via a web-based platform.  |
| Hardware management     | Hardware installation is required; it necessitates RFID readers, microcontroller boards, and RFID cards. | Specific hardware is required, necessitating high-quality CCTV cameras or webcams.  | Requires NFC-enabled smartphones and NFC tags.   | Requires the installation of fingerprint scanning devices.   | No specialized hardware is required; it utilizes students' existing smartphones and computers.   |
| Anti-fraud/accuracy     | High vulnerability; susceptible to proxy attendance (buddy punching) and tag collision issues.           | Very high accuracy; excellent at preventing proxy attendance, though accuracy may decrease in low-light conditions or poor camera angles. | High accuracy; requires devices to be in close proximity (<5 cm) and checks IMEI to prevent device swapping. | Very high accuracy; extremely difficult to forge, but scanning failures may occur if fingers are wet or dirty. | High accuracy; prevents proxy attendance by requiring students to take a live photo confirming their location in the classroom while scanning. |
| Pilot location/scope    | Various institutions, e.g., SMP Negeri 35 Palembang (Indonesia).   | Gujarat University (India) and University of Kigali (Rwanda).   | Pontifical University of Salamanca (Spain).  | Madrasah Aliyah Nurul Falah (Indonesia) and other institutions.  | Mahasarakham Business School (Thailand) and adopted by over 1,000 institutions, including in China and Laos.                                   |
| Evaluation/satisfaction | Moderate to good; fast processing but constrained by high initial hardware installation costs.           | High satisfaction and highly accurate detection (F1-score 90-94%) significantly reduce time, but the system is complex.                   | High satisfaction; rated 8.62/10 by students and 9.25/10 by lecturers.                                       | Good, 100% fraud prevention, but it causes delays/queuing and raises hygiene concerns (e.g., post-COVID-19).   | Extremely high satisfaction; 92.84% user satisfaction (from 27,070 respondents), noted for its ease of use.                                    |
| Backend development     | Developed with PHP, MySQL, and Arduino IDE (for the device side).  | Developed using Python, Flask, Firebase Realtime DB, and artificial neural networks.  | Web portal for data management and MySQL database.   | Standard database management systems (SQL) alongside desktop applications.                                     | Developed with PHP and a MySQL database on a cloud server.   |

In contrast to hardware-dependent approaches, the SmartCloud QR system adopts a cloud-based software-as-a-service architecture that eliminates the need for dedicated hardware infrastructure. By leveraging students' existing smartphones and integrating live photo capture with location verification, the system effectively mitigates proxy attendance while maintaining deployment scalability. To ensure responsible data governance and privacy protection, captured images used for identity verification are securely stored for a limited retention period of 14 days. After this period, the system automatically deletes the images from the cloud server to release storage capacity and minimize unnecessary data accumulation. This retention policy balances identity verification requirements with data minimization principles and cloud resource efficiency.

The web-based architecture enables rapid institutional adoption without significant capital expenditure. Although minor usability challenges were reported, particularly regarding photo uploading and reliance on stable internet connectivity, overall satisfaction levels were substantially high. Overall, the comparative findings suggest that SmartCloud QR achieves a pragmatic balance between scalability,

cost-efficiency, fraud prevention, data governance compliance, and implementation feasibility, thereby providing a practical digital solution aligned with contemporary educational management needs.

Based on the empirical results, the implementation of the online attendance system using QR code technology demonstrates significant improvements in both operational efficiency and user satisfaction. These findings are contextualized in relation to prior research. They also highlight the system's broader implications for educational management practices.

**Efficiency and time reduction:** the current study found that the online attendance system reduced the time required for attendance in large classrooms, which previously exceeded 30 minutes. The average user satisfaction score for the system's capability to reduce the time required for tasks was 4.31 out of 5, indicating high effectiveness. This result aligns with previous research by Talip and Zulkifli [34], who demonstrated that QR code-based attendance systems significantly decrease the time needed for attendance recording compared to traditional methods.

Overall, user satisfaction with the system was high, with an average satisfaction rate of 92.84%. The system's ability to meet user needs scored an average of 4.29, and its effectiveness in facilitating work efficiency scored 4.31. These findings are consistent with the results of Nuhi *et al.*, who reported that QR code-based systems improved accuracy and user satisfaction in higher education institutions. Additionally, the adoption of a software-as-a-service model ensured that the system was accessible, scalable, and simple to manage, further enhancing user satisfaction [44], [24].

**Technological barriers and training:** faculty members expressed a desire for a fast and modern attendance system, but lacked the technical expertise and resources to develop and maintain such systems independently. The adoption of a free cloud-based software-as-a-service model effectively mitigated this barrier by eliminating development complexity and reducing operational burdens. By shifting infrastructure management to a centralized cloud environment, institutions can ensure long-term sustainability through automatic updates, centralized data storage, and scalable architecture without recurring hardware investments.

Furthermore, the software-as-a-service deployment model enhances cost-effectiveness by minimizing capital expenditures associated with hardware procurement, system maintenance, and IT personnel training. This approach supports resource-constrained institutions seeking digital transformation without significant financial risk. Beyond immediate usability, the web-based and API-compatible architecture also facilitates integration with broader educational IT ecosystems, including learning management systems (LMS), student information systems, and institutional data analytics platforms [48]. Beck *et al.* [49] support this perspective, emphasizing that user-friendly and accessible digital technologies significantly enhance efficiency and long-term institutional effectiveness. Accordingly, the SmartCloud QR system not only addresses immediate technological barriers but also contributes to sustainable digital infrastructure development within educational management contexts.

**Data security and privacy:** the system incorporates multiple layers of technical and procedural safeguards to ensure data protection and responsible identity verification. In addition to SSL/TLS encryption and secure authentication mechanisms [39], [40], QR codes are generated and verified through the central system and can only be activated by the instructor during a limited attendance window. This time-restricted activation mechanism reduces the risk of unauthorized access or external distribution of QR codes. Students are required to scan the instructor-issued QR code within the designated time frame and capture a live classroom photo to verify their physical presence, thereby minimizing proxy attendance attempts.

To address data privacy concerns related to image-based verification, captured photos are securely stored in the cloud server for a limited retention period of 14 days solely for verification and auditing purposes. After this period, the system automatically deletes the images to release storage resources and prevent unnecessary long-term data accumulation. This data minimization approach aligns with privacy-by-design principles and reduces exposure risks associated with storing sensitive visual information. Collectively, these layered safeguards strengthen system security while balancing fraud prevention with responsible data governance practices in educational environments [40].

**Comparison with traditional methods:** the study highlighted several limitations of traditional attendance methods, such as the risk of lost attendance sheets and limited space for annotations. The digital system addressed these issues by providing a secure, centralized database for storing attendance records and offering unlimited space for annotations [44]. This improvement aligns with findings of Schwartz *et al.* [50], who noted that digital systems enhance data integrity and reliability.

The findings presented in Figure 5 can be further interpreted through the lens of the TAM. According to Davis [43], TAM posits that two primary factors—perceived usefulness and perceived ease of use—influence users' attitudes toward adopting a new technology. In this study, the high acceptance rate (93%) indicates that users found the SmartCloud QR attendance system useful in enhancing attendance tracking efficiency, aligning with the perceived usefulness construct. Additionally, the system's simple

design, mobile accessibility, and automated processes likely contributed to a favorable perception of ease of use, reflecting the perceived ease of use construct.

These results suggest that both perceived usefulness and perceived ease of use positively influenced user acceptance, leading to widespread adoption across faculty and student groups. This supports prior research demonstrating that educational technologies with clear benefits and user-friendly designs are more readily embraced in academic contexts [42]. The findings further extend TAM by suggesting that perceived usefulness in institutional attendance systems is influenced not solely by task efficiency but also by embedded fraud-prevention mechanisms and the cost-minimizing software-as-a-service deployment model, highlighting the multidimensional nature of utility perception in educational informatics contexts. Despite the large sample size, the voluntary response sampling design may introduce self-selection bias, whereby users who were more satisfied or digitally engaged were more likely to participate in the survey. Although the substantial number of respondents enhances statistical precision, the non-probability sampling approach limits the generalizability of the findings.

In addition, while the system presumes access to smartphone devices, national digital access reports indicate that smartphone penetration among university students exceeds 94.84%, thereby substantially reducing digital divide concerns within higher education environments. Nevertheless, future research may explore adaptive deployment models to accommodate institutions with varying levels of technological infrastructure. Taken together, the implementation of the QR code-based attendance system through a software-as-a-service architecture significantly improved operational efficiency and strengthened identity verification mechanisms in educational institutions. Future research should investigate the long-term effects of such systems on student performance, behavioral engagement, and institutional analytics integration, as well as employ probability-based sampling strategies to further enhance external validity.

#### 4. CONCLUSION

This study's implementation of SmartCloud QR through a cloud-based software-as-a-service architecture demonstrates that scalable, cost-efficient, and hardware-independent attendance management is feasible in contemporary educational settings. By leveraging students' existing smartphones—devices that are already widely owned and routinely carried—the system eliminates the need for additional hardware investment, resulting in near-zero infrastructure cost for institutions. The integration of QR code scanning, live photo verification, and cloud-based processing enhances operational efficiency, mitigates proxy attendance, and supports responsible data governance through controlled retention policies. Although minor statistical differences were observed across gender and user roles, the inclusion of p-values and effect size measures (Cohen's *d*) confirms that the differences are statistically insignificant or practically negligible, indicating broadly consistent acceptance across user groups. Beyond immediate efficiency gains, the system contributes to long-term sustainability by reducing capital expenditure, minimizing maintenance requirements, and enabling seamless scalability within broader educational IT ecosystems. Future research should enhance this framework by prioritizing the integration of high-speed facial recognition algorithms over location-based methods like geo-fencing. This approach ensures physical presence within the classroom while investigating multi-face detection techniques to minimize processing latency, enabling near-instantaneous attendance marking for large student cohorts.

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#### AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization

M : **M**ethodology

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E : Writing - Review & **E**ditng

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

## CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

## INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

## ETHICAL APPROVAL

The research related to human participation complied with all relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration. The study was reviewed and approved under an exemption review by the Mahasarakham University Ethics Committee for Research Involving Human Subjects, Thailand (approval number: 318-329/2025).

## DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author, [KC], upon reasonable request.

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