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An Integrated Web and Mobile-Based Unified Digital Management System for Polytechnic Institutions

Manali Rajendra Patil, Krrish Mukesh Galicha, Pranali Pandurang Jadhav, Bhargav Vinayak Kandalkar * and Sagar Vilasrao Chavan

Department of Computer Science and Engineering, Sanjay Ghodawat Institute, Kolhapur, India.

Abstract

Polytechnic institutions often rely on fragmented digital tools and manual procedures for academic and administrative operations, leading to data inconsistency, delayed communication, and limited transparency among stakeholders. Existing systems usually operate in isolation and fail to provide a unified platform accessible to students, parents, faculty members, and administrators. This work aims to design and implement an integrated web and mobile-based unified digital management system specifically tailored for polytechnic institutions.

The proposed system consolidates core academic and administrative modules, including student information management, attendance tracking, internal assessment management, academic calendars, notifications, and role-based access control. The architecture is developed using a centralized server with RESTful APIs, enabling seamless data synchronization between web-based dashboards for faculty and administrators and mobile applications for students and parents. Secure authentication mechanisms and role-specific interfaces ensure controlled access and data privacy.

The system was deployed and evaluated in a controlled institutional environment. Performance analysis indicates a reduction of approximately 40–50% in manual data handling time for faculty members, while real-time access to academic information significantly improved communication efficiency among stakeholders. User feedback further highlights enhanced transparency and ease of access compared to traditional methods.

The proposed unified system demonstrates that integrating web and mobile technologies into a single digital platform can effectively improve operational efficiency, data accuracy, and stakeholder engagement in polytechnic institutions, contributing toward scalable and sustainable digital transformation in technical education.

Keywords: Unified Digital Management System; Web and Mobile Applications; Role-Based Access Control; OAuth

1. Introduction

The use of digital technologies in higher education has steadily increased over the past decade, transforming the way academic and administrative activities are carried out. Polytechnic institutions, in particular, function through the coordinated involvement of multiple stakeholders, including students, parents, teaching staff, heads of departments, and institutional administrators. Each of these stakeholders generates and consumes large amounts of academic and operational information on a daily basis. Managing attendance records, internal assessments, academic progress, notices, and administrative data in an organized manner therefore requires a centralized digital platform capable of supporting structured data handling and smooth communication across departments.

* Corresponding author: Bhargav V. Kandalkar

Although several academic management solutions are currently available, most of them operate in isolation and address only specific institutional needs. Many existing systems are designed to manage a single function such as attendance tracking or examination processing, without offering integration with other academic or administrative modules. In addition, a number of platforms provide access only through web applications or only through mobile applications, which limits flexibility and accessibility for users. These limitations often result in data inconsistency, repetitive data entry, and delayed information flow. The need for a unified system that supports real-time access, multi-user interaction, and seamless web and mobile connectivity has therefore become increasingly important for polytechnic institutions.

To address these challenges, the proposed unified digital management system is designed using a modular and scalable system architecture. The architecture consists of a centralized database for secure data storage, a backend server responsible for business logic and data validation, and synchronized web and mobile applications for user interaction. Role-based access control mechanisms ensure that each user category is granted access only to relevant information and functionalities. The system architecture emphasizes secure communication, data consistency, and real-time synchronization across all modules, enabling reliable academic and administrative operations.

In conclusion, the unified web and mobile based digital management system provides a comprehensive solution for managing academic and administrative processes within polytechnic institutions. By consolidating multiple institutional functions into a single integrated platform, the system minimizes manual effort, reduces data redundancy, and enhances transparency. The proposed system supports efficient communication, accurate data management, and informed decision-making, making it a practical and scalable digital solution for modern polytechnic education environments.

2. Literature Review

Research on digital management systems in higher education shows a gradual shift from basic student information systems to more integrated academic platforms. Early systems were primarily designed to manage student records, attendance, and examination data, which improved administrative accuracy but offered minimal coordination across departments. As highlighted by Chaitra (2018), these systems lacked centralized control and were insufficient for institutions with multiple academic stakeholders.

With the advancement of web technologies, several studies proposed web-based college management systems using platforms such as Java, PHP, and cloud databases. These systems improved accessibility and reduced manual effort in handling academic and faculty-related processes. However, most implementations functioned as standalone applications, leading to fragmented data storage and limited interoperability, as observed in recent smart college management studies.

Popular platforms such as Fedena, Teach Us, and OpenSIS attempted to address these limitations by offering comprehensive academic modules. While these platforms provide useful features like attendance monitoring, assessment management, and communication tools, they often face challenges related to customization, scalability, and deployment cost, particularly for polytechnic institutions with specific operational needs.

Recent literature emphasizes ERP-based academic systems as a unified solution for integrating academic and administrative functions. Studies by Pawar et al. (2023) indicate improved operational efficiency through ERP adoption, but also report high complexity and limited adaptability. Additionally, secure role-based access has been identified as a critical requirement. Patil et al. (2025) demonstrated the effectiveness of JWT-based authentication for secure multi-role interaction.

Overall, existing solutions lack flexibility, scalability, and unified data handling. This research addresses these gaps by proposing a centralized, role-based unified digital management system tailored for polytechnic institutions.

2.1. Research Gap & Objectives

2.1.1. Research Gap

After studying existing college management systems and related research work, it is clear that many solutions are available, but they do not fully solve the real problems faced by colleges in daily operations.

- Most existing systems work as separate modules (attendance, exams, records) and are not integrated into a single platform.
- Current applications show poor performance when many users access the system at the same time.
- Advanced college management systems are costly and difficult for small and medium institutions to adopt.
- Real-time updating of academic information is weak, causing delays and inconsistencies in records.
- Many systems are complex to use and not designed for non-technical users such as parents and staff.

These limitations show that there is a clear gap in developing a single, low-cost, accurate, scalable, and real-time unified college management application, which this project aims to address.

Objectives

The main objective of this project is to develop a College Unified Management Application that simplifies academic and administrative activities and reduces dependency on manual work.

The specific objectives of the project are:

- To develop a single unified platform that integrates all major college activities.
- To improve system performance and response time during high user activity.
- To design a low-cost and efficient solution suitable for institutions with limited budgets.
- To ensure real-time updating of academic and administrative data across all modules.
- To create a simple and user-friendly interface for easy adoption by all stakeholders.
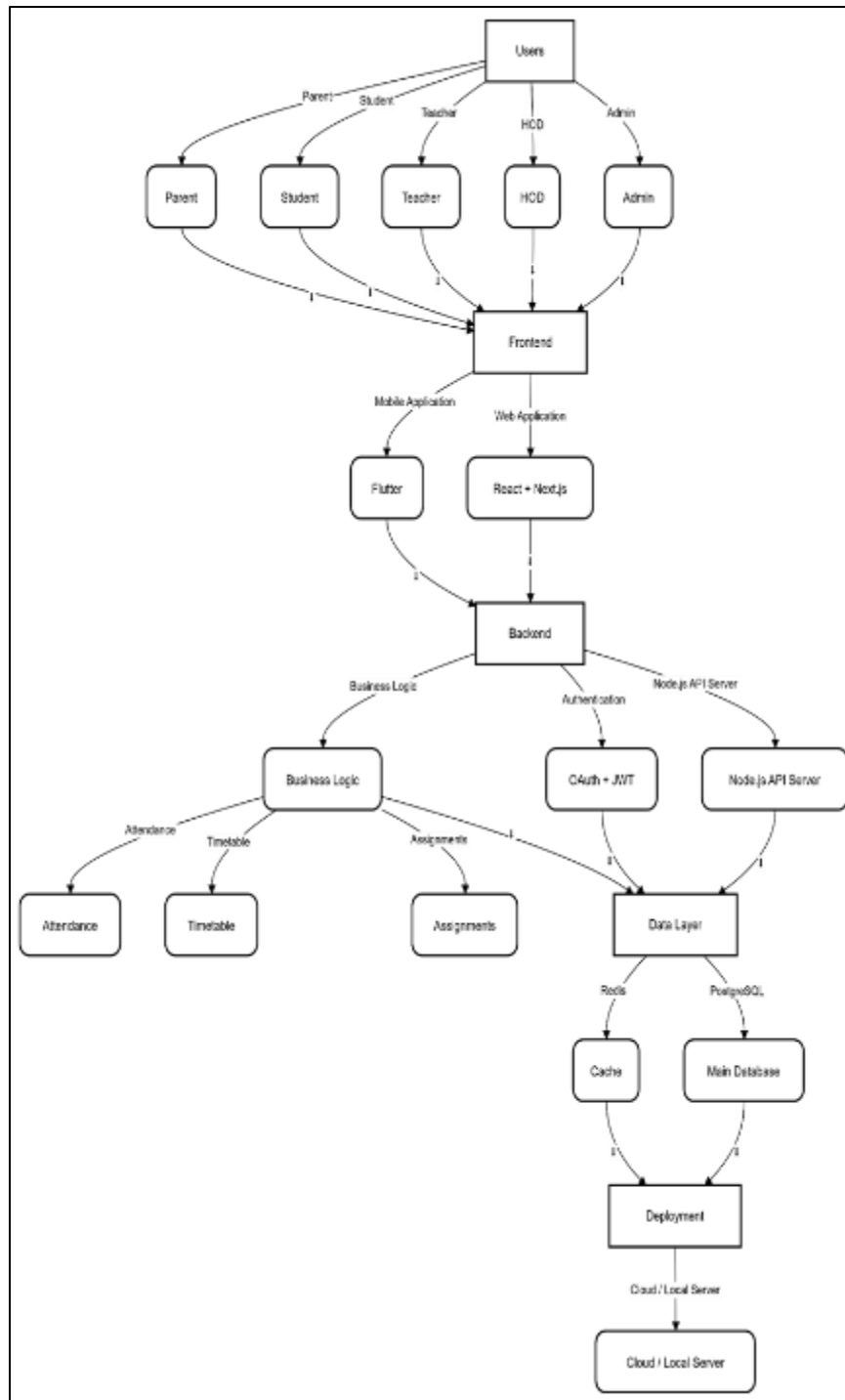
Figure 1 System Architecture of the Proposed System

2.2. System Architecture

The College Unified Management Application is developed using a multi-tier centralized architecture. This architecture is widely used in modern software systems because it divides the system into separate layers, where each layer has its own responsibility. By separating functions into layers, the system becomes easier to manage, more secure, and capable of handling future expansion.

The application works on a client–server model. All users access the system through web or mobile applications, while a central server processes requests and manages data. This ensures that all information is stored and controlled at one point, improving reliability and coordination.

The system architecture is organized into five main layers:

- User Layer
- Presentation Layer
- Application Layer
- Data Layer
- Security and Deployment Layer

This structure ensures that modifications in one layer do not disturb the functioning of other layers, making the system flexible and maintainable.

2.3. User Layer

The user layer includes all individuals who interact with the system:

- Administrator
  Head of Department (HOD)
- Teachers
  Students
  Parent

Each user accesses the system using a unique login ID and password. After login, the system identifies the user's role and displays features accordingly. For example:

- The administrator manages users and system settings
- The HOD supervises departmental activities
- Teachers upload study material and record attendance
- Students view academic information
- Parents monitor student performance
- This role separation improves security and ensures that users cannot access unauthorized features.

2.4. Presentation Layer (Frontend Layer)

The presentation layer acts as the interface between users and the system. It is responsible for displaying information and accepting user input.

This layer consists of two interfaces:

2.4.1. Web Interface

The web interface is developed using React with Next.js and is mainly used by administrators, HODs, and teachers. It provides:

- Quick page loading
- Interactive dashboards
- Smooth navigation across modules

Next.js improves performance by optimizing page rendering and routing.

2.5. Mobile Interface

The mobile application is developed using Flutter and is mainly used by students and parents. It allows fast access to:

- Attendance records
- Notes and assignments
- Academic calendar and notifications

Flutter allows the same application to run on both Android and iOS platforms, reducing development effort and ensuring uniform design.

The presentation layer never communicates directly with the database. All requests are securely sent to the backend server.

2.6. Application Layer (Backend Layer)

The application layer is the main processing unit of the system. It is developed using Node.js, which efficiently handles multiple user requests at the same time.

This layer performs essential operations such as:

- Verifying login credentials
- Checking user permissions
- Processing business logic
- Managing system workflows
- Communicating with the database

For example, when a teacher records attendance:

- The request is sent from the frontend
- The backend verifies the teacher's authorization
- The data is checked for correctness
- The database is updated
- The updated information is sent back instantly
- This ensures that only valid and authorized actions are stored in the system.

2.6.1. Data Layer

The data layer stores and manages all application data.

PostgreSQL Database

PostgreSQL is used as the primary database to store structured information such as:

- User profiles
- Attendance records
- Timetables
  Assignment details
- Academic events

Relational constraints maintain data accuracy and prevent inconsistencies.

2.6.2. Redis Cache

Redis is used for storing frequently accessed data in memory, such as:

- Active user sessions
- Timetable details
- Dashboard data

This minimizes repeated database queries and improves system speed.

2.6.3. Security and Deployment Layer

Security is applied throughout the system using:

- OAuth 2.0 for safe user authentication
- JWT for session validation
- Role-based access control to restrict unauthorized operations

All communication between components is secured to protect sensitive information.

The system is tested on a local server and designed for cloud deployment. Cloud support enables:

- Load balancing
- Continuous availability
- Easy system expansion

This allows the application to grow with increasing users and features.

Overall Working of the Architecture

The complete system works as follows:

- User logs in through web or mobile application
- Frontend sends the request to the backend server
- Backend verifies user identity and role
- Required business logic is executed
- Database is accessed or updated
- Processed data is returned to frontend
- User views updated information instantly

This flow ensures smooth operation, high accuracy, and reliable performance of the system

3. Experimental Setup & Results

To evaluate the effectiveness and reliability of the proposed Unified College Management System (UCMS), a structured experimental setup was designed. The system was deployed in a controlled environment simulating real college operations with different user roles including administrators, Heads of Departments, teachers, students, and parents. Test data representing student records, attendance entries, subject allocations, and timetable information were used to validate system functionality.

A series of test cases were performed to verify the core modules of the system. These included user authentication, role-based access control, attendance management, student data management, subject assignment, and parent information access. Each test case was evaluated based on correctness of output, response time, and successful execution without errors. The results showed that all major functionalities operated as expected with high reliability.

3.1. Comparative Analysis

In the realm of educational institutions, several digital platforms have been developed to streamline academic and administrative processes. Below is an overview of three such systems

3.1.1. TeachUs App

Overview: TeachUs is an Indian-developed mobile application designed to automate and manage various college activities. It offers features such as attendance tracking, syllabus progress monitoring, lecture scheduling, digital noticeboards, and feedback collection. The app aims to digitize manual processes and enhance communication among students, faculty, and administration.

Limitations:

Some users report issues with incorrect attendance marking and glitches in certain features. Limited customization options for institutions with unique requirements. Dependency on internet connectivity for certain functionalities

3.1.2. Fedena

Overview: Fedena is a comprehensive school management software that caters to K-12 and higher education institutions. It provides over 50 features, including gradebooks, attendance management, fee collection, timetable

scheduling, and HR management. Fedena is known for its modular approach, allowing institutions to select and implement features as per their needs.

Limitations:

The free version offers limited features, many advanced functionalities are part of the paid plans. Customization may require technical expertise or additional costs. Some users have reported a steep learning curve for new users

3.1.3. openSIS

Overview: openSIS is an open-source Student Information System (SIS) that caters to K-12 schools, colleges, and universities. It offers features like student demographics, attendance tracking, gradebooks, scheduling, and report cards. Being open-source, it provides institutions with the flexibility to customize and extend the system as needed.

Limitations:

The user interface may appear dated compared to modern applications. Requires technical expertise for installation, customization, and maintenance. Limited mobile support, which may affect accessibility for users on the go.

While existing systems like TeachUs, Fedena, and openSIS offer valuable features, they each have limitations in areas such as customization, mobile accessibility, and specific functionalities. Our project aims to bridge these gaps by providing a unified platform with enhanced features tailored to the needs of modern educational institutions with an intuitive UI which is easy to understand and use for anyone.

4. Discussion

The experimental evaluation and comparative analysis show that the proposed Unified College Management System (UCMS) provides clear improvements over existing methods used for academic management. These improvements are mainly due to its unified system design, structured role-based hierarchy, and the use of modern technologies. By bringing together attendance management, student records, examination data, timetable scheduling, and institutional communication into a single platform, the system removes the need for multiple separate applications and reduces manual effort.

In practical use, UCMS helps reduce the workload of college staff by automating regular academic tasks and providing real-time access to important information. Administrators and Heads of Departments can monitor college activities more efficiently, teachers can manage classes and student data more easily, and parents are able to view their children's academic progress and receive important notices directly. The use of Flutter for mobile applications and React for web dashboards ensures a smooth and user-friendly experience across different devices.

A key strength of the system lies in its hierarchical role-based structure, which ensures organized and secure management of institutional data. The flow of authority from administrators to Heads of Departments, teachers, students, and parents create a clear chain of responsibility and controlled access to information. Each user is provided only the permissions relevant to their role, reducing the risk of unauthorized modifications and data misuse. This structured approach simplifies system management, improves accountability, and allows the platform to function efficiently even in large and complex institutional environments.

5. Conclusion

This paper presented the design and implementation of a Unified College Management System aimed at improving the efficiency and reliability of academic and administrative operations within educational institutions. The proposed system integrates key functionalities such as attendance management, student information, examination records, timetable scheduling, and institutional communication into a single unified platform supported by mobile and web applications.

Experimental evaluation and comparative analysis demonstrate that the system achieves higher data accuracy, reduced operational redundancy, and improved usability compared to conventional fragmented approaches. The defined hierarchical structure and role-based access control ensure secure and organized management of institutional workflows. Overall, the objectives of centralized data management, system integration, and enhanced stakeholder interaction were successfully achieved.

Future scope

Although the proposed Unified College Management System provides a comprehensive and efficient solution for managing academic and administrative operations, several enhancements can further improve its capabilities and applicability. Future development will focus on increasing the system's scalability to support differently structured institutions and larger user bases through cloud-based deployment and distributed data management. This will enable institutions of varying sizes to adopt the platform without performance degradation.

The integration of artificial intelligence and machine learning techniques presents significant potential for improving decision-making and academic monitoring. Predictive analytics can be incorporated to forecast student performance, identify at-risk students, and optimize timetable and resource allocation. Intelligent notification systems can be developed to provide personalized academic recommendations and early alerts to students, parents, and faculty.

Additional improvements include the expansion of mobile application features such as offline data access, enhanced parent engagement tools, and multilingual support to increase accessibility. Integration with biometric attendance systems is a possible expansion too, national education platforms, and external learning management systems can further extend the system's functionality. These advancements will allow the proposed platform to evolve into a comprehensive digital ecosystem for modern educational institutions.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

References

[1] Manali Rajendra Patil,Krrish Mukesh Galicha,Pranali Pandurang Jadhav,Bhargav Vinayak Kandalkar,Sagar V. Chavan, **"JWT And Its Impact On The User And Application Interactions"**, International Journal of Creative Research Thoughts (IJCRT), ISSN:2320-2882, Volume.13, Issue 10, pp.c460-c469, October 2025 :http://www.ijcrt.org/papers/IJCRT2510293.pdf

[2] Chaitra, B. S. (2018). *An Innovative Information System for College Management.* International Journal of Management, Technology, and Social Sciences (IJMTS), researchgate.net

[3] A Smart and Efficient College Management System (2025). *JNAO-NU Journal*, jnao-nu.com

[4] Pawar, A., Kadam, A., & Shah, S. (2023). *A Study on the Effectiveness of College ERP Systems in Higher Education Institutions.* International Research Journal of Modernization in Engineering, Technology and Science, irjmets.com

[5] *ERP Systems in Higher Education: A Systematic Literature Review* (2025), researchgate.net

[6] ERP for College Management System (2021). *International Journal of Advanced Research in Computer and Communication Engineering (IJARCCE)*, ijarcce.com

[7] *College Management System Research* (2023). *IJRSRCEIT Journal*, ijsrcseit.com

[8] Ferraiolo, D. F., Kuhn, D. R., & Chandrasekarouli, R. (2007). *Role-Based Access Control.* Artech House, wikipedia.org