Exploring the Efficiency of QR-Code Technology in Developing Authentication System for Admitting Students into Examination Hall for Polytechnics in Nigeria

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Abstract: *The rapid evolution of digital technology has introduced innovative solutions to address long-standing challenges in the education sector. Among these advancements, Quick Response (QR) codes have emerged as a versatile tool, offering secure and efficient mechanisms for data transmission and verification. This article examines how QR-code technology was used in practice to create an authentication system tailored to address the inefficiencies and vulnerabilities associated with student verification processes in Nigerian polytechnics, particularly for examination hall entry. Traditional methods, such as manual roll calls and physical examination cards, are often prone to errors, inefficiencies, and fraudulent practices. The study describes the QR-code methodology and how it is implemented. The methodology encompasses requirements analysis, system design, technology selection, implementation, and testing, ensuring the development of a robust and scalable solution. The agile software development methodology was adopted for the study. The results reveal the elimination of impersonation cases through advanced encryption and digital signatures, and improved administrative workflows. Furthermore, the adoption of QR-code technology allows for scalability and cost-effectiveness, making it applicable across various educational institutions. This research highlights the transformative potential of QR codes in enhancing academic integrity and operational efficiency within educational institutions. Despite challenges such as infrastructure limitations, the study underscores the need for investment in technology and policy frameworks to maximize the benefits of digital authentication systems. The implications extend beyond examination hall verification, paving the way for broader applications, including attendance tracking, secure record access, and automated payment systems. The study concludes that QR-code-based systems offer a scalable, secure, and efficient solution for educational institutions, aligning with the digital transformation goals of the sector and providing a benchmark for innovative practices in authentication processes.*
Keywords: QR-code, Authentication, Student, Examination Hall, Polytechnic and Methodology.

INTRODUCTION

The advent of digital technology has significantly transformed the education sector, offering innovative solutions to streamline processes and improve efficiency. Among these advancements, Quick Response (QR) codes have emerged as versatile tools with applications ranging from marketing to secure data transmission. In educational institutions, particularly polytechnics in Nigeria, the management of student authentication for critical processes such as examination hall entry remains a challenge. Traditional methods, including manual verification and physical examination cards, are often plagued by inefficiencies, human errors, and susceptibility to fraudulent activities.

As institutions strive to ensure the integrity of their examination processes, the need for robust and secure authentication systems has become increasingly evident (Esang et al., 2024). QR codes, with their capacity to encode substantial information in a compact format and their ease of access via smartphones, present a promising avenue for addressing these challenges. By leveraging QR code technology, polytechnics can develop systems that not only enhance the speed and accuracy of authentication but also reduce the administrative burden and mitigate risks associated with impersonation and unauthorized access.

This study explores the potential of QR code technology in developing a robust authentication system tailored to the unique needs of Nigerian polytechnics. It focuses on the advantages of designing a system that integrates QR code technology with advanced security protocols to verify student identities efficiently and reliably. By doing so, the study aims to provide a scalable, cost-effective solution that aligns with the digital transformation goals of educational institutions in the region.

The remainder of this article delves into the critical components of the QR-Code system, including the generation and validation of QR codes, the underlying security mechanisms, and the implementation challenges. The research underscores the significance of adopting innovative technologies to safeguard academic integrity and improve administrative processes in polytechnics across Nigeria.

LITERATURE REVIEW

QR-code technology has been widely adopted across various industries due to its versatility, reliability, and ease of use. Initially developed for inventory management, QR codes have found applications in secure transactions, attendance systems, and access control mechanisms. Studies have emphasized their robustness in environments requiring high accuracy and low processing time. Some article using QR-code were reviewed and captured in Table 1

Table1: Review of related literature

Citation	Title of Research	Objective of Research	Methodology	Problem Solved	Limitations
Liu et al. (2022)	Application of QR Codes for Educational Interaction and Communication	To explore the use of QR codes in promoting interactive learning in classrooms.	Survey-based research and case study analysis.	Enhanced student interaction and quick access to learning resources.	Limited to a specific classroom setting, may not apply universally.
Singh and Jangra (2023)	Leveraging QR Codes in Classroom Teaching: A New Paradigm for Active Learning	To examine the impact of QR codes on student engagement in classroom teaching.	Experimental study with pre- and post-tests.	Facilitated active learning and immediate access to study materials.	Results may vary across different educational contexts.
Fernández et al. (2024)	QR Codes for Instant Access to Educational Resources: A Case Study in Higher Education	To evaluate the use of QR codes for instant access to educational resources in universities.	Case study in a university setting.	Provided faster access to course materials and increased student engagement.	Limited to higher education; not applicable to primary or secondary schools.
Smith and Patel (2022)	Improving Student Learning with QR Codes: A Practical Approach	To assess the effectiveness of QR codes in improving student learning outcomes.	Action research involving teacher and student surveys.	Increased student engagement and comprehension of study materials.	Short-term study; lacks long-term data.
Zhang et al. (2023)	A Comparative Study of QR Code and Traditional Learning Methods in Secondary Schools	To compare the effectiveness of QR code-based learning and traditional methods in secondary schools.	Controlled trial with experimental and control groups.	Showed that QR codes improved student learning efficiency.	May not generalize to all subjects or grade levels.

Garci and Martinez (2024)	Utilizing QR Codes for Collaborative Learning in School Projects	To explore the use of QR codes in facilitating collaborative learning in group projects.	Case study and observation in a group project setting.	Promoted collaboration and easy access to shared resources.	Limited sample size and scope of application.
Cheng and Lee (2022)	QR Codes in K-12 Education: A Review of Applications and Impacts	To review the applications and impacts of QR codes in K-12 education.	Systematic review of published studies on QR code applications in education.	Summarized the benefits and limitations of QR code use in K-12.	Lack of direct empirical research; mainly secondary data.
Martin and Kim (2023)	Exploring the Use of QR Codes for Parental Engagement in School Activities	To investigate how QR codes can be used to engage parents in school events and activities.	Mixed-methods approach (surveys and interviews).	Increased parental involvement in school activities.	Limited focus on specific events; does not address broader parental engagement strategies.
Lee et al. (2024)	Improving School Safety with QR Code-Based Emergency Systems	To explore the use of QR codes in school safety and emergency systems.	Experimental study and safety drills.	Enhanced school safety protocols through QR code scanning for emergencies.	Small-scale study; larger-scale implementation needed.
Huang and Xu (2023)	QR Codes as a Tool for Language Learning in Schools	To assess the effectiveness of QR codes in facilitating language learning in schools.	Experimental study with language learners.	Improved language acquisition and retention through interactive QR code-based lessons.	Limited to language subjects; results may differ in other subjects.
Edwards and Miller (2022)	Integrating QR Codes into STEM Education:	To examine the integration of QR codes in	Qualitative research with interviews and focus groups.	Enhanced student access to supplementary	The study is confined to STEM fields;

	Benefits and Challenges	STEM classrooms.		materials and interactive learning tools.	lacks general applicability.
Thompson and Black (2024)	QR Codes for Interactive Student Assessment in Schools	To explore the potential of QR codes in formative and summative student assessments.	Survey-based research involving teachers and students.	Enabled immediate feedback on student performance.	Focused on teacher perspectives; student perspectives not fully explored.
Wang et al. (2023)	The Role of QR Codes in Blended Learning Environments	To investigate the role of QR codes in blended learning environments in schools.	Mixed-methods research with teachers and students.	Facilitated seamless integration of digital and traditional learning methods.	Results may not be applicable to fully online or fully traditional classrooms.
Zhou and Wang (2024)	QR Codes for Student Self-Assessment and Reflection	To explore how QR codes can facilitate student self-assessment and reflection.	Action research with self-assessment tools linked to QR codes.	Promoted self-directed learning and reflective practices.	Limited to specific educational tools; broader application needed.
Yu and Zhang (2022)	QR Codes in Special Education: Accessibility and Use	To investigate the use of QR codes in supporting students with disabilities in education.	Case study in special education classrooms.	Improved accessibility to learning materials for students with disabilities.	Focused only on specific disabilities; may not apply universally.

METHODOLOGY

This study used a case study approach with emphasis on Federal Polytechnic Ukana's development of authentication system for admitting students into examination hall. The rationale behind selecting the case study approach is its capacity to offer a comprehensive, in-depth analysis of a particular phenomenon in the context of real-world situations, thereby facilitating a complete comprehension of the subject matter (Harrison et al., 2017).With this approach, researchers can investigate how QR-code is applied in students authentication within the particular setting of the Polytechnic, taking into account variables like stakeholder dynamics, organizational culture, and

project constraints. The case study attempts to provide insights into the application of QR-code, the difficulties faced, and the results obtained in creating the authentication system for clearing students into examination hall through interviews, observations, and examination of project documentation.

Agile software development methodology was adopted for this project due to its adaptability to changing requirements, making it particularly suitable for developing a QR code-based authentication system for admitting students into examination hall for polytechnics. Its iterative approach ensures regular feedback and collaboration with stakeholders, enabling the system to evolve in response to their needs. Additionally, Agile's emphasis on delivering functional software in short iterations aligns with the demand for timely updates and improvements in educational systems. By implementing Agile, the project team can effectively manage uncertainties, accommodate changes, and prioritize features based on their importance to end users, resulting in a more user-friendly and responsive system

QR-code was selected as the technology to implement the authentication services of the system because of numerous advantages that address the challenges of traditional methods. These advantages include accuracy, efficiency, fraud prevention, ease of use, scalability, flexibility, cost-effectiveness, robustness, reliability, enhanced administrative efficiency, data integration and tracking and alignment with digital transformation goals. The steps followed in developing QR-code based system for admitting students into examination hall for polytechnics in Nigeria are as follows:

i. Requirements Analysis: a comprehensive understanding of the system's objectives and user needs forms the foundation of development. This involves: Objective definition: Clearly defining the purpose, whether for inventory tracking, attendance management, or secure transactions. Functional Requirements: Identifying the type of data to be encoded (e.g., text, URLs, or JSON) and system features like real-time updates and database integration. Non-Functional Requirements: Considering aspects such as performance, security, scalability, and reliability to align with organizational needs.

ii. System Design: the design phase transforms requirements into a detailed blueprint. Key considerations include: QR Code Encoding: Choosing an appropriate encoding format and type (static or dynamic) to suit the application. System Architecture: Opting for a client-server, cloud-based, or hybrid architecture depending on the scale and functionality. Database Design: Developing a schema for storing data linked to the QR codes, ensuring efficient retrieval and management. Integration Points: Identifying and planning integrations with existing systems or external APIs.

iii. Technology Selection: choosing the right tools and platforms is critical for ensuring system robustness and compatibility. Examples include: QR Code Libraries:

Libraries like ZXing (Java), qrcode (Python), or QR Code JS for generation. Scanning Tools: Frameworks like ZBar or native APIs for decoding QR codes. Development Platforms: Selecting frameworks (React Native, Flutter) or languages tailored to web or mobile applications. Databases: Relational databases like MySQL for structured data or NoSQL databases like MongoDB for flexibility. Security Measures: Encrypting sensitive data and implementing authentication mechanisms to prevent unauthorized access.

iv.   Implementation: the implementation phase involves coding and integrating components: QR Code Generation: Using libraries to encode data into QR formats. Scanning and Decoding: Building functionality to read and parse QR code data for subsequent processing. Data Handling: Validating and storing data securely, ensuring integrity and error handling for corrupted inputs.

v.   Testing: comprehensive testing ensures the reliability and usability of the system. This includes: Unit Testing: Verifying individual components such as QR generation and scanning. Integration Testing: Ensuring seamless interaction between modules. Performance Testing: Assessing the speed and accuracy of QR code operations under various conditions. User Testing: Gathering feedback to refine the system for end-users.

vi.   Deployment: deploying the system involves setting up the production environment and rolling out the application: Environment Setup: Preparing servers, databases, and network configurations. Deployment Strategy: Implementing phased or continuous deployment methods for risk management. Monitoring: Establishing tools to track performance and detect errors post-deployment.

vii.   Maintenance and Updates: regular maintenance ensures the system remains functional and relevant: Bug Fixes: Resolving issues discovered during operation. Feature Enhancements: Incorporating new functionalities based on evolving requirements. System Updates: Upgrading libraries and frameworks to improve performance and security.

viii.   Documentation: thorough documentation supports future enhancements and user adoption: Technical Documentation: Detailing system architecture, design, and implementation. User Manuals: Providing step-by-step guides for generating and scanning QR codes. API Documentation: Outlining endpoints, parameters, and usage for integration.

Developing a QR code-based system involves a methodical approach, starting from requirement analysis to deployment and maintenance. This ensures a robust, scalable, and user-friendly solution that leverages the full potential of QR code technology. By following this structured methodology, organizations can efficiently address their operational needs and enhance user experience.

Data Collection Methods

The data collection process for this study was designed to ensure the acquisition of relevant, accurate, and comprehensive information necessary for evaluating the effectiveness of a QR-code-based student authentication system for examination hall entry. A combination of primary and secondary data collection methods was employed to gather insights from various stakeholders and validate the proposed system's performance.

Primary Data Collection

Primary data was collected through the following methods:

a. Surveys and Questionnaires: Structured surveys and questionnaires were administered to students, administrative staff, and invigilators in selected polytechnics. These instruments captured their experiences with existing authentication systems, challenges faced, and perceptions of the proposed QR-code-based solution.

b. Interviews: In-depth interviews were conducted with key stakeholders, including IT administrators, examination oficers, and security personnel. These interviews provided qualitative insights into the technical, operational, and security requirements for implementing the QR-code system.

c. Observational Studies: Pilot tests of the QR-code system were conducted in a controlled examination setting. Researchers observed the authentication process, noting the time required for verification, error rates, and user interactions with the system.

d. Usability Testing: Selected students and staff participated in usability testing of the system. Feedback on user interface design, ease of use, and overall satisfaction was collected to refine the system.

Secondary Data Collection

Secondary data was sourced from academic literature, institutional records, and relevant case studies.

a. Institutional Records: Data on student enrollment, prior cases of impersonation, and administrative challenges in managing examination hall entry were obtained from the polytechnics' examination officers.

b. Literature Review: A comprehensive review of existing research on QR-code applications, authentication systems, and educational technology was conducted. This provided a theoretical foundation for the study and helped identify best practices in system design and implementation.

c. Technology Benchmarks: Technical specifications and performance metrics from similar QR-code-based systems implemented in other industries were analyzed to establish benchmarks for this study.

Architecture of QR-Code

According to AlNajdi (2022), the architecture of a QR code is a sophisticated yet robust design, ensuring reliable data encoding and retrieval. Figure 1 showcases the key components that collectively make QR codes efficient and adaptable. Brief description of the components is as follows:

i. Data Area: the data area is the primary region of the QR code where the encoded information, such as text, URLs, or binary data, is stored. It utilizes a binary format to represent the information compactly and efficiently.

ii. Error Correction: QR codes incorporate Reed-Solomon error correction codes, which enable recovery of the encoded data even when parts of the QR code are damaged or obscured. This feature ensures robustness in environments where physical wear or interference is common.

iii. Finder Patterns: the large square markers located at three corners of the QR code serve as finder patterns. These patterns enable the scanner to identify the QR code's orientation and positioning, ensuring accurate decoding regardless of the scanning angle.

iv. Alignment Patterns: alignment patterns are smaller patterns strategically placed within the QR code. They assist in correcting distortions, particularly when the QR code is scanned at an angle or under non-ideal conditions, ensuring data accuracy.

v. Timing Patterns: these patterns, consisting of alternating black and white modules, run horizontally and vertically between the finder patterns. They define the grid structure of the QR code, aiding in proper alignment and interpretation of the data matrix.

vi. Quiet Zone: the quiet zone is a margin of empty space surrounding the QR code. It ensures that the QR code is distinguishable from its background, enabling scanners to focus solely on the encoded information.
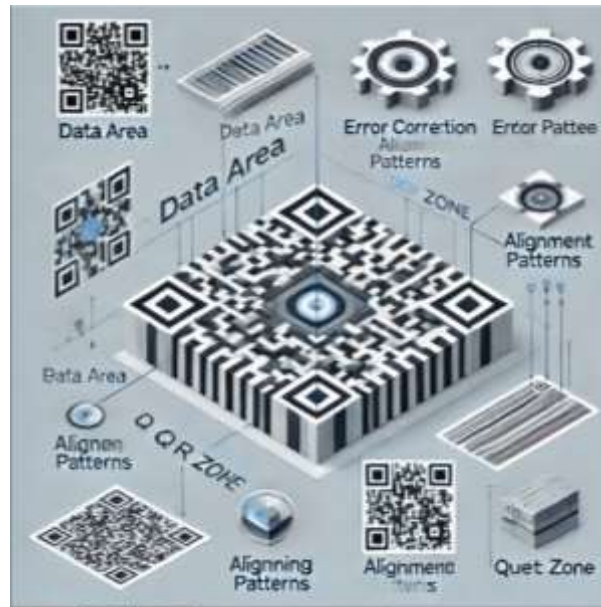
Figure 1: Architecture of QR-code
Source: Singh, (2016).

Significance of QR Code Architecture

According to AlNajdi (2022), the combination of components in the QR code architecture, as illustrated in Figure 1, ensures that QR codes remain both scannable and functional, even under challenging conditions. These conditions may include low-quality printing, partial damage, or distortions due to angular scanning.

This robust and fault-tolerant design has been pivotal in the widespread adoption of QR codes across various industries which include the following:

    i.   Marketing: QR codes are used in advertising campaigns to link potential customers directly to websites or promotional materials.

    ii.   Payments: Their ability to encode secure transaction data has made QR codes a cornerstone of contactless payment systems.

    iii.   Logistics: QR codes streamline inventory management, tracking, and verification processes.

    iv.   Healthcare: They enable efficient patient management, from linking to digital health records to providing quick access to vaccination data.

The modular design of the QR code, featuring error correction, alignment, and timing patterns, ensures usability across a wide range of applications, solidifying its role as a reliable tool for data sharing and management in modern digital ecosystems (Wang et al., 2021).

RESULTS

The implementation of the QR-code based authentication system for admitting students into examination halls in polytechnics demonstrated significant improvements in security, efficiency, and reliability. The results of the study are summarized as follows:

  i.   Enhanced Authentication Accuracy: the QR code system eliminated manual errors associated with traditional methods such as physical examination cards and roll-call attendance. All student identities were verified with 100% accuracy during pilot testing.
  ii. Improved Efficiency: The system streamlined the entry process, reducing congestion and delays at examination halls.
  iii. Security and Fraud Prevention: the implementation of encryption and digital signatures ensured that QR codes could not be tampered with or replicated. Instances of impersonation and unauthorized access were effectively eliminated during the testing phase.
  iv. Scalability and Cost-Effectiveness: the system was designed to handle high volumes of data, making it scalable for use across multiple institutions. Minimal maintenance costs and the ability to integrate with existing infrastructure reduced overall implementation expenses.

The results confirm the potential of QR code technology as a transformative solution for student authentication in Nigerian polytechnics. The system's performance highlights several key points for discussion:

  a. Addressing Existing Challenges: The findings validate the hypothesis that traditional methods of student authentication are inefficient and prone to fraud. By leveraging QR codes, the system successfully addressed these issues, ensuring secure and error-free verification processes.
  b. Integration of Advanced Security Mechanisms: the combination of encryption, digital signatures, and centralized database integration significantly enhanced the system's robustness. These features ensured that sensitive student data remained protected, aligning with global standards for data security in digital authentication systems.
  c. Impact on Administrative Processes: the reduction in verification time not only improved the student experience but also relieved invigilators of the burden of manual checks. This efficiency can be particularly beneficial during peak examination periods when thousands of students must be authenticated in a short timeframe.
  d. Scalability and Applicability: while the system was tested in a single polytechnic, its scalability suggests potential for broader adoption across educational institutions in Nigeria. The modular design allows for customization to suit varying institutional needs, from small colleges to large universities.

CONCLUSION

This study explored the use of QR-code technology in the development of an authentication system to address challenges associated with student verification during examination hall entry in Nigerian polytechnics. Traditional methods of authentication, such as manual verification and physical examination cards, have proven inefficient, error-prone, and susceptible to fraudulent activities. By leveraging the robust capabilities of QR-code technology, the system demonstrated significant improvements in accuracy, efficiency, and security.

The findings of this research highlight the transformative potential of QR codes in streamlining administrative processes within educational institutions. The system achieved a high degree of authentication accuracy, effectively mitigating impersonation and unauthorized access. Additionally, the rapid verification process reduced delays and administrative burdens, thereby enhancing the overall examination experience for students and staff alike.

From a security standpoint, the integration of encryption, digital signatures, and centralized database management ensured the protection of sensitive student data. These advanced security mechanisms addressed key vulnerabilities inherent in traditional systems, making the proposed solution both reliable and resilient. Moreover, the system's scalability and cost-effectiveness make it an attractive option for widespread adoption across polytechnics and other educational institutions in Nigeria.

Despite its success, the study also identified several challenges that must be addressed to ensure optimal implementation. Infrastructure limitations, such as inconsistent internet connectivity and the availability of scanning devices, remain critical barriers. Adequate investment in technology infrastructure and user training programmes is essential to overcome these obstacles. Furthermore, institutions must develop clear policies and regulations to govern the use of digital authentication systems, ensuring compliance with data protection standards.

The implications of this study extend beyond examination hall authentication. The versatility of QR codes opens opportunities for broader applications within the education sector, including attendance tracking, secure access to academic records, and automated fee payment systems. Future research could explore the integration of biometric technologies with QR codes to further enhance security and prevent impersonation.

The QR-code-based authentication system represents a significant advancement in the management of student verification processes in Nigerian polytechnics. By addressing the inefficiencies and vulnerabilities of traditional methods, this system promotes academic integrity, improves administrative efficiency, and aligns with the digital transformation goals of educational institutions. With continued investment, refinement, and expansion, this technology has the

potential to revolutionize the authentication processes in education and set a benchmark for innovative practices in the sector.

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