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CLASSROOM AND LABORATORY SMART ACCESS CONTROL SYSTEM

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ABSTRACT

This descriptive research focused on the development of a Classroom and Laboratory Smart Access Control System for Zhuhai City Polytechnic in Zhuhai, Guandong Province, China The system is designed to enhance access control, facilitate remote locking and unlocking of doors, manage user rights, and monitor the health of door locks within the institution's classrooms and laboratories. Emphasizing low power consumption, the system caters to various users, including laboratory administrators, teaching staff, classroom managers, and students at Zhuhai City Polytechnic. Built upon RouterOS technology, the Smart Access Control System aims to improve the efficiency and convenience of laboratory management.In contrast to traditional access control systems, this new system is accessible through personal computers and the WeChat platform on mobile phones, eliminating the need for a separate application. It offers advantages such as rapid response, high convenience, superior availability, and reduced power consumption. The system's effectiveness was assessed according to the international standard ISO/IEC 25010. Evaluation by IT experts confirmed that the system satisfies all eight dimensions of ISO/IEC 25010: Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Maintainability, and Portability.Reliability, Security, Maintainability, Portability.

Keywords: Smart Access Control, RouterOS, access control, ISO/IEC 25010, software quality standard.

INTRODUCTION

With the rapid advancement of information technology and the Internet of Things, intelligent access control systems have become widely adopted across government agencies, enterprises, and educational institutions. These systems represent a significant enhancement in access management, providing both convenience and security by integrating communication technology and image recognition for unified management via the Internet (China Public Security Bureau, 2012).

Compared to traditional systems, intelligent access control offers greater user convenience. For instance, in Victoria, Australia, smart classroom and access control systems have been integrated to promote educational advancement and multicultural development (Yuan, 2016). Similarly, the introduction of intelligent access control systems in universities helps address campus security issues effectively (Okafor, 2022).

The global shift toward intelligent and automated solutions has transformed access control systems in multiple sectors. In healthcare, intelligent

access systems are now being used to control sensitive areas, such as operating rooms and pharmacies, ensuring only authorized personnel can enter (Ding et al., 2021). Similarly, in government buildings, these systems have been critical in improving the security and efficiency of managing sensitive areas and controlling the flow of staff and visitors (Yin & Li, 2018). By incorporating technologies such as facial recognition, biometric data, and real-time surveillance, these intelligent systems enhance security protocols while simplifying administrative tasks.

Another key industry where intelligent access control systems are making an impact is the hospitality industry. Many hotels have adopted digital key cards and mobile applications that allow guests to unlock doors using their smartphones, reducing the need for physical keys and improving the overall guest experience (Chen et al., 2020). In transportation hubs like airports and train stations, intelligent access control systems play a vital role in monitoring passenger movements and ensuring that secure areas are properly restricted (Fang & Zhou, 2019). These examples highlight the diverse applications of intelligent access control, demonstrating their utility in environments where security, convenience, and efficiency are critical.

With the rising adoption of Internet of Things (IoT) devices, intelligent access control systems are becoming more integrated into the broader framework of smart city development. Urban infrastructure now includes systems that allow for automated parking access, building entry, and smart traffic management. These advancements help city planners optimize resources and enhance urban living conditions (Liu et al., 2021). As smart city projects continue to develop worldwide, the need for secure, adaptable, and user-friendly access control systems is expected to grow.

Research by the China Institute of Economics and Industry highlights that intelligent access control systems, which utilize sensors, identity authentication, and network communication, overcome the limitations of traditional methods (China Institute of Economics and Industry, 2021). For higher education institutions, smart classrooms are vital for enhancing teaching quality and learning environments amidst modernization (Shen, 2020). Additionally, balancing classroom and laboratory resources and incorporating intelligent access control can optimize management (Wang et al., 2022).

While intelligent access control systems offer numerous advantages, implementing them in educational settings like universities poses unique challenges. One significant issue is the integration of legacy systems with modern technologies. Many educational institutions, especially those with older infrastructure, still rely on outdated access control systems that may not easily accommodate newer technologies such as biometric authentication or IoT connectivity (Ning & Zheng, 2021). Transitioning from these legacy systems often requires significant investments in both hardware and software, as well as retraining staff to manage and operate the new systems effectively.

Another challenge faced by universities is balancing security with accessibility. While intelligent access control systems can provide robust security measures, there is a need to ensure that students, faculty, and staff can access classrooms and laboratories easily without facing unnecessary delays or technical difficulties (Jiang et al., 2022). Striking this balance is particularly important for educational institutions, where efficient access to learning spaces is critical to the academic experience. Additionally, the presence of multiple user groups, including full-time students, visiting scholars, and external vendors, adds complexity to the access management process.

The Key Work Points of Digital Guangdong Construction for 2024 emphasize the need for modernized classroom and laboratory management to keep pace with social and educational developments (Guangdong Provincial Government Service and Data Administration, 2024). The Guangdong Provincial Department of Education advocates for the digital transformation of education, including the development of digital campuses and innovative teaching methods (Guangdong Provincial Department of Education, 2023).

Zhuhai City Polytechnic, located in Zhuhai, Guangdong Province, currently relies on traditional mechanical locks and manual key management for its classrooms and laboratories. This approach is time-consuming, prone to key duplication, and lacks effective security. The adoption of intelligent access control systems, supported by new technologies, addresses these issues and enhances management efficiency. Studies indicate that while intelligent access control systems have improved security and convenience in various sectors (Guo, 2022; Mu, 2021), challenges such as high-power consumption and complexity remain (Song et al., 2020; Zhang et al., 2023).

To address these challenges, this study develops a low-power, lightweight smart access control system for Zhuhai City Polytechnic. The system aims to improve classroom and laboratory management efficiency by offering intelligent access control and health monitoring of door locks. It uses a three-layer architecture—front-end application, management backend, and database—built on a B/S model to enhance usability, security, and adaptability.

The proposed system is designed to provide efficient access control, remote door management, and usage monitoring while minimizing power consumption. This development is expected to significantly improve management practices and resource utilization at Zhuhai City Polytechnic, contributing to the broader goal of advancing digital education infrastructure.

Conceptual Framework

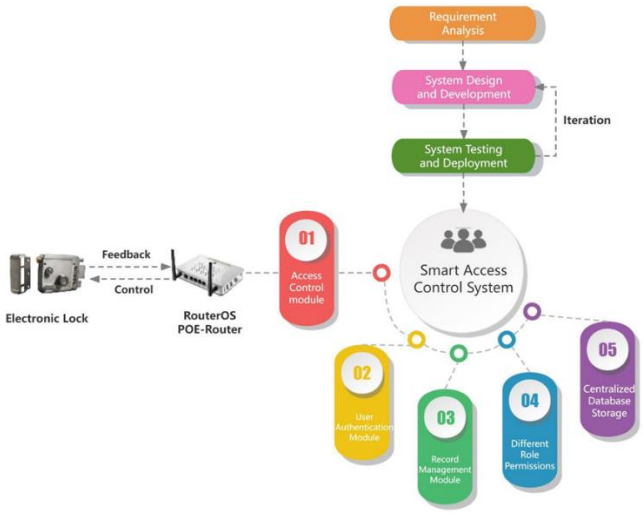

Figure 1. Conceptual Framework of the Study (Zhang 2018)

The Smart Access Control System was designed and developed using new technologies and Internet advancements, following the framework established in Zhang's 2018 study. This conceptual framework outlines research recommendations and implementation strategies and details the processes required to deploy the system. It identifies problems to be addressed and corresponding functional modules within the Smart Access Control System, particularly the RouterOS technology-based system. At Zhuhai City Polytechnic, the Smart Access Control System, implemented in various classrooms and laboratories, has streamlined management between educational administrators, site managers, and teachers. This system enhances the scientific and retrospective aspects of site management. The ultimate outcome is an information system that leverages RouterOS technology to address classroom management challenges and alleviate staff shortages, thereby improving teaching quality and classroom safety perceptions. The system development process consists of three main stages:

1. Requirements Analysis. This phase involves a thorough analysis and definition of the Smart Access Control System's requirements. Through research and interviews with relevant stakeholders, the necessary functions and features are determined to ensure the system meets user needs and expectations.
2. System Design and Development. Based on the requirements analysis, this phase focuses on

designing and developing the system. It includes creating the system's architecture and modules to define the overall structure and functional interactions. Subsequently, software code and configurations are developed to enable features such as user authentication, access control, and record management.

3. System Testing and Deployment. After development, the system undergoes comprehensive testing to ensure correctness and reliability. This includes functional, performance, and security tests. Upon successful testing, the system is deployed at the access control site, requiring configuration and parameter settings to ensure proper interaction with hardware and the network environment. Post-deployment, user training and technical support are provided to ensure smooth operation and user satisfaction.

The Smart Access Control System features access control, user authentication, record management, and backtracking capabilities. It allows users to configure access rights and module permissions according to their management roles. Additionally, it generates usage reports to track classroom utilization, providing data for scheduling and evaluating teaching quality.

The quality of the developed system is assessed based on ISO/IEC 25010 Software Quality Standard, which replaced ISO/IEC 9126 as the latest software quality standard. As highlighted by Dong et al. (2019) from the Yunnan Provincial Key Laboratory of Computer Application, ISO/IEC 25010 is crucial for evaluating software quality in terms of functional suitability, compatibility, performance, reliability, security, and more. Additionally, Haoues (2017) developed a software architecture selection guide to assist architects in aligning with desired quality objectives.

Statement of the Problem

This study developed a low-power classroom and laboratory smart access control system.

Specifically, this study answered the following questions.

1. What are the problems and challenges encountered by the participants of Zhuhai City Polytechnic in managing classrooms and laboratories in terms?
   1.1 Large Number of Classrooms and Laboratories
   1.2 Manual Management and Door Opening
   1.3 Manual Registration and Record-Keeping
   1.4 Inefficient Backtracking of Records
   1.5 Difficulties in Report Management
2. What system can be developed to address the problems and challenges encountered by the participants in classroom and laboratory management at Zhuhai City Polytechnic?
3. What is the extent of compliance of the developed system to the standards of ISO/IEC 25010 Systems and software Quality Requirements and Evaluation (SQuaRE) in terms of the following:
   3.1 Functional Suitability
   3.2 Performance Efficiency
   3.3 Compatibility
   3.4 Usability
   3.5 Reliability
   3.6 Security
   3.7 Maintainability
   3.8 Portability
4. What enhancement can be done to improve the developed system?

METHODOLOGY

Research Design

This study aims to design and develop a Classroom and Laboratory Smart Access Control System for Zhuhai City Polytechnic. Additionally, it includes the creation of small programs for online platforms such as WeChat to enable remote operation. The research employs descriptive and developmental study methodologies to gather relevant data.

In the system development process, the agile Scrum methodology is applied. Scrum involves breaking down a project into a series of user needs and features, known as product backlog items. It

relies on incremental development, where each sprint results in a deliverable product that is refined based on stakeholder and customer feedback. If issues or changes arise, the Scrum team can swiftly adjust product goals in subsequent sprints, leading to more valuable iterations. This iterative approach allows the team to better understand customer needs, enhance product functionality, and address issues effectively throughout the project. Stakeholders benefit from active participation at each step and receive results that meet their expectations. The flexibility of the Scrum methodology makes it an ideal choice, offering significant advantages for both the development team and customers.

Participants of the Study

The participants of the study were primarily the laboratory administrators and maintenance staff at Zhuhai City Polytechnic. They were central to the deployment and use of the access control system across various classrooms. The involvement of IT experts was also crucial to ensure the system's compliance with ISO/IEC 25010 Software Quality Standard.

Table 1. Frequency and Percentage Distribution of the Participants

Participants	Frequency	Percentage
IT Experts	9	30
Laboratory Administrator and Maintenance staff	9	30
School Administrators	2	10
Teachers	10	30
Total	30	100

Instrumentation

The researcher collected the data using the following instruments:

Interview Guide. The interview guide was used to identify the current use and process of classroom door locks and the problems encountered by room administrators in opening classrooms. It also aimed to identify issues experienced by senior school administrators in accessing classroom usage and frequency.

ISO 25010 Software Quality Standardized Questionnaire. This tool was employed to determine the extent to which the developed system complied with ISO 25010 Software Quality Standard.

Data Gathering Procedure

To obtain the data needed for the investigation, the researcher undertook the following procedure:

1. The researcher obtained clearance from the Research Ethics Committee (REC) of St. Paul University Philippines to ensure the ethical soundness of the study.
2. After obtaining clearance from the REC, the researcher sought endorsement from the dissertation adviser and the Dean of the Graduate School for data gathering. Likewise, permission from the administrators of Zuhai City Polytechnic was obtained for the conduct the study.
3. Before the data collection, the validity of the research tools was established, and the identification of the participants of the study was undertaken.
4. Informed consent from the participants was likewise sought to ensure that the study conforms to the ethical norms of research.
5. Upon approval of the school heads, the researcher conferred with the people involved in gathering the data.
6. The following are the details of the processes involved in obtaining the specific data:
7. Administration of the Questionnaire. The questionnaire was administered to the participants.
8. The obtained quantitative data was organized through the Excel spreadsheet. Meanwhile, the qualitative data was analyzed through thematic analysis.
9. Moreover, the research ensured data privacy by safeguarding the anonymity and confidentiality of the data, and regulating the data access, data security, and data disposal.

Data Analysis

In analyzing the data, the researcher used the following tools:

Thematic Analysis. This was used to determine the problems and challenges encountered by the participants in classroom and laboratory management at Zhuhai City Polytechnic. It was also used to analyze the suggested enhancements which can be done to improve the developed syste.

Mean. This was used to determine the extent of compliance of the developed system with the ISO/IEC 25010 Software Quality Standard as assessed by the IT experts. To interpret the Weighted means, the following scale was used:

Weight	Weighted	Descriptive Rating
5	4.20 - 5.00	Very Great Extent
4	3.40 - 4.19	Great Extent
3	2.60 - 3.39	Moderate Extent
2	1.80 - 2.59	Little Extent
1	1.00 - 1.79	Very Little Extent

RESULTS AND DISCUSSION

The presentation follows the sequence of the research questions as stipulated in the statement of the problem.

1. Problems and Challenges Encountered by the Participants in Classroom and Laboratory Management at Zhuhai City Polytechnic

The thematic analysis of the participants' open-ended responses regarding the problems and challenges encountered by the participants in classroom and laboratory management at Zhuhai City Polytechnic generated the following:

1.1 Large Number of Classrooms and Laboratories

The extensive number of classrooms and laboratories, combined with their widespread locations, necessitates a significant number of management personnel

1.2 Manual Management and Door Opening

The processes of registration and door opening are completed manually, leading to low management efficiency.

1.3 Manual Registration and Record-Keeping

The use of manual forms to register and save records lacks the ability to summarize data effectively.

1.4 Inefficient Backtracking of Records

Retrieving and backtracking usage records manually is cumbersome and inefficient.

1.5 Difficulties in Report Management

The generation of reports is delayed and challenging due to the manual management and use.

2. Develoment of Smart Access Control System to address the Problems and Challenges Encountered in the Classroom and Laboratory Management of Zhuhai City Polytechnic.

In this study, RouterOS technology was integrated with access control systems. A RouterOS router equipped with a POE (Power over Ethernet) network port replaced the traditional access control module. The electronic lock was connected to the router's POE port using a network cable. This setup allowed the router to power the electronic lock and transmit the unlocking signal through the seventh and eighth core copper wires of the POE port.

When a user sends an unlock request via the mobile app or other terminals, the management background verifies the user's identity and permissions. Upon successful verification, the background system generates an unlocking signal and sends it to the RouterOS router. The router then forwards this unlocking signal to the electronic lock's mechanism to open the door. Additionally, the router records the unlocking events and transmits this information to the background system for logging and monitoring. This configuration enables remote control and monitoring of the electronic lock through the RouterOS router, with the POE port simplifying wiring and system management.

The Smart Access Control System developed by this institute is a LAN-based application designed to provide efficient access control management for classrooms and laboratories at Zhuhai City Polytechnic. The system features modules for access

control, user authentication, record management, and backtracking. Managers can perform remote visual operations using online platform mini-programs like WeChat. The system also designates a school administrator role for centralized management, offering usage reports as needed. Additionally, the background system monitors the frequency and timing of classroom door operations, supporting academic and classroom management departments in planning and scheduling.

The system employs a three-layer architecture: the system application front-end, the management background, and the database. Different user roles have distinct permissions. The system administrator configures classroom and laboratory door information, establishes management positions based on needs, and provides precise authorizations. Classroom and laboratory administrators can scan QR codes to unlock doors, check door switch status and logs via WeChat, and perform remote or batch door operations. The gating system server manages tasks such as finding, refreshing, and providing feedback.

3. Extent of Compliance of the Developed System with the ISO/IEC 25010 Software Quality Standards

The analysis of IT experts' evaluation of the extent of compliance of the developed system with the ISO 25010 Software Quality Standards along functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability generated the following results.

Table 3. Summary of Evaluation of the System's Compliance with the ISO/IEC 25010 Criteria

Dimensions	Category Mean	Descriptive Interpretation
A. Functional Suitability	4.53	Very Great Extent
B. Performance Efficiency	4.13	Great Extent
C. Compatibility	3.90	Great Extent
D. Usability	4.20	Very Great Extent
E. Reliability	4.40	Very Great Extent
F. Security	4.46	Very Great Extent
G. Maintainability	3.56	Great Extent
H. Portability	4.03	Great Extent
Overall Category Mean	4.15	Great Extent

Table 3 presents the summary of the evaluation of the IT experts on developed systems' compliance with the ISO/IEC 25010 Software Quality Standards in terms of functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability.

The table reveals that the developed system was evaluated by the IT experts to be compliant with the ISO/IEC Software Quality Standards as evidence by the overall category mean of 4.15, described as great extent. Specifically, Functional Suitability was rated highest, having a mean of 4.53. On the other hand, Maintainability obtained the lowest with a category mean of 3.56.

The general evaluation results by IT experts align with Song (2015), which examined the assessment and management of software quality through eight ISO 25010 features: functional suitability, performance efficiency, compatibility, usability, reliability, security, maintainability, and portability, along with their sub-features. The findings indicate that the developed system meets these requirements and achieves a high level of software quality.

4. Proposed Enhancements to Improve the Developed System

To further enhance the Smart Access Control System developed for Zhuhai City Polytechnic, users and IT experts provided the following suggestions.

- User Feedback Integration. The administrators may Implement a feedback mechanism that allows visitors to rate and comment on their access control experiences, improving the system based on user input.
- Curriculum Integration. The administrators may align the system with the school's curriculum to create a more integrated and

intelligent management model that supports educational objectives.

- Interface Enhancement. The developer/researcher could revamp the front-end interface to make it more visually appealing, enhancing user experience and satisfaction.

CONCLUSION

Based on the study's findings and results, the following conclusion was drawn.

The Classroom and Laboratory Smart Access Control System is an effective solution for Zhuhai City Polytechnic, enhancing the management efficiency, security, and user engagement within the school's classrooms and laboratories. Located in Zhuhai City, Guangdong Province, the Polytechnic required a streamlined, convenient, and secure access control system to optimize classroom and laboratory management. The researchers developed a system that adheres to ISO/IEC 25010 quality standards, achieving "very large extent" compliance in Functional Suitability, Usability, Reliability, and Security. This system significantly addresses the needs of Zhuhai City Polytechnic for improved classroom and laboratory management.

RECOMMENDATIONS

Based on the findings presented and the conclusion drawn, the researcher recommends the following:

1. For ZHUHAI CITY POLYTECHNIC Laboratory Administrators and Maintenance Staff:

1.1 Enhance Training Programs. Provide regular, comprehensive training to improve the technical skills and knowledge of laboratory administrators and maintenance staff, ensuring they can effectively operate and maintain the smart access control system.

1.2 Implement Preventive Maintenance. Develop a preventive maintenance schedule to regularly check and maintain the system, helping to identify and resolve potential issues before they escalate.

2. For ZHUHAI CITY POLYTECHNIC Academic Affairs Office:

2.1 Promote Awareness and Utilization. Conduct workshops and training sessions to educate faculty and staff on the benefits and functionalities of the smart access control system, encouraging full utilization to enhance classroom and laboratory management.

2.2 Monitor System Usage. Implement a monitoring system to track the usage and effectiveness of the smart access control system, providing valuable insights for continuous improvement.

3. For Teachers:

3.1 Promote Awareness and Responsibility. Educate teachers on the importance of responsible use of the smart access control system, encouraging adherence to institutional rules to ensure the system's effectiveness and security.

3.2 Provide Training and Support. Offer training sessions to familiarize teachers with the system and its features and establish a support system to address any issues they may encounter.

4. For the Researcher:

4.1 Explore Collaboration Opportunities. Encourage researchers to collaborate with the smart access control system to leverage its data and analytics for enhancing research projects and improving management practices.

4.2 Research System Optimization. Promote studies focused on optimizing the system's efficiency, accuracy, and security to contribute to its continuous improvement.

5. For Future Researchers:

5.1 Expand Research on Smart Access Control Systems. Encourage exploration of advanced applications and technologies in smart access control, including biometrics, artificial intelligence, and IoT integration.

5.2 Evaluate System Performance and Impact. Conduct comprehensive evaluations of the system's performance and its impact on classroom and laboratory management, providing insights for future enhancements and implementations.

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