Development of a QR-Based Automated Attendance Management System For Tertiary Institutions

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ABSTRACT Attendance plays a vital role in monitoring student participation and maintaining academic standards in higher institutions. The traditional way of monitoring and maintaining student academic activities such as lectures, laboratory practical participation, etc is that students write their names and matriculation numbers (Student ID) on sheet of paper. However, this method of recording attendance are often inefficient, error-prone, time-consuming, and susceptible to impersonation. To address these challenges, this study presents the design and implementation of a QR-based automated attendance management system. The system was architected using UML diagrams to model user interactions and core processes including QR code generation, scanning, and attendance validation. The system was built with the MERN stack (MongoDB, Express.js, React.js, Node.js), the application features role-based authentication for students and lecturers, real-time attendance tracking through dynamic QR codes, automated data validation with timestamp verification, and cloud-based profile management with Cloudinary integration. This full-stack solution transforms traditional or manual attendance processes into an automated, scalable system for tertiary institutions. The system generates unique, time-sensitive QR codes that lecturers display for each lecture session. Students mark their attendance by scanning the code, after which their name and matriculation number (Student ID) are automatically recorded in a centralized database.

Keywords: Attendance, QR-based, automated attendance, UML diagrams, real-time, attendance tracking, dynamic QR Codes

INTRODUCTION

Universally, Information Technology (IT) represents an essential tool that helps countries enhance their respective economies in the educational and industrial sectors [1]. Therefore the tracking of student attendance remains a cornerstone of educational assessment, providing crucial insights into academic engagement and participation patterns. Attendance systems have been rated as amongst the critical criteria that reflect domain achievements in both academic and organizations setting and their performances have contributed better to organizations, industries and universities compared with traditional methods that are time-consuming and inefficient [2].

In the early stages of formal education, attendance tracking primarily involved paper-based registers and roll calls, which served the needs of smaller student populations. However, the dramatic expansion of higher education enrollment in recent decades has exposed the limitations of these conventional methods. Educational institutions now face mounting challenges in managing attendance records for large student populations, particularly in ensuring accuracy, preventing proxy attendance, and generating timely analytic for academic assessment. The modern educational landscape faces multiple critical challenges in attendance management. Manual attendance systems consume valuable instruction time, with studies indicating that traditional roll calls could take up to 10-15 minutes of each class session, making it time consuming and an high level of impersonation as absentee can be on the list through their friends that attended the class due to the lower lecturer/student ratio and large class size. Consequently, it is very difficult to manage the attendance and determine whether each student actually made seventy-five percent (75%) of

lecture attendance as required by the university authority [3].

Recent technological advancements, particularly in mobile computing and QR Code technology, have opened new possibilities for attendance management. QR Codes, first developed in 1994 by Masahiro Hara at Denso Wave for tracking automotive parts [4], have evolved into versatile tools for information management. QR Codes make it possible for large volume of information to be arranged in small spaces due to its capability to hold a lot of information [3]. The implementation of these systems has shown promising results, as researchers have concluded that they are effective in easing up the process of checking and recording attendance [5]. Their application in educational settings offers promising solutions to long-standing attendance management challenges, providing a cost-effective, secure, and user-friendly alternative to traditional method. Building on the integration of QR code technology, this study focuses on integrating QR codes to create a secure, efficient, and automated attendance management system for tertiary institutions.

RELATED WORK

Many studies have reported various technique for implementing an automated attendance management system.

An RFID-based attendance system developed by R *et al.* in [8] that utilized Radio Frequency Identification (RFID) technology to track student and faculty attendance, simplifying the payroll management process. The system was designed to monitor attendance across multiple locations within an educational institution, such as classrooms, libraries, laboratories, hostels, mess halls, and administrative offices. This system uses RFID tags and readers to track student and faculty attendance across various locations within an institution. While it simplifies payroll and tracks movement,

a major flaw is the ease with which tags can be swapped, allowing for proxy attendance. The system also has high hardware costs and maintenance needs.

Korukanti *et al.* in [9], utilized a face recognition technology to improve the accuracy and efficiency of their attendance tracking processes. One of the key benefits of face recognition technology in attendance management is the elimination of manual tracking, as it automates the attendance recording process. This not only saves time and resources but also reduces the potential for human error.

Tumenayu and Benjamin in [3] focused was targeted at the design and implementation of mobile attendance management system using embedded QR ID Card to address the problem of poor lecture attendance for the Universities, (University of Cross River as a case study) by building a system that will help curb this act. This mobile attendance system was designed for universities to address poor lecture attendance. It uses an embedded QR ID card and a mobile application to ensure students are physically present in class. The system uses a student's image and personal data from a database for real-time identification. While it offers a modern, real-time solution for attendance tracking, the summary notes a complex registration process and a manual daily update by an administrator, which may not be fully automated.

A contactless attendance management system based on Artificial Intelligence (AI) technology study by Rajamanogaran *et al.* in [7] explained that the system used Deep learning along with Neural networks which enabled the system to captured students face as they entered the lecture-room. This system may not be accurate at all time as it captures the student face including the eye lens. The system could fail if a student's facial appearance or the environmental conditions changed.

Memane *et al.* in [6] developed a biometric fingerprint-based system to track student attendance in educational institutions. The system, which combines fingerprint scanning with recognition technology, uses a Raspberry Pi as its controller, along with an Arduino and a camera. Its main goal was to create a transparent system with real-time data and reports, replacing traditional paper methods.

These above works rely heavily on specialized hardware and mobile applications. However, these solutions are often costly to implement and difficult to maintain due to a number of inherent problem. This study filled these gaps by utilizing a web based solution for the attendance management system, making it accessible and available everywhere, with scalable maintenance.

METHODOLOGY

This study is structured through a detailed methodology which include the system architecture, system design, system requirements, development tools and frameworks used to achieved the aim of this study.

System Architecture

The system follows a modular architecture that ensures scalability, effectiveness, ease of maintenance, and better performance. The system comprises several interconnected components, each responsible for specific functionalities.

As demonstrated schematically in Figure 1, the system acts as a representative illustration of interaction between different components of the QR based attendance management system. It shows how the flow of data takes place between frontend, backend and database showing how the lecturers generate a dynamic QR code that is scanned by students for attendance, after which the system processes and keeps secure records for attendance.

The system is built using three-tier architecture model, which includes:

i. Presentation Layer (Frontend): An appealing and attractive user-facing

interface for an interactive and responsive experience.

ii. Application Layer (Backend): This layer handles the authentication, authorization, QR code generation, attendance report generation etc.

iii. Database Layer (Storage): The storage stores user details, attendance records, and other necessary details securely

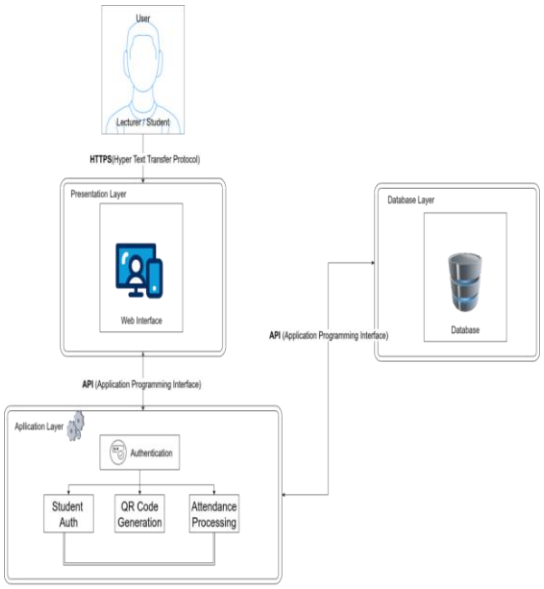

Figure 1 QR-Based Automated Attendance Management System Architecture Diagram

SYSTEM DESIGN

System Users: A top-down model was adopted and the analysis is broken down into different components where the design started from the main component down to the elementary components. The system is categorized into two major subsections: lecturer subsection, and student subsection. Each of the subsections has a different user privileges to use the system as shown in figure 2.

Lecturer: In the lecturer space, Each has its profile, unique to individual lecturers, once he/she is successfully registered. The profile contains critical information, including name, email, and department. After logging into the system, the lecturer is directed immediately to the dashboard, which is the control center for attendance management.

Student: Once the student is authenticated successfully, he/she is redirected to the student dashboard. This profile is inclusive of basic information such as name, matriculation number, course enrollment etc. The student is able to update profile information including editing or deleting the account

if need arises.

The system allows lecturers to generate a time-sensitive QR code for a specific course. Students can scan this code from a screen or a printout to mark their attendance. The attendance data is then securely stored in a database, and lecturers can download a compiled report for future use. The system validates every QR codes generated and ensures that students do not reuse or share them after expiration, ensuring safety against marking attendance fraudulently. It increases transparency and minimizes attendance fraud while making the overall attendance management process streamlined.

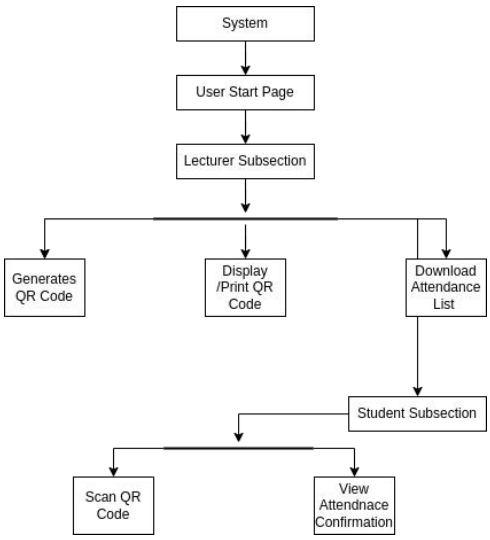

Figure 2 QR-Based Automated Attendance Management System Top Down Design Approach

Use Case Diagram: The use case diagram in figure 3 described the system interacts with different users (actors) and the system. It defines what functionalities the system provides and how users interact with it.

Class Diagram: The class diagram in figure 4 provides an outline of the basic architecture of the dynamic QR-based automated attendance management system. At the very core of the system are the two main user classes (lecturer and student) which are derived from a common user super-class that describes key attributes associated with all users, such as name, email, department and password, and the basic functions of login, logout and profile management.

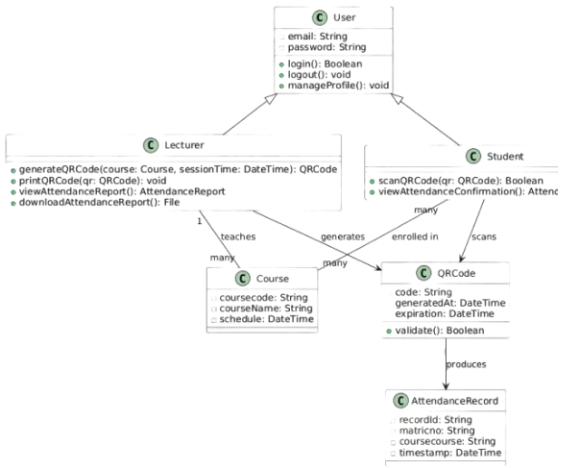

Figure 4 QR-Based Automated Attendance Management System Class Diagram

Activity Diagram: The activity diagram captures the complete workflow of the QR-based attendance management system, ensuring clarity in the system's operations and error-handling procedures. Figure 5 shows the activity diagram for the system.

Flowchart Diagram: Figure 6 provides a comprehensive visual representation of the entire workflow QR-based attendance management system.

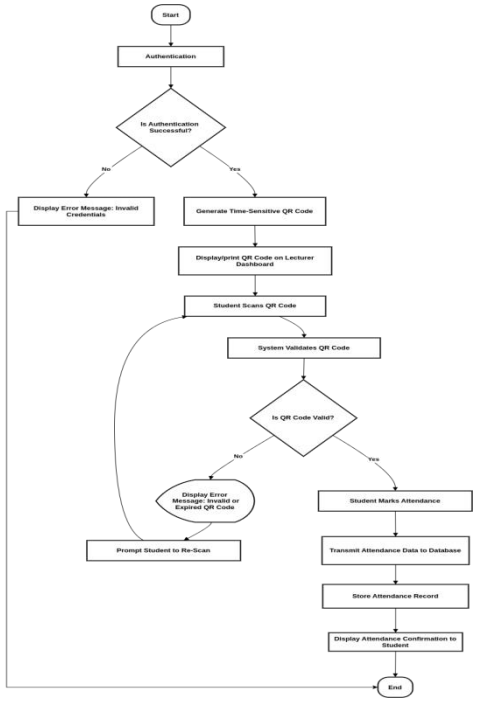

Figure 6 QR-Based Automated Attendance Management System Flowchart Diagram

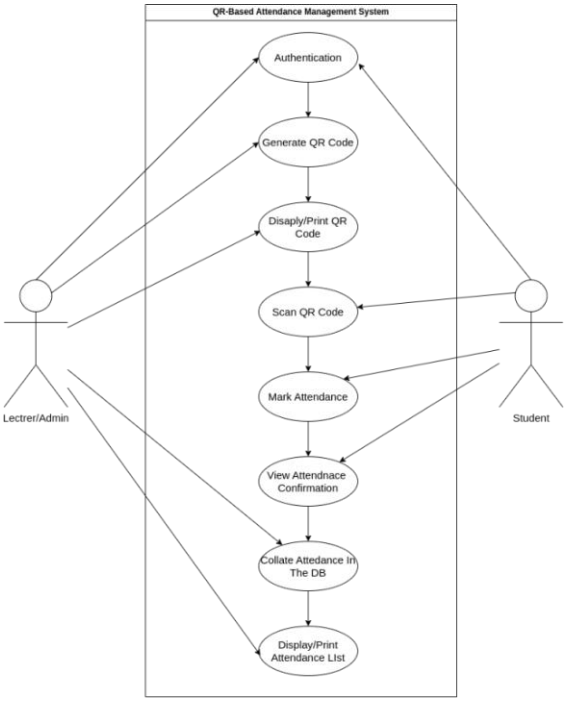

Figure 3 QR-Based Automated Attendance Management System Use Case Diagram

Figure 5 QR-Based Automated Attendance Management System Activity Diagram

System Requirements

The system requirements for a QR-code-based automated attendance management system cover hardware, software, and operational demands.

Hardware: A robust server is required to host the back-end and database. Additionally, students and lecturers need mobile devices or laptops to access the application.

Software: The system requires a secure back-end built with appropriate programming languages and frameworks, as well as a user-friendly web interface for both students and lecturers.

Database: A No-sql database was used for securely storing user accounts, detailed attendance records, and system logs.

Operational Requirements: The system is designed for scalability and easy maintenance, ensuring it can accommodate a growing number of users and adapt to future institutional needs.

This comprehensive approach ensures the system is not only effective at accurately tracking attendance but also robust enough for modern educational environments.

Development Tools and Frameworks

The system is built on the MERN stack, TypeScript with React.js and TailwindCSS for a dynamic, interactive front end, and Node.js with Express.js for a clean back end. It uses a MongoDB database to store user and attendance data and a QR code generation library to create secure, time-sensitive QR codes.

RESULTS

The QR-based automated attendance

management system was deployed and tested during lecture activities. The system provides a comprehensive digital solution for educational institutions, revolutionizing traditional attendance tracking methods through advanced technology integration. The system supports dual user roles where lecturers and students register through secure sign-up processes with multi-layered email verification, profile setup including profile picture uploads, and role-based authentication mechanisms. During the registration phase, students provide academic details such as full name, email address, matriculation number (student ID), etc, while lecturers input just the same credentials. The core functionality revolves around lecturers generating unique QR codes for each individual lecture session, with these codes containing sophisticated encrypted data including comprehensive lecture session details, timestamps, course identifiers and security tokens to prevent unauthorized duplication. These dynamically generated QR codes can be conveniently displayed on lecture-room screens, projected onto whiteboards, or printed as physical paper for posting around the lecture venue, providing flexible accessibility options for students. The attendance marking process involves students using their mobile devices to scan the displayed QR code through the system dedicated in-app scanner, with the system performing real-time QR-code validation and duplicate scan prevention to ensure completely authentic attendance marking while eliminating possibilities of proxy attendance. The system features attendance tracking and analytics capabilities that automatically record precise timestamps for each student attendance, maintain detailed attendance histories, calculate real-time and cumulative attendance rates with percentage breakdowns, and generate comprehensive reports in multiple

professional formats including PDF for formal documentation and CSV for data analysis purposes that can be seamlessly downloaded and printed for permanent institutional records and administrative requirements. Lecturers benefit from powerful monitoring tools that allow them to observe live attendance statistics during active sessions, analyze detailed attendance trends across different time periods and courses, and generate comparative reports between different lectures. The system incorporates advanced profile management systems for both users, enabling personal information update, view complete attendance history/reports, track performance across multiple courses, access detailed analytics dash--boards, customize report formats. Figure 8-18 diagrammatically illustrates the system interfaces and operations.

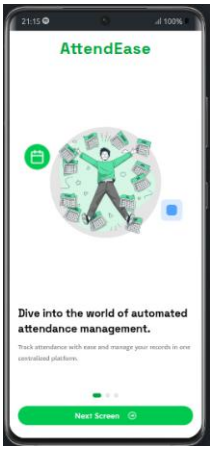

Figure 6 Landing page

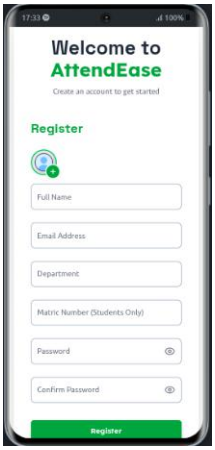

Figure 7 Sign up page

Figure 8 Sign in page

Figure 9 Lecturer dashboard

Figure 10 Student dashboard

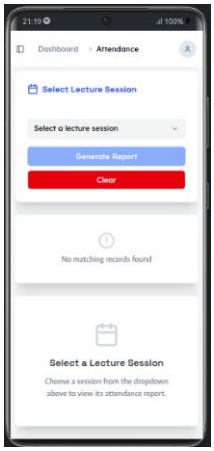

Figure 11 Lecturer attendance

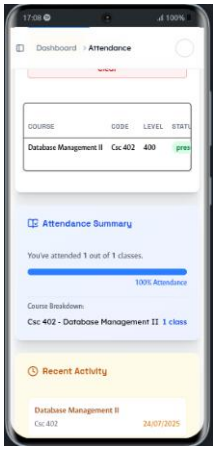

Figure 12 Attendance

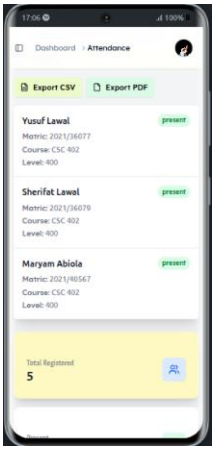

Figure 13 Attendance

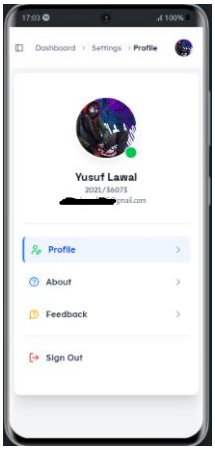

Figure 18 Student settings page

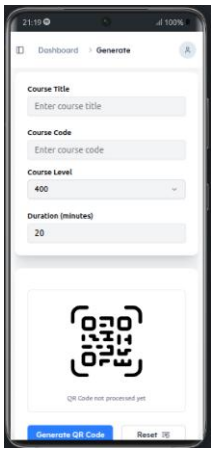

Figure 14 Generate QR code

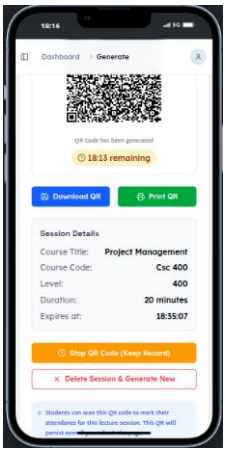

Figure 15 Generated QR code

Figure 16 Scan QR code

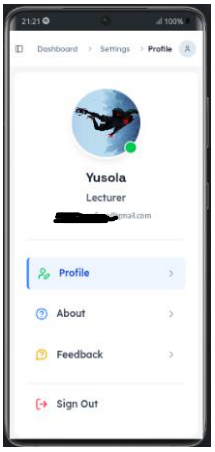

Figure 17 Lecturer settings page

Conducted test showed that each student tended to mark their attendance in approximately 3-6 seconds using the QR-based system, though this metric may vary due to network connectivity problems. This attendance taking speed differs drastically from the traditional mode of taking attendance, which typically required instructors to call out names individually and wait for student responses, consuming significantly more class time. The automated system eliminated the need for manual roll call procedures and reduced the overall time investment required for attendance tracking.

Students feedback as shown in figure 19

indicated overwhelmingly positive responses to the QR-based attendance system, with most participants finding it intuitive and user-friendly, requiring minimal instruction or technical support. Students particularly appreciated the speed and convenience of the scanning process compared to traditional attendance methods.

feedbacks

	category String	message String
1	"feature"	"Very impressive "
2	"other"	"Nice work!!"
3	"general"	"Nice work. Very useful …
4	"general"	"Wowwwww. Great work. Be…
5	"other"	"Good work... Need this …

Figure 19 Users' feedback

DISCUSSION

This study successfully achieved its aim of designing and implementing a secure and efficient QR-based automated attendance management system for tertiary institutions. The system demonstrated significant improvements over traditional attendance methods and proved to be highly effective in addressing the common challenges faced in educational settings.

System Performance and Efficiency: The most notable finding from this study was the dramatic improvement in attendance marking speed. Students were able to mark their attendance in just 3-6 seconds using the QR-based system, which represents a massive time saving compared to traditional roll call methods. In traditional attendance taking, instructors typically spend 5-15 minutes calling out names and waiting for student responses, especially in large classes. This means that for a class of 50 students, the QR system saves approximately 10-12 minutes per session. Over an entire semester, this time saving can add up to several hours of valuable teaching time that can be better used for actual instruction.

The speed variation of 3-6 seconds observed during testing was mainly due to network connectivity issues, which is a common challenge in many educational institutions. However, even with these occasional delays, the system

still performed much faster than manual methods. The quick scanning process also meant that students could mark their attendance without disrupting the flow of the lecture, as they could scan the QR code as they entered the classroom or during the first few minutes of class.

User Acceptance and Experience: The positive feedback from students indicates few user acceptance of the new system. Students found the QR scanning process intuitive and easy to use, which is crucial for successful system adoption. The fact that minimal instruction or technical support was required suggests that the system design was user-friendly and accessible to students with varying levels of technical expertise.

The positive student response is particularly important because resistance to new technology is often a major barrier to successful implementation in educational settings. If this system is adopted and scaled, it will reduce the burden on lecturers while demonstrating that society is open to change and willing to embrace new innovations.

Advantages Over Traditional Methods: The implemented system addresses several key problems associated with traditional attendance methods. First, it eliminates the time-consuming process of calling names individually, which often disrupts the learning environment and reduces actual teaching time However it did not eliminate the calling process of names itself. Second, the automated system reduces human error that commonly occurs in manual attendance recording, such as marking wrong names or losing attendance sheets.

The QR-based system also provides better security compared to manual methods. Traditional attendance sheets can be easily manipulated, and proxy attendance (where one student signs for another) is difficult to prevent. The QR system's real-time validation and time-

window restrictions make it much harder for students to mark attendance fraudulently.

Technical Implementation Success: The successful implementation of the system demonstrates that QR technology is well-suited for attendance management in tertiary institutions. The choice of QR codes proved to be appropriate because most students already own smartphones capable of scanning QR codes, and the technology is familiar to young people who regularly use mobile devices.

The system's ability to generate unique QR codes for each lecture session and validate them in real-time shows that the technical design was sound. The integration of security features such as time windows and session-specific codes helps prevent misuse while maintaining ease of use.

Limitations and Challenges: Despite the positive results, some limitations were identified during the study. The main challenge was network connectivity, which occasionally caused delays in the scanning process. This issue is common in many educational institutions where internet infrastructure may not be optimal. However, this limitation did not significantly impact the overall effectiveness of the system.

Implications for Educational Institutions: The results of this study have important implications for tertiary institutions considering modernizing their attendance systems. The significant time savings, positive user feedback, and improved accuracy suggest that QR-based attendance systems can provide substantial benefits over traditional methods.

For institutions struggling with attendance tracking in large lecture-room or those looking to reduce administrative burden on faculty, implementing similar systems could lead to meaningful improvements in operational efficiency. The time saved

from attendance taking can be redirected to actual lecturing and learning activities, potentially improving educational outcomes.

While this study focused on basic attendance tracking, the positive results suggest that similar QR-based systems could be expanded to include additional features such as integration with learning management systems, detailed analytics on student attendance patterns, and automated reporting for administrative purposes.

The success of this implementation provides a foundation for further research into mobile-based solutions for educational administration and demonstrates the potential for technology to solve practical problems in educational settings while improving user experience.

CONLUSION

This study successfully achieved its aim of designing and implementing a secure and efficient QR-based automated attendance management system for tertiary institutions. All four objectives were systematically accomplished, resulting in a practical solution that addresses the longstanding challenges of traditional attendance tracking methods.

The comprehensive literature review provided valuable insights into existing QR-based attendance systems, which informed the design decisions and helped identify best practices and potential improvements. The system design incorporated essential security features including time-window validation, session-specific QR codes, and real-time verification to prevent fraudulent attendance marking while maintaining user-friendly operation.

The successful implementation demonstrated the practical viability of QR technology for attendance management in educational settings. The system effectively eliminated the time-consuming manual roll call process, reducing attendance marking time from several minutes to just 3-6 seconds per

student. This significant improvement translates to substantial time savings that can be redirected toward actual teaching and learning activities, enhancing the overall educational experience.

The evaluation results confirmed the system's effectiveness, with positive student feedback indicating high user acceptance and satisfaction. Students found the QR scanning process intuitive and convenient, requiring minimal technical support or training. The system's performance exceeded expectations in terms of speed, accuracy, and user experience compared to traditional attendance methods.

The study contributes to the growing body of knowledge on educational technology applications by demonstrating that simple, cost-effective solutions can significantly improve administrative processes in tertiary institutions. The QR-based approach offers several advantages including reduced human error, enhanced security against proxy attendance, automated record-keeping, and improved data accuracy for institutional reporting.

However, the study also identified important considerations for implementation, particularly the need for reliable network connectivity and ensuring universal smartphone access among students. These challenges, while manageable, should be addressed during system deployment to maximize effectiveness.

The research provides a foundation for future developments in automated attendance systems and demonstrates the potential for expanding QR-based solutions to other administrative functions within educational institutions. Future work could explore integration with learning management systems, advanced analytics capabilities, and broader institutional applications.

Finally, the QR-based automated attendance management system represents a practical, efficient, and

secure solution for tertiary institutions seeking to modernize their attendance tracking processes. The positive results and student acceptance suggest that similar implementations could benefit educational institutions worldwide, contributing to improved operational efficiency and enhanced focus on core educational activities. This study validates the effectiveness of QR technology in solving real-world educational challenges while providing a blueprint for institutions considering similar technological upgrades.

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