Design and Implementation of a Web based Laboratory Management System (WBLMS) (A Case Study of Federal Polytechnic, Ile – Oluji, Ondo State)

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ABSTRACT
The purpose of this study is to design and implement a Web-Based Laboratory Management System (WBLMS) for the effective management of laboratory equipment and resources at the Federal Polytechnic, Ile-Oluji, Ondo State. The research addresses the existing challenges faced by the institution's Computer Science Department, such as the manual tracking of ICT gadgets and the inefficient management of laboratory resources. The primary objective is to create a system that automates the reservation, tracking, and inventory management processes, thereby enhancing efficiency and reducing errors. The study follows a system development methodology, which includes requirement analysis, design, implementation, and testing phases. A user-centric approach was adopted to ensure that the system meets the specific needs of laboratory staff and students. The WBLMS consists of key modules, including a login page for administrator authentication, a dashboard that displays current gadget reservations, and sections for managing transactions, items, borrowers, rooms, and inventory. Additional features include graphs for data visualization and a history section for tracking past activities. The system was deployed in the ICT laboratory, and initial testing demonstrated a significant improvement in resource management. The WBLMS allows real-time monitoring of borrowed equipment, including model, brand, and quantity, which streamlines the laboratory's operations. The study concludes that the WBLMS enhances the overall efficiency of laboratory management by providing an automated, user-friendly interface. The implementation of this system reduces manual effort, minimizes human error, and ensures accurate record-keeping, making it a valuable tool for academic institutions.

Keywords
Web-Based Laboratory Management System (WBLMS), ICT Resource Management, Inventory Tracking, Automation

1. INTRODUCTION
Laboratory management plays a crucial role in the smooth operation of academic institutions, particularly in technical and computer science departments, where the efficient handling of ICT resources is essential for practical learning and research. In many institutions, laboratory management is still handled manually, resulting in inefficiencies such as mismanagement of resources, data entry errors, and difficulty in tracking borrowed equipment. This problem is prevalent in the Federal Polytechnic, Ile-Oluji, Ondo State, where the current system relies heavily on manual processes that are time-consuming, prone to errors, and lack real-time monitoring. This study aims to design and implement a Web-Based Laboratory Management System (WBLMS) that automates the process of managing laboratory resources in the ICT laboratory of the Computer Science Department, providing a more efficient, reliable, and user-friendly platform for laboratory staff and students.

The scope of this study encompasses the development of a web-based application that streamlines laboratory operations by offering functionalities such as real-time tracking of borrowed ICT equipment, automated inventory management, reservation of resources, and detailed monitoring of equipment usage. The WBLMS is designed with multiple modules that facilitate user login, transaction management, borrower and item records, and data visualization through graphical reports. The system also includes features for room allocation and historical tracking of all laboratory activities, ensuring comprehensive management of laboratory resources. The significance of this study lies in its potential to transform the way laboratory resources are managed in academic institutions. By automating the inventory and reservation processes, the WBLMS significantly reduces manual effort and minimizes the risk of human error. This, in turn, leads to increased efficiency, better utilization of resources, and improved user satisfaction. Additionally, the system provides laboratory administrators with real-time data on the status of equipment, enabling better decision-making and effective management of ICT resources. Similar studies have shown that the implementation of web-based management systems in educational environments enhances operational efficiency and resource accountability [1][2]. This research not only addresses the specific challenges faced by the Federal Polytechnic, Ile-Oluji but also contributes to the growing body of knowledge on the use of information technology in educational resource management. By offering a practical solution tailored to the needs of the institution, this study demonstrates how ICT innovations can be leveraged to improve operational processes in academic settings.

2. RELATED WORKS
In the domain of web-based laboratory management systems (LMS), there has been significant progress toward automating various aspects of laboratory functions, including resource tracking, equipment monitoring, and user management. Various studies have highlighted the effectiveness of LMS in enhancing the operational efficiency of labs, particularly in educational and research institutions.

One study by [3] emphasized the role of performance testing in laboratory environments and introduced a model for web-based systems that aim to optimize software deployment and resource management. This approach, similar to LMS, underscores the need for accurate performance assessment in real-time, especially in technical labs such as the one proposed for the ICT laboratory at the Federal Polytechnic, Ile-Oluji. A related study [4] on web-based remote laboratory systems provided insights into how LMS can support remote laboratory work, particularly for embedded systems. This model demonstrated how students and researchers can conduct experiments remotely, a key advantage in resource-limited settings.

Furthermore, research by [5] discussed the design of distance laboratories for engineering education, focusing on web-based software and hardware integration. This study parallels the

Federal Polytechnic project by highlighting the importance of online platforms for managing complex technical resources and offering detailed user interfaces for system administrators. Another relevant study by [6] explored how virtual tours and building information models (BIMs) can be integrated into laboratory management systems using IoT technologies. Their system enhanced facility management by allowing real-time monitoring of laboratory assets, which is directly relevant to the proposed system for ICT gadgets and borrower tracking.

Lastly, [7] proposed a state-driven approach to resource management within distributed web applications, focusing on scalable deployment across laboratory systems. This model could inform the design of the WBLMS for the Computer Science department's ICT laboratory by offering methods for handling large datasets and managing multiple users simultaneously. Each of these works contributes valuable perspectives to the design and implementation of web-based laboratory systems, focusing on resource management, automation, and user interface design—core components of the proposed WBLMS for the Federal Polytechnic's ICT laboratory.

3. METHODOLOGY

The methodology for the design and implementation of the Web-Based Laboratory Management System (WBLMS) for the Federal Polytechnic, Ile-Oluji, Ondo State, is divided into several key stages to ensure the software meets the institution's specific needs and efficiently manages ICT laboratory resources.

3.1 System Requirements Gathering

i. Stakeholder Engagement: This phase involves interacting with key stakeholders, such as the ICT lab administrators, lecturers, and students, to identify requirements for managing laboratory resources. The primary data collected includes the types of ICT gadgets (e.g., computers, projectors, printers) in the lab, the expected borrowing process, inventory tracking, and user management.

ii. Requirements Documentation: All functional and non-functional requirements are documented. Functional requirements include user authentication (admin and borrower login), gadget reservation, gadget inventory management, and transaction records. Non-functional requirements include system performance, scalability, and security.

3.2 System Design

i. Database Design: The system requires a relational database for storing information about items, transactions, users, rooms, and borrower details. The database schema is structured with key tables such as:

ii. Users: Stores login credentials, roles (admin, borrower), and personal details.

iii. Inventory: Keeps details of available ICT gadgets (e.g., model, brand, quantity).

iv. Transactions: Tracks gadgets borrowed and returned, along with timestamps.

v. Borrowers: Stores borrower information, including department, ID, and history.

vi. Rooms: Stores information about rooms where gadgets are located.

3.3 User Interface Design

The system's user interface is divided into different sections: Login, Dashboard, Transactions, Inventory Management, Borrowers, Rooms, User Management, and History. Each section provides specific functionality for the administrators to manage laboratory operations effectively.

i. Admin Dashboard: Provides an overview of reservations, gadget availability, and system usage.

ii. Transactions Module: Tracks the borrowing and returning of gadgets, including due dates.

3.4 System Development

i. Front-End Development: The front end is developed using web technologies such as HTML, CSS, and JavaScript for dynamic content and interactivity. The framework Bootstrap is used to ensure responsive design for mobile and desktop use.

ii. Back-End Development: The back end is developed using PHP and MySQL for the database. PHP is chosen for server-side scripting to handle user requests, manage sessions, and interact with the database. APIs are developed to communicate between the front end and the back end for operations such as fetching inventory data, updating transaction logs, and managing user sessions.

iii. Authentication and Authorization: JWT (JSON Web Token) or Session-based Authentication is implemented to manage user login and ensure only authorized users (admins) can perform sensitive operations, such as adding new items to the inventory or viewing transaction histories.

3.5 Testing and Validation

i. Unit Testing: Each module is tested individually to ensure functionality, such as login, data retrieval, and gadget reservation processes.

ii. Integration Testing: Ensures that all components (database, front-end, back-end) work together smoothly.

iii. User Acceptance Testing (UAT): The system is deployed in a test environment, and the stakeholders, such as lab administrators, perform operations to validate if the system meets their needs.

3.6 Deployment and Maintenance

i. Deployment: The system is deployed on a Linux-based server, accessible via a web browser over the institution's local intranet or the internet, depending on the configuration. Apache is used as the web server, and MySQL is used for the database.

ii. Maintenance: Regular maintenance is performed to ensure system performance and security. Updates may be rolled out periodically based on feedback from users or changing requirements.

3.7 Architecture of the System

i. **User Interface:** The front-end interface allows the admin to log in and manage the laboratory's inventory, borrowers, and transactions. The design is made user-friendly for quick access to key system features like reservations, transaction logs, and inventory status.

ii. **Application Layer:** This is the core of the system where business logic resides. It processes user requests, such as fetching inventory details or recording a new transaction, by communicating with the database. It also handles authentication, ensuring that only authorized users can access or manipulate data.

iii. **Database Layer:** All information related to ICT gadgets, users, and transactions is stored in the MySQL database. This layer is essential for persistent data storage and retrieval during system operations.

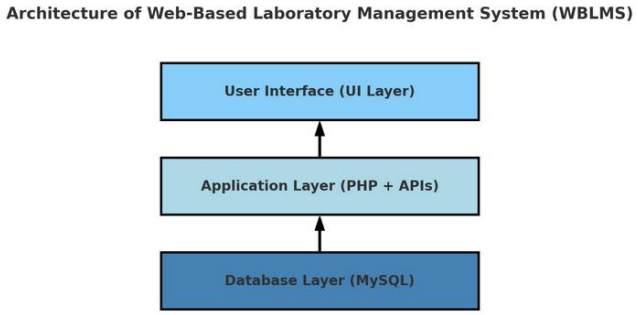

Fig 1 – Architecture of Web-Based Laboratory Management System

4. DISCUSSION

The diagram depicts the login interface of the Laboratory Management System, designed with simplicity and usability in mind. Users are prompted to enter their username and password, ensuring secure access. The layout is clean, with a clear title at the top, followed by input fields and a "Log in" button. The inclusion of the institution's logo, The Federal Polytechnic, Ile-Oluji, personalizes the system for the institution, while the additional link at the bottom provides access to a member's page for potential non-admin users.

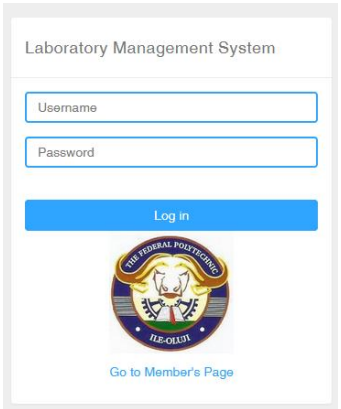

Fig 2 – Login Page

4.1 Dashboard

The dashboard shown is part of the Laboratory Management System for FEDPOLEL (Federal Polytechnic Ile-Oluji). It provides a comprehensive overview for administrators to manage ICT laboratory resources efficiently. On the left, a sidebar offers various navigation options, including Dashboard, Transaction, Item, Borrower, Room, Inventory, Graph, User, and History, allowing users to quickly switch between different system functionalities. In the main panel, an inventory table is displayed, showing ICT gadgets in the lab. Each entry lists the Model, Category (e.g., AVR, TV, Projector), Brand, Quantity, and Status of the gadgets. The administrator can use export options like CSV, Excel, PDF, or print the list. The Search bar on the top right allows quick filtering of items in the inventory. This streamlined layout ensures lab administrators can easily track the availability and status of all ICT equipment.

4.2 Navigation Panel

The navigation options on the left sidebar of the Laboratory Management System (LMS) dashboard provide access to different features and functionalities:

i. Dashboard: The central hub where administrators can get an overview of key metrics and information such as recent transactions, inventory status, and system notifications. It provides a quick snapshot of lab operations and equipment usage.

ii. Transaction: This section tracks all the lending and borrowing activities within the laboratory. It logs each transaction, including who borrowed what item, the quantity, and the date of borrowing/return. It's essential for maintaining accurate records of ICT gadgets.

iii. Item: This tab manages all items or gadgets available in the ICT laboratory. Administrators can add, modify, or remove items in the system. Information like model, category, brand, and quantity is recorded here for each item.

iv. Borrower: In this section, the system manages information about all the individuals who have borrowed or are authorized to borrow equipment from the lab. It contains details about each borrower, such as their name, department, and borrowing history.

v. Room: This module is used to track and manage different rooms or locations within the lab or institution. It allows the administrator to assign and allocate equipment to specific rooms, ensuring proper distribution and tracking of resources.

vi. Inventory: The Inventory tab gives a detailed overview of all lab equipment, including their current quantity and status (e.g., new, in-use, or damaged). It provides administrators with tools for managing the stock of available items in real-time.

vii. Graph: This section likely provides visual reports and analytics on lab usage, such as the frequency of borrowed items, inventory trends, and other key metrics. It allows for quick interpretation of data through graphical representations.

viii. User: The User tab manages system users and their roles (e.g., administrators or staff). Administrators can add or remove users and assign privileges, controlling access to different sections of the LMS.

ix. History: This option stores a log of all past actions within the system, such as previous transactions, item modifications, or borrower information changes. It's essential for auditing and tracking the historical use of lab resources.

Each of these options helps maintain efficient management and smooth operations within the ICT laboratory, ensuring resources are properly tracked and utilized.

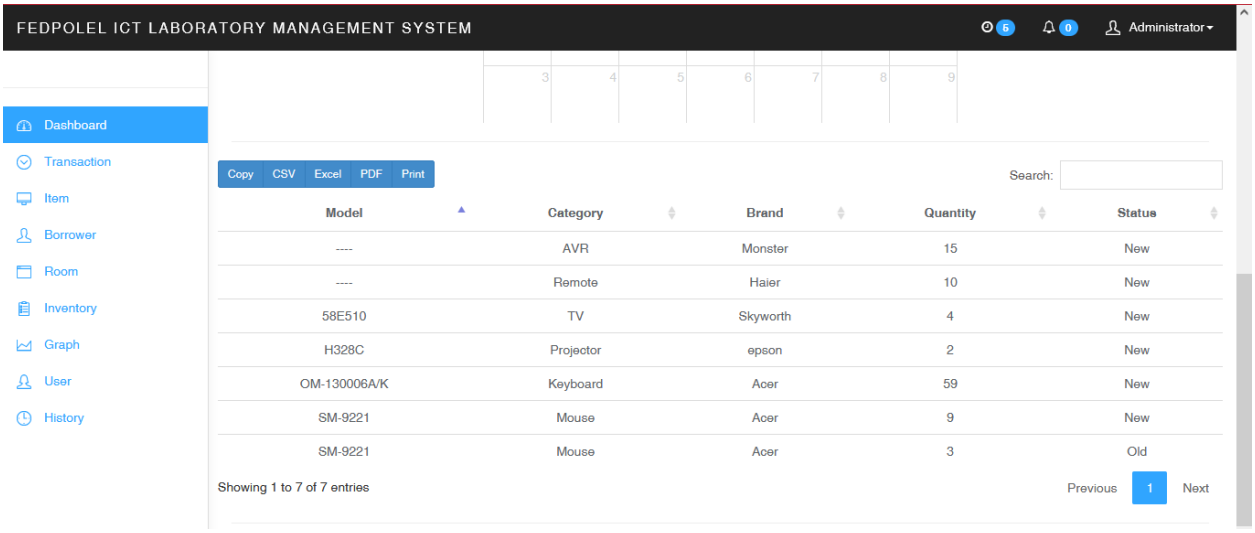

Fig 3 – Dashboard of the System

The Item section in the Laboratory Management System (LMS) is responsible for managing and displaying information related to all ICT laboratory equipment:

i. Image: This column displays a visual representation or image of the item (e.g., mouse, projector, remote) for easy identification.

ii. Model: Shows the specific model name or number of each item (e.g., SM-9221 for a mouse). This helps distinguish between different types or versions of similar devices.

iii. Category: Specifies the category of each item, such as Mouse, AVR (Automatic Voltage Regulator), Projector, Keyboard, or Remote. This helps in organizing and grouping similar types of equipment.

iv. Brand: Indicates the brand or manufacturer of the item (e.g., Acer, Haier, Epson). This provides additional information about the product's make and origin.

v. Quantity: Displays the total number of units available for each item in the inventory. This column helps administrators keep track of stock levels.

vi. Quantity Left: Shows the remaining number of units available after some have been borrowed or used. This information is crucial for knowing which items are in short supply.

vii. Status: Indicates the condition or status of the item, such as "NEW" or "OLD". This helps in tracking the usability or wear of the equipment.

viii. Action: Provides a button labeled "More info" that allows the administrator to view more detailed information about the item, including its borrowing history, maintenance records, or other relevant data.

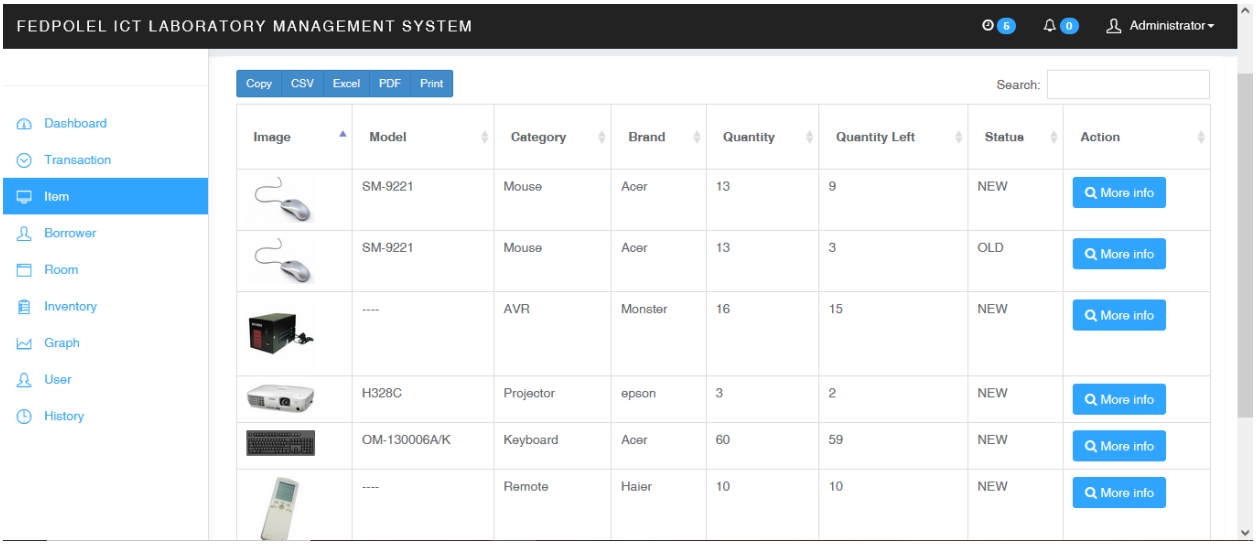

Fig 4 – Item section of the system

At the top, there are options to export the list of items in various formats, such as CSV, Excel, PDF, or to print the inventory directly. A Search bar is also available to quickly find specific items by model, category, or brand. This section ensures that administrators can efficiently manage the ICT equipment inventory, monitor availability, and track the condition and usage of each item.

4.3 Relational database design

Figure 5 below shows relational database design with several interconnected tables, used for managing the system:

i. Borrow (lms19.borrow): Tracks borrowing transactions. date_borrow (timestamp), borrowed (item identifier), member_id (link to member), stock_id, quantity, status, and date_return (expected return date).

ii. Room Equipment (lms19.room_equipment): Represents equipment assigned to rooms. Attributes include: equipment_id, room_id (link to rooms), and quantity.

iii. History Logs (lms19.history_logs): Logs actions performed in the system for auditing purposes. Attributes: description, table_name, status_name, user_type, user_id, date_created.

iv. Equipment Inventory (lms19.equipment_inventory): Holds information about equipment available for use. Attributes: equipment_id, remarks, status.

v. Member (lms19.member): Represents users of the system, such as members or employees. Attributes: User details such as id, name, school, contact, gender, department, password, and status.

vi. Item Inventory (lms19.item_inventory): Manages stock-level information for various items. Attributes: inventory_itemstock, item_remarks, date_change (likely when the stock changed).

vii. Room (lms19.room): Stores information about rooms where equipment is stored or can be reserved. Attributes: id, room_name, status, date_added.

viii. Item Transfer (lms19.item_transfer): Tracks movement of items between locations or persons. Attributes: item_id, roomID, quantity, date_transfer, person_in_charge.

ix. Item (lms19.item): Represents individual items or equipment in the system. Attributes: deviceID, category, brand, description, type, status.

x. User (lms19.user): Tracks system users (admin, etc.), separate from member. Attributes: username, password, status.

xi. Reservation (lms19.reservation): Manages reservations of items or rooms. Attributes: reservation_code, member_id, stock_id, room_id, assign, status, remarks.

xii. Reservation Status (lms19.reservation_status): Tracks the status of reservations. Attributes: reservation_code, remark.

xiii. Relationships: The system relies heavily on foreign keys to link data across tables. For instance, Borrow links to Member (via member_id) and Item (via stock_id), Room Equipment links Room and Equipment, Reservation is tied to Members, Items, and Rooms.

Overall, this ERD is designed to manage an equipment borrowing and reservation system with detailed tracking of inventory, transfers, and user interactions.

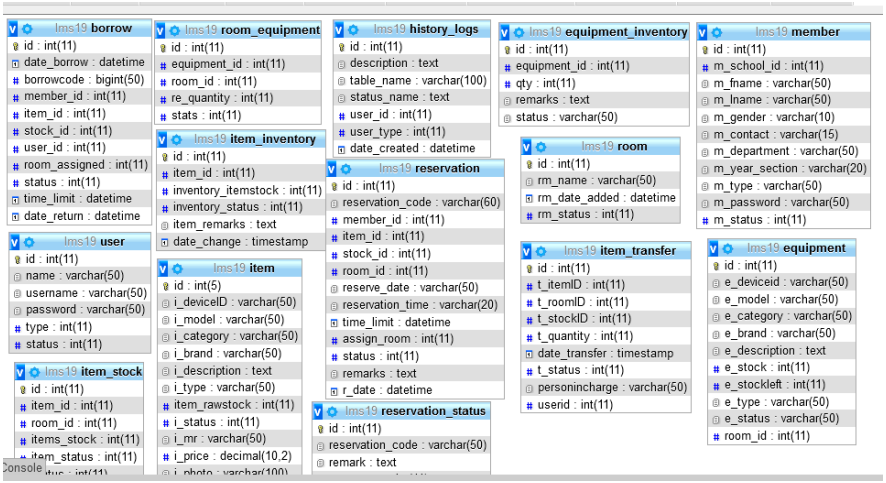

Fig 5 – Database Design of the system

5. CONCLUSION

In conclusion, the Web-Based Laboratory Management System (WBLMS) designed for the ICT Laboratory at the Federal Polytechnic, Ile-Oluji, offers a streamlined and efficient solution for managing laboratory resources. By integrating essential features such as inventory management, transaction tracking, borrower records, and real-time status updates, the system significantly reduces the administrative workload while enhancing the accuracy of lab operations. The user-friendly interface ensures that administrators can easily monitor equipment usage, track borrowings, and maintain updated records, thereby improving overall accountability and resource management. Moreover, the system's ability to generate detailed reports and visual representations of data facilitates better decision-making, enabling timely interventions when resources are running low or need maintenance. By deploying the WBLMS, the ICT Laboratory can optimize the availability and management of its equipment, fostering a more organized and efficient environment for both staff and students. The case study of the Federal Polytechnic, Ile-Oluji, demonstrates the system's practicality and scalability, making it adaptable to other institutions with similar needs. Future enhancements could involve integrating more advanced features such as predictive maintenance alerts or incorporating artificial intelligence to further streamline operations and enhance user experience. Overall, the WBLMS is a valuable tool for ensuring

effective management of laboratory resources in academic environments.

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