IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Enhanced Library Book Tracking And Management System

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Abstract: As libraries embrace advanced technologies to enhance efficiency and user experience, this project presents a Library Management System integrating Radio-Frequency Identification (RFID) and Internet of Things (IoT). This system modernizes library operations by enabling seamless book borrowing and returning through RFID-enabled student identity cards and book tags. When a student places their card near an RFID reader, the system instantly verifies their identity, ensuring fast, secure, and error-free transactions.Beyond automation, the system incorporates real-time tracking of books within library racks, minimizing misplaced or lost items. Additionally, automated notifications remind students of due dates and alert them about overdue books, promoting timely returns. Designed for efficiency at minimal cost, this system optimizes library management, enhances security, and offers a more organized and user-friendly experience.

Index Terms **–** Library Management System, RFID, IoT, Real-Time Tracking, Automated Notifications, Book Borrowing and Returning, Student Identity Verification, Misplaced Book Detection, Smart Library, Low-Cost Automation.

I. INTRODUCTION

A **Library Management System (LMS)** is a digital solution designed to automate and streamline library operations, enhancing overall efficiency by handling book borrowing, returns, and record-keeping with minimal human intervention. It simplifies the tracking of book availability, exact location, and due dates, significantly reducing errors and improving organization through centralized digital records. By digitizing these processes, LMS offers quick and accurate access to essential library functions for both users and administrators.

Beyond basic automation, LMS strengthens library security by minimizing theft and misplacement through robust digital tracking and user authentication. It provides students and staff with instant access to book details, borrowing history, and automated notifications for due dates or overdue items. Furthermore, LMS reduces the burden of manual labor, scales effortlessly with growing library demands, and integrates advanced technologies like **Radio-Frequency Identification (RFID)** and the **Internet of Things (IoT)** to enable real-time tracking and seamless, secure user interactions.

These features collectively transform traditional library systems into smart, efficient, and user-friendly environments.
The adoption of LMS leads to better time management for both librarians and users. It lays the foundation for scalable and future-ready academic infrastructure.

II. LITERATURE SURVEY

[1]The literature survey explores a variety of **RFID and IoT-based smart library management systems** developed to automate and enhance traditional library functions. One significant study, conducted by **Ms. Shiny Christobel J and her team in 2024**, presents an RFID and IoT-based smart student identity card tailored for library environments. This system streamlines book transactions and user verification by employing RFID-enabled ID cards, thereby reducing manual work and human error. IoT modules enable real-time communication between components, ensuring efficient and fast responses during book issue/return. The system further allows centralized data management, making it easier for administrators to monitor library usage patterns. Its future scope emphasizes features like **real-time book location tracking, misplaced book detection, and AI-powered personalized book recommendations**, which collectively aim to improve user satisfaction and operational control.

[2] Another influential study, led by **Phani Gannamraju, Satyanarayana Yarramsetti, and L.S. Kumar in 2021**, focuses on building a smart library management system using **RFID tags, readers, ESP8266 microcontrollers, and a robust backend database**. This system significantly reduces manual labor by automating the process of book issuance and returns. It demonstrates how **Wi-Fi-enabled microcontrollers** can interact with databases in real-time, providing instant updates on book status. The study highlights challenges like managing tag-reader conflicts and handling large user volumes simultaneously. Future enhancements proposed include **grace period tracking for book returns**, **automatic fine calculations**, **integration with cloud storage**, and **error handling in microcontroller communications** to improve the reliability and robustness of the system for large-scale deployment.

[3] A third notable contribution is from **Vadlakonda Sai Vedanth and his team (2023)**, who introduced an RFID-based automated library system leveraging **Arduino microcontrollers and Bluetooth modules** to handle book transactions. This system emphasizes minimizing staff intervention and improving accuracy in book inventory management. It illustrates how combining **low-cost microcontrollers with RFID technology** can lead to scalable automation solutions. However, it also points out critical challenges such as **high initial setup costs**, **system security**, **power dependency**, and **limited scalability** due to Bluetooth's range and connectivity limitations. The authors suggest transitioning to **Wi-Fi or cloud-based platforms** and incorporating **real-time monitoring dashboards** for better control. These studies collectively underline the potential of **RFID and IoT** in revolutionizing library operations by enabling **automated processes, real-time tracking, secure authentication, and intelligent notifications**. Future systems are expected to focus on **predictive analytics, seamless integration with mobile apps, and multi-library synchronization** for a more dynamic and user-centric library experience.

III. PROPOSED SYSTEM

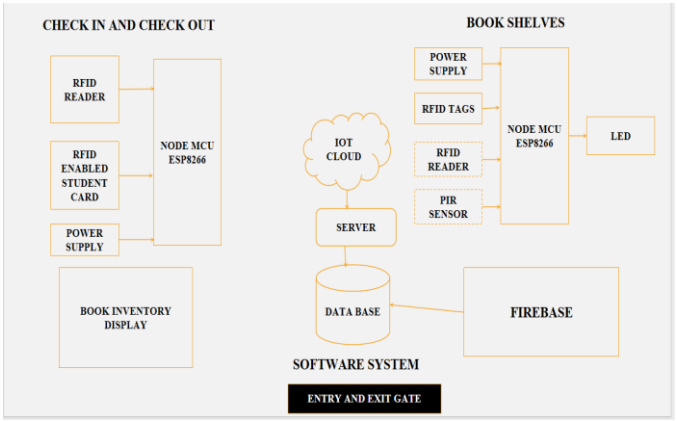

Fig.3.1: Block Diagram

The implementation of the library management system follows a systematic approach beginning with hardware setup and integration with software components. Cost-effective RFID tags are selected for books and compatible readers installed on shelves, while ESP8266 boards serve as the central processing units handling data communication between RFID readers and the Firebase database.

The physical infrastructure includes modified library racks accommodating RFID readers and antennas for optimal scanning, along with strategically placed LEDs for book location visualization and servo motors for automated access control. The software implementation integrates PHP for backend operations, MySQL for persistent data storage, and Firebase for real-time synchronization.Advanced features are systematically implemented including book inventory display with LED indicators, due date notification system alerting students before deadlines, and misplaced book tracking those records last seen locations.

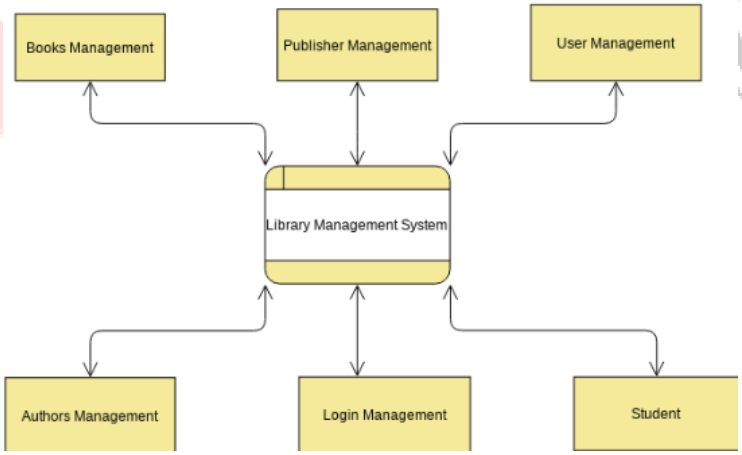

Fig.3.2: Flow chart

The entire system undergoes regular maintenance and calibration to ensure continuous reliable operation, with ongoing software updates addressing any emerging requirements or optimizations to enhance the library user experience.

IV. METHODOLOGY

Step 1: RFID and IoT Hardware Integration
The system starts by tagging each library book with a low-cost RFID tag that stores essential identification details. RFID readers are strategically installed on the library racks to detect the placement or removal of books. These readers are connected to ESP8266 microcontroller boards, which serve as the central processors. The ESP8266 units handle RFID data and communicate with Firebase using IoT protocols, ensuring that every scan is captured and reflected in real-time. The racks are physically modified to hold the readers and antennas in optimal positions for unobstructed scanning and accurate book detection.

Step 2: LED-Based Book Location Indicator
To assist users in locating books easily, the system includes LED indicators placed near each rack. When a student searches for a book through the web interface, the ESP8266 fetches the book's ID from Firebase and identifies its current location. It then activates the corresponding LED on the specific rack, guiding the user directly to the book. This minimizes time spent searching and significantly improves the library experience, especially in larger setups.

Step 3: Misplaced Book Detection System
The RFID-based tracking system also supports misplaced book detection. Every time a book is scanned, the system records the last known location by logging which rack's RFID reader detected it. If a book is found at a different location from its expected one, it is flagged as misplaced. This feature allows librarians to quickly identify and retrieve misfiled books, helping maintain an organized and efficient inventory system.

Step 4: Automated Access Control at Checkout
For secure and automated book issuing, a servo motor-controlled barrier is integrated at the library exit. This barrier operates only when both a valid student ID card and a valid book RFID tag are scanned. If both scans are verified successfully, the barrier opens automatically, allowing the student to exit with the book. This access control system ensures that only authorized users can check out books, adding a layer of security without requiring manual intervention.

Step 5: Real-Time and Historical Data Management
The backend system combines Firebase and MySQL for managing both real-time and historical data. Firebase Realtime Database handles immediate RFID updates and live book tracking, while MySQL is used to store long-term data such as borrowing history, student records, and reports. PHP scripts manage communication between the two databases, ensuring synchronized updates whenever a book is issued or returned. This hybrid setup ensures both speed and reliability.

Step 6: User Interface and Notification System
The software includes two dashboards: one for students and another for administrators. Students can view their borrowing history, check due dates, and track book availability in real time. The admin dashboard provides complete control over inventory, student activity, and misplaced book reports. Additionally, a notification system is implemented to send automatic email alerts two days before a book is due, reminding students to return their books on time and reducing overdue instances.

V. RESULTS AND DISCUSSION

The Smart Library Management System was developed to transform the traditional library experience into a modern, automated environment. By integrating RFID, NodeMCU, Firebase, and PHP, the system automates book tracking, student activity monitoring, and resource management. The key goals were to minimize human error, reduce manual workload, improve book accessibility, and provide a smoother experience for both students and administrators. The project includes core modules like LED-based Book Identification, Real-Time Login/Logout Tracking, Misplaced Book Detection, and Automated Email Reminders.

Hardware Implementation and Real time update Results:

The hardware setup, featuring NodeMCU ESP8266, RFID reader, PIR sensor, LEDs, and a servo motor, was successfully assembled and integrated.

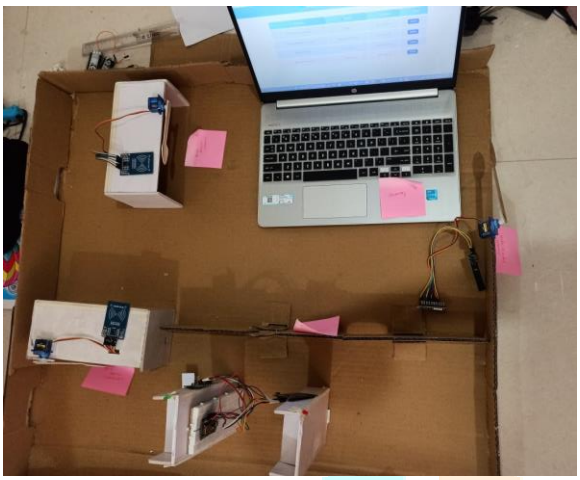

Fig.5.1: Library hardware prototype-1

K.Lohitha	9-4-2025	15:28:24	out
K.Lohitha	9-4-2025	15:29:9	in
K.Lohitha	9-4-2025	15:30:7	out
K.Lohitha	9-4-2025	15:37:39	in
K.Lohitha	9-4-2025	15:37:50	out
K.Lohitha	9-4-2025	15:41:1	in
K.Lohitha	9-4-2025	15:41:14	out
K.Lohitha	9-4-2025	15:44:28	in
K.Lohitha	9-4-2025	15:45:18	out
K.Lohitha	9-4-2025	15:48:51	in
K.Lohitha	9-4-2025	15:49:3	out

Fig.5.3: Real Time updated sheet

Serial Monitor output confirmed accurate RFID tag detection, real-time motion sensing, and responsive LED/servo actions, indicating proper hardware communication and functionality.

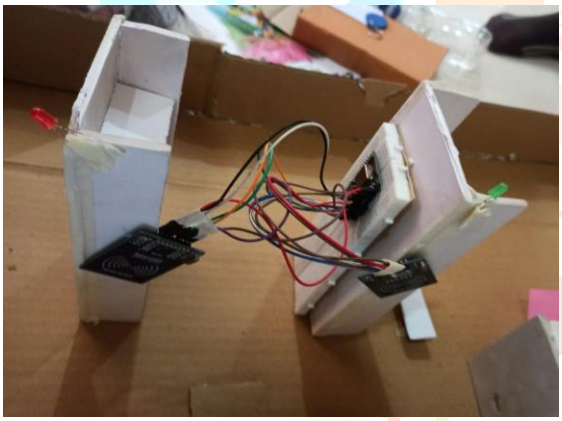

Fig.5.2: Library hardware prototype-2

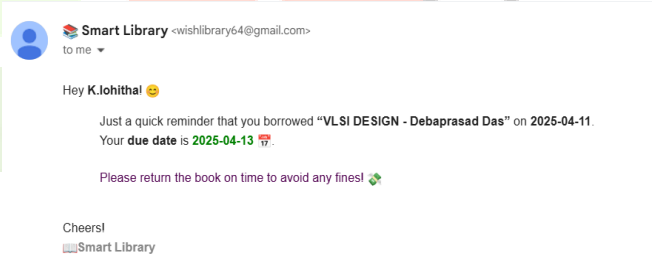

Fig.5.4: Notification alert in Mail

Hardware Implementation:

The hardware setup includes cost-effective RFID tags attached to each book, storing unique identification data. RFID readers are embedded into modified library shelves for optimal tag scanning. These readers are connected to ESP8266 microcontrollers, which act as the central processors, handling RFID data and enabling communication with IoT platforms like Firebase. Additional components like LED indicators are installed on each rack for book location assistance, and a servo motor is placed at checkout points for access control.

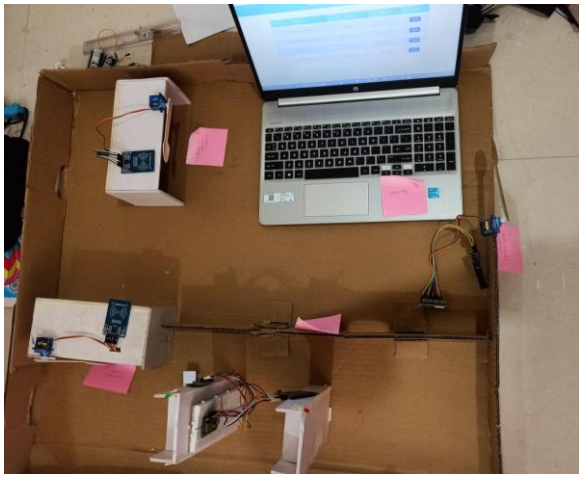

Fig.5.5: IMPLEMENTATION SETUP

Hardware Setup

The implementation begins with integrating RFID readers via SPI communication with the ESP8266 modules, allowing the system to detect book placements or removals in real time. When a book is searched, the ESP8266 identifies its location from Firebase and lights up the corresponding rack's LED. For misplaced books, the last detected reader location is logged for recovery assistance. At checkout, the servo motor-based barrier grants access only upon valid RFID scans of both student and book, ensuring secure and automated library operations.

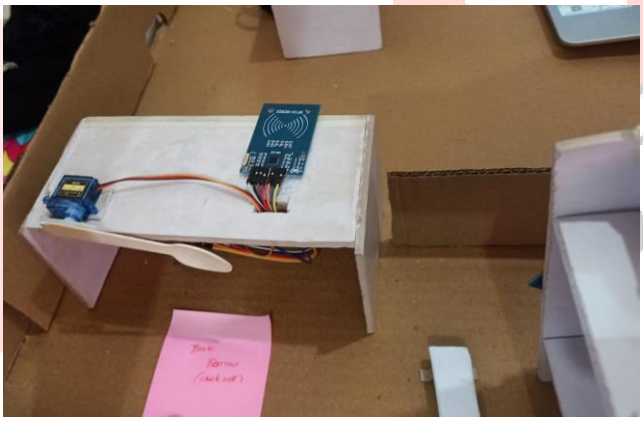

Fig.5.6: Hardware setup

Firebase Integration

Firebase Realtime Database plays a pivotal role in handling live events within the system. When a student scans their RFID card or performs a book search, data is instantly transmitted to Firebase by the ESP8266 microcontroller. This enables real-

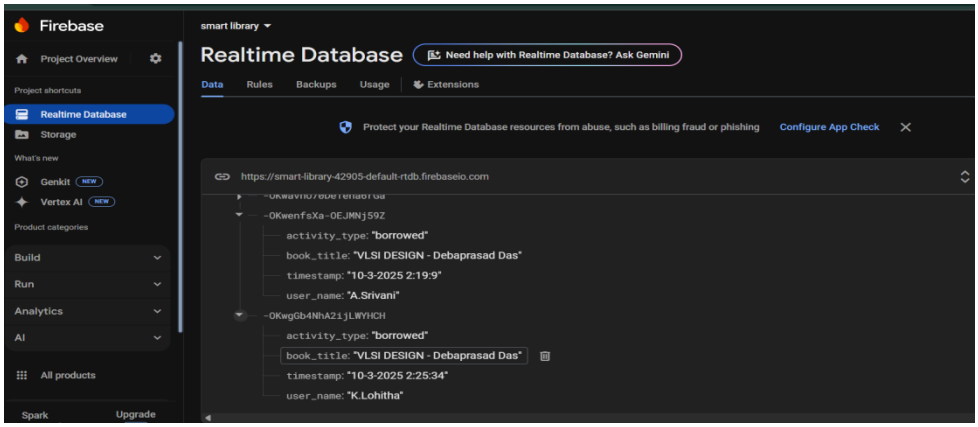

Fig 5.7: Firebase Database

time synchronization of the system, allowing immediate updates to the interface and backend regarding book availability, location tracking, and user login status. The integration is facilitated using the Kreait Firebase PHP SDK, which allows secure and efficient communication between the PHP server and the Firebase database. Firebase is also used to activate hardware responses such as LED indicators for book location and to maintain a live status feed of books and users, thereby streamlining operations that require instantaneous system behavior

MySQL and XAMPP

To support structured and persistent data storage, the system incorporates MySQL as the local relational database, hosted through the XAMPP server. While Firebase manages real-time functionalities, MySQL is used for long-term storage of transactional data, including student registrations, book issue and return records, overdue tracking, fine calculations, and complete borrowing histories

	Table	Action	Rows	Type	Collation	Size	Overhead
☐	all_books	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	16.0 KiB	-
☐	books	Browse Structure Search Insert Empty Drop	4	InnoDB	utf8mb4_general_ci	32.0 KiB	-
☐	book_activity	Browse Structure Search Insert Empty Drop	1	InnoDB	utf8mb4_general_ci	32.0 KiB	-
☐	book_scans	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	16.0 KiB	-
☐	due_mail_log	Browse Structure Search Insert Empty Drop	19	InnoDB	utf8mb4_general_ci	16.0 KiB	-
☐	firebase_books_mirror	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	16.0 KiB	-
☐	issued_books	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	16.0 KiB	-
☐	misplaced_scans	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	16.0 KiB	-
☐	transactions	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	48.0 KiB	-
☐	users	Browse Structure Search Insert Empty Drop	7	InnoDB	utf8mb4_general_ci	48.0 KiB	-
☐	user_activity	Browse Structure Search Insert Empty Drop	0	InnoDB	utf8mb4_general_ci	16.0 KiB	-
	11 tables	Sum	31	InnoDB	utf8mb4_general_ci	272.0 KiB	0 B

Fig.5.8: Database tables

The database architecture is designed to ensure data normalization and consistency, allowing efficient query execution and reliable storage for generating reports. By maintaining this dual-database setup, the system effectively separates dynamic updates from historical data management, which enhances both performance and scalability.

PHP Backend:

At the core of the software logic lies a PHP backend that integrates and manages all interactions between the hardware, databases, and user interface.

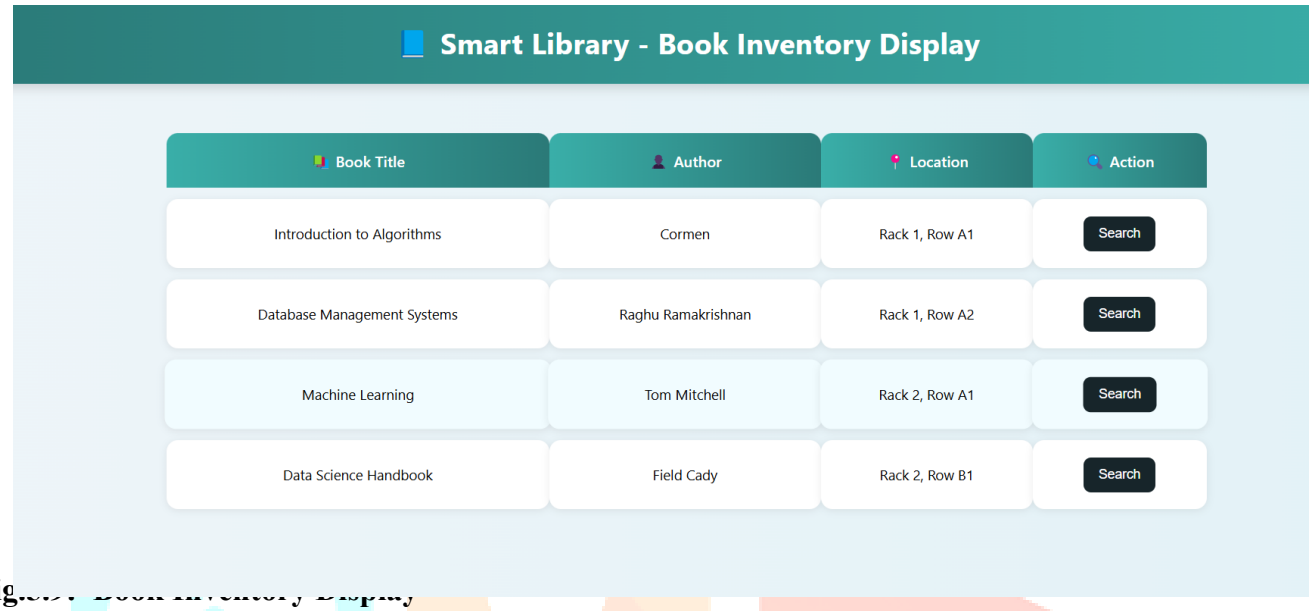

Fig.5.9: Book Inventory Display

This backend is responsible for user authentication, utilizing secure password hashing and session management to protect account data. It manages RFID event handling by processing input from the NodeMCU and coordinating with both Firebase and MySQL to ensure that check-ins, check-outs, and book status updates are accurately reflected across the system. The PHP backend also supports administrative functionalities such as generating Excel-based daily reports, sending automated email reminders for due dates, and providing real-time monitoring dashboards. This cohesive integration not only enhances system reliability and user access but also reinforces data security and system modularity.

Website:

The system also includes a dynamic and responsive website interface that acts as the primary user access point for both students and administrators. Developed using HTML, CSS, JavaScript, and PHP, the website offers seamless navigation and interactive features tailored to each user role. Students can log in to view their borrowing history, check book availability in real time, and receive notifications about upcoming due dates directly through their dashboard.

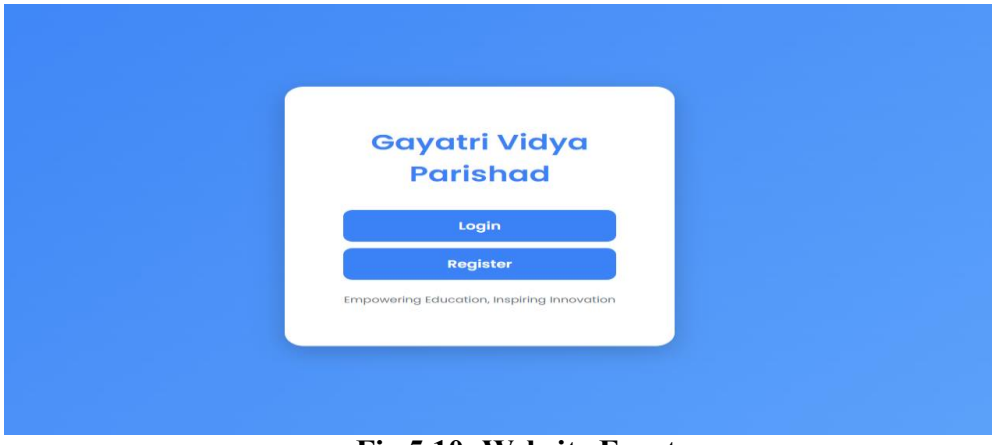

Fig.5.10: Website Front page

On the administrator side, the interface provides comprehensive control over the library's operations, including the ability to monitor live check-ins and check-outs, track misplaced books, manage the inventory display, and generate downloadable reports. The interface communicates continuously with both Firebase for real-time updates and MySQL for retrieving detailed records. Designed for accessibility and scalability, the website ensures a smooth experience across various devices while maintaining secure login protocols and user data protection.

VI. CONCLUSION

The RFID-based Smart Library Management System marks a transformative step in modernizing library operations by effectively integrating IoT hardware with real-time software solutions. Leveraging ESP8266 microcontrollers, RFID technology, Firebase for real-time data synchronization, and a PHP-MySQL backend, the system addresses critical challenges such as accurate book tracking, efficient inventory management, and streamlined borrower services. Key innovations—like LED-guided book location, automated due date reminders, and misplaced book detection—greatly enhance user experience and administrative control. This comprehensive solution not only minimizes manual effort and reduces human error but also ensures a more organized, accessible, and responsive library environment. As libraries adapt to the demands of the digital age, this scalable and cost-effective system provides a solid foundation for future enhancements, ensuring sustained usability and operational excellence.

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