

Research Article

Digital Logbook Management System for Enhancing Laboratory Record-Keeping: A Case Study of Computer Science Department, Niger State Polytechnic Zungeru

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Abstract

The management of laboratory activities has long been a challenge for academic institutions that rely on manual logbook systems. These traditional systems are prone to inefficiencies such as data loss, illegibility of records, and difficulties in monitoring students' progress during laboratory sessions. In light of these issues, the need for a more streamlined, efficient, and secure method for managing laboratory logbooks has become evident. This study focuses on the implementation of an Electronic Laboratory Logbook Management System for the Computer Science Department of Niger State Polytechnic, Zungeru. The aim is to replace the traditional manual system with a digital platform that allows both instructors and students to manage laboratory records seamlessly. The system enables students to record their laboratory activities, track their progress, and submit work online, while instructors can monitor and evaluate students' performance, assign tasks, and generate reports. The system was developed using a combination of web technologies, including PHP for server-side scripting, MySQL for database management, HTML and CSS for front end design, and JavaScript for interactive elements. The system also features role-based access control, ensuring that only authorized users (students, instructors, and administrators) can access specific functionalities. Key functionalities of the system include user authentication and authorization, digital logbook entry, real-time data synchronization, and automated report generation. The system also incorporates a backup feature to safeguard data in case of hardware failures or other unforeseen events. The implementation of this system aims to significantly reduce administrative workload, enhance the accuracy of records, and improve the overall experience of laboratory management. Furthermore, it introduces greater accountability by enabling easy tracking and retrieval of laboratory records, thus improving the overall efficiency of the department's laboratory operations.

Keywords

Electronic Laboratory Logbook, Laboratory Management System, Digital Record Management, Student Progress Monitoring, Role-Based Access Control, Data Security

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Received: 9 September 2026; **Accepted:** 21 September 2026; **Published:** 20 October 2026



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1. Introduction

Laboratory logbooks are fundamental tools within academic settings as they document activities carried out in various laboratory sessions. The efficient management of laboratory logbooks is crucial for educational institutions to ensure proper record-keeping and easy access to historical data. The Computer Science Department at Niger State Polytechnic Zungeru recognized the need for an upgraded system to manage their laboratory logbooks effectively. This study focuses on the design and implementation of an electronic laboratory logbook management system tailored to the specific needs of the department [1].

The purpose of this study is to design and implement an electronic laboratory logbook management system for the Computer Science department at Niger State Polytechnic, Zungeru. The proposed system provide a centralized location for storing and accessing laboratory data, which was helpful to improve the accuracy and reliability of laboratory results [2].

Additionally, the system was automated many of the tasks associated with data management, which was helpful to reduce the amount of time and effort required to manage laboratory data. The proposed system was developed using a web-based platform, which allow laboratory data to be accessed from any device with an internet connection. The system was also a user-friendly interface, which make it easy for laboratory personnel to enter and retrieve data.

Additionally, the system included a number of features that was help to improve the accuracy and reliability of laboratory data, such as data validation and error checking. The proposed system was to be evaluated using a case study approach, which was involved implementing the system in the Computer Science department at Niger State Polytechnic, Zungeru. The case study was to be used to assess the effectiveness of the system in improving the accuracy and reliability of laboratory data, as well as its impact on the amount of time and effort required to manage laboratory.

1.1. Statement of Problem

The current paper-based logbook system used by the computer science department of Niger State Polytechnic Zungeru has numerous limitations, including poor data organization, limited collaboration, and data security concerns. These challenges hinder the department's ability to efficiently and effectively manage laboratory data and experiments.

1.2. Aim and Objectives

The aim of this project is to design and implement an Electronic Laboratory Logbook Management System for the Computer Science department at Niger State Polytechnic, Zungeru. The objectives include:

Developing a user-friendly interface for logging and accessing laboratory data.

Implementing secure user authentication and data encryption mechanisms.

Enabling efficient collaboration and data sharing among students and departmental members.

Enhancing data integrity and ensuring compliance with academic standards.

1.3. Scope of the Study

This project was focus on the design and implementation of an electronic laboratory logbook management system for the computer science department of Niger State Polytechnic Zungeru. The system was enable researchers and scientists to record, organize, and manage their laboratory data and experiments.

1.4. Significance of the Study

The implementation of an electronic laboratory logbook management system for the computer science department of Niger State Polytechnic Zungeru was provide numerous benefits, including improved data organization, enhanced collaboration, increased data security, and streamlined data retrieval. This system was enable researchers and scientists to efficiently and effectively manage laboratory data and experiments, ultimately accelerating scientific discoveries and innovation.

2. Literature Review

An electronic laboratory logbook management system is a digital platform that enables researchers, students, and scientists to record, organize, and manage their laboratory data and experiments. Electronic laboratory logbooks offer numerous advantages over traditional paper-based logbooks, including improved data organization, enhanced collaboration, increased data security, and streamlined data retrieval. [3] surveyed 107 anaesthetic trainees at Universiti Kebangsaan Malaysia to evaluate their logbook system and found that anaesthetic logbooks are useful for monitoring postgraduate training and competency, but many trainees considered the existing system inconvenient. Only 43.9% found it easy and convenient to use, while feedback to trainees was also limited. The study recommended a *simplified, fully digital logbook system* with effective feedback mechanisms to improve accessibility, record management, and training outcomes.

Furthermore [4] established that the integration of real and virtual laboratories provides a more effective approach to inquiry-based learning because it combines the hands-on practi-

cal experience of real laboratories with the visualization, flexibility, safety, and repeatability of virtual environments, thereby improving students' conceptual understanding, practical skills, and inquiry abilities, although its success depends largely on appropriate sequencing, effective teacher guidance, adequate technological infrastructure, and proper instructional framework.

Another study by [5] reviewed the use of electronic engineering logbooks across the electrical engineering curriculum and found that they provide an easier way to store, access, share, and assess students' work compared with traditional paper logbooks. The study showed that electronic logbooks also make it easier for lecturers to give feedback and for students to include data, diagrams, simulations, and other study materials. However, challenges such as limited access to suitable devices, difficulty entering equations, and the possibility of cheating were identified. Overall, the authors found that electronic logbooks were well received and provide students with documentation skills that are useful in engineering practice.

Moreover, [6] examined the use of electronic logbooks in engineering education and found that they make it easier for students to record, store, and share their practical work. The study showed that electronic logbooks also help lecturers monitor students' activities and provide feedback, while allowing students to include useful materials such as diagrams, data, and simulations. However, challenges such as access to suitable devices, entering mathematical equations, and preventing dishonest practices were identified. Overall, the study concluded that electronic logbooks are useful tools for improving practical learning and developing students' professional documentation skills.

Additionally [7] evaluated an e-logbook for Medical Licensure students in Zambia's decentralized training system, finding general acceptance among students and mentors but significant barriers including software terminology mismatches, time-consuming web-based mentor review, unreliable internet, and workflow delays. While the technical infrastructure proved feasible, design flaws from the inflexible off-the-shelf platform limited uptake, leading authors to recommend a co-designed, context-specific solution with continuous training to realize the e-logbook's potential for strengthening skills assessment in low-resource settings.

Conversely some authors explored nursing students' experiences with paper-based logbooks in Indonesia, finding that students viewed them primarily as obligatory administrative documents rather than useful learning tools. Paper logbooks were criticized as bulky, easily damaged, and prone to loss, leading to rushed, inaccurate entries. Students strongly preferred online alternatives for their portability and ease of smartphone access. The study [8] concluded that transitioning to well-designed digital logbooks could improve documentation quality and competency development.

Despite this, the study proposed a digital logbook model to address the limitations of traditional paper-based logbooks

used during industrial training [7]. The study identified problems such as incomplete entries, inconsistent reporting, delayed feedback, and difficulties in verifying students' activities. The proposed model incorporated student daily reporting, supervisor verification, centralized data management, and an interactive monitoring dashboard. The evaluation showed high user acceptance, indicating that the system could improve reporting accuracy, supervision, and the overall management of industrial training activities.

Similarly, [9] designed a web-based system to automate laboratory resource management at the Federal Polytechnic, Ile-Iluji, addressing problems like manual errors and poor tracking. The system, built with PHP and MySQL, handles inventory, borrowing, and reservations through an easy-to-use dashboard, providing real-time updates on equipment status. After testing, the system reduced administrative effort, improved accuracy, and made resource monitoring more efficient, offering a practical model for other academic institutions.

Also, the authors propose a Digital Laboratory Information System (DLIS) concept to replace conventional paper-based laboratory management in educational and research institutions by leveraging computerized systems integrated with the Internet of Things (IoT). The DLIS consolidates diverse laboratory data including inventory, equipment conditions, logbooks, booking, scheduling, and borrowing records into a unified software platform featuring separate admin and user interfaces with differential access privileges [10]. The system enables real-time remote access via electronic devices (smartphones, tablets, notebooks) through remote desktop applications, overcoming temporal and spatial limitations inherent in manual systems. Admin users can update inventory data, approve bookings, and manage accounts, while users can view equipment availability and conditions, submit booking requests, and digitally record laboratory visits. The authors conclude that DLIS offers significant advantages over conventional methods, including improved data accuracy, reduced paper usage, enhanced data security, minimized data loss risk, and flexible anytime-anywhere accessibility, positioning it as a more efficient and sustainable approach to laboratory information management in the Industry 4.0 era.

In line with previous research [11] developed an electronic logbook system (ESPRES) to replace manual recording of postgraduate research activities, addressing issues of lost records and poor supervision monitoring. Built with Agile methods and PHP/MySQL, the system allows students to log meetings, supervisors to verify progress in real time, and generates automatic reports to ensure timely completion of research. [12] examined LearnLOG, a Google Sheets-based digital logbook for accounting trainees, and found that it significantly improved monitoring efficiency and user satisfaction compared to paper-based methods, suggesting digital logbooks offer a practical solution for practical training programs. Similarly Mirici [13] demonstrated significant learning gains, found that virtual laboratories significantly improved STEM learning

outcomes and student engagement in secondary schools, with post-test scores rising from 58.4% to 78.6%, while also addressing resource and safety limitations of traditional labs.

In fact [14] proposed and evaluated an asynchronous online feedback practice model for laboratory-based courses in engineering education, addressing the challenge of delivering practical hands-on training through digital platforms. The model, built on the student-feedback interaction theory and implemented via Moodle, allows students to access instructional videos and materials, submit practical results through video recordings and reports, and receive iterative feedback from instructors. In an experiment with 200 students, the online feedback group ($n=100$) achieved higher average scores (7.28 vs. 7.07) and better assignment completion rates than the traditional face-to-face group, with statistical analysis confirming significant improvement. Instructor surveys also validated that the model effectively met course learning outcomes. The study concludes that this online feedback approach offers a viable alternative to traditional lab instruction, providing flexibility and self-directed learning while maintaining educational quality.

his mixed-methods study evaluated logbook usefulness in an undergraduate surgical rotation at the University of Tabuk, Saudi Arabia, involving 89 students and 6 teachers. While 83.3% of teachers and 75.3% of students perceived logbooks as useful for learning enhancing identification of weaknesses, encouraging patient case exposure, and improving writing skills barriers included poor-quality feedback, lack of feedback discussion opportunities, and unfair marking. Fourth-year students perceived logbooks significantly more positively than sixth-year students, while gender and academic performance showed no significant differences. The study concludes that logbooks are valuable learning tools, but their effectiveness depends on quality feedback, departmental development, and careful supervision, particularly for junior students [1].

Specifically [15] developed an electronic logbook system (e-Log platform) for the BM@N experiment at JINR to replace inefficient paper journals and an earlier file-based system that lacked search capabilities and integration with other software. The platform automatically transfers key log data to the central experiment database for offline analysis and includes additional services like email notifications and FreeIPA authentication. Successfully tested and deployed, the e-Log platform has streamlined data recording and retrieval, ensuring logbook information is readily available for processing and physics analysis in the NICA study.

Based on the comprehensive literature review and identified gaps, the proposed Electronic Laboratory Logbook Management System would prioritize a user-centered design that provides role-specific interfaces tailored to students, lecturers, and administrators, alongside multi-modal feedback mechanisms incorporating text and attachment to enhance communication and learning outcomes. Supervision can be significantly enhanced through real-time monitoring dashboards and predictive analytics, allowing lecturers to identify at-risk students, track

progress, and intervene proactively. Data integrity would be strengthened through automated verification processes.

The reviewed literature shows that electronic laboratory logbooks and digital logbook systems have significant advantages over traditional paper-based systems. Previous studies have demonstrated improvements in *data organization, accessibility, supervision, feedback, security, report management, and monitoring of student activities*.

However, several gaps remain in the existing literature. First, some existing systems focus on specific areas such as medical training, industrial training, postgraduate research, or laboratory resource management rather than providing a *comprehensive electronic laboratory logbook specifically designed for students in higher educational institutions*. The literature also identifies usability and implementation problems, including inconvenient interfaces, limited feedback, unreliable internet connectivity, inflexible software, difficulty entering mathematical information, and the need for suitable devices.

Therefore, the major research gap identified from the reviewed literature is the *absence of a fully integrated, user-centered Electronic Laboratory Logbook Management System that combines student registration, course management, electronic practical report submission, lecturer supervision, report approval, assessment and grading, HOD monitoring, administrative management, centralized database storage, and automated reporting in one platform*.

The proposed system addresses this gap by providing *role-based interfaces for students, lecturers, administrators, and HODs*, together with centralized data management and monitoring functions. It was also emphasize improved feedback, report verification, accessibility, and efficient supervision. These features are intended to overcome the limitations identified in previous studies and provide a more suitable solution for managing laboratory and practical activities in an academic institution. The proposed direction is consistent with the literature's call for user-centered design, role-specific interfaces, improved feedback, real-time monitoring, automated verification, and integration with institutional systems.

Finally, the system would enable seamless integration with existing institutional systems such as learning management platforms, student databases, and IoT infrastructure for real-time equipment tracking, creating a comprehensive, scalable, and sustainable digital ecosystem that addresses the limitations of both traditional paper-based and current electronic logbook systems.

3. System Design

The system design phase involves outlining the overall architecture and specifications of the Electronic Laboratory Logbook Management System for the Computer Science Department at Niger State Polytechnic Zungeru. It encompasses various aspects such as architectural design, abstract specifications, interface design, data structure design, and algorithm design. The

System Design describes how the *Electronic Laboratory/Student Logbook Management System* was structured and how its different components worked together. Based on the architectural design and flow chart provided, the system is designed as a *centralized web-based application* in which students, lecturers, administrators, and Heads of Department (HODs) access different functions according to their responsibilities. All major activities are connected to a central database for storing, retrieving, updating, and managing information.

3.1. Design Methodology

This study adopted a *mixed-methods research design* com-

binning both qualitative and quantitative approaches to comprehensively evaluate the Electronic Laboratory Logbook Management System (ELLMS). The research was conducted in three distinct phases: (i) requirements gathering and analysis, (ii) system design and development, and (iii) system evaluation and validation.

The choice of a mixed-methods approach was informed by the need to capture both the technical performance metrics of the system (quantitative) and the user experiences, perceptions, and contextual challenges (qualitative) associated with its implementation. This triangulation of methods enhanced the validity and reliability of the research findings [16].

Table 1. Research Design Framework.

Phase	Objective	Methods	Duration
Phase 1	Requirements Elicitation	Interviews, Questionnaires, Document Analysis	4 weeks
Phase 2	System Development	Agile Development, Iterative Prototyping	12 weeks
Phase 3	System Evaluation	UAT, Performance Testing, Surveys	4 weeks

3.2. Study Population and Sampling

3.2.1. Target Population

The study population comprised all stakeholders within the Computer Science Department of Niger State Polytechnic, Zungeru, who interact with laboratory logbook systems. This included:

- 1) *Students*: ND I, ND II, HND I, and HND II students enrolled in laboratory-based courses.
- 2) *Lecturers/Instructors*: Academic staff responsible for supervising laboratory sessions.
- 3) *Technologists*: Laboratory technologists managing equipment and practical sessions.
- 4) *Administrators*: Departmental administrative staff.
- 5) *HOD*: Head of Department overseeing academic activities.

3.2.2. Sample Size Determination

The sample size was determined using *Taro Yamane's formula* [17]:

$$n = \frac{N}{1+N(e)^2}$$

where:

n = required sample size

N = total population

e = margin of error (0.05)

Given a total population of 450 students and 25 academic/administrative staff:

$$n = \frac{450}{1+450(0.05)^2} = \frac{450}{2.125} = 212 \text{ students}$$

For staff, given the smaller population, a *census sampling* approach was adopted, including all 25 staff members.

3.2.3. Sampling Technique

Stratified random sampling was employed to ensure proportional representation across academic levels (ND I, ND II, HND I, HND II) and gender. The strata were defined based on:

- 1) Academic level (4 strata).
- 2) Gender (2 strata).

Table 2. Sample Distribution by Stratum.

Stratum	Population	Sample Size	Percentage
ND I Students	120	57	26.9%
ND II Students	110	52	24.5%
HND I Students	115	54	25.5%
HND II Students	105	49	23.1%
Total Students	450	212	100%
Lecturers	12	12	100%

Stratum	Population	Sample Size	Percentage
Technologists	6	6	100%
Administrators	4	4	100%
HOD	1	1	100%
Total Staff	23	23	100%

3.3. Data Collection Methods and Instruments

3.3.1. Requirements Elicitation Phase

1) Semi-Structured Interviews

Semi-structured interviews were conducted with key stakeholders to understand the existing manual logbook system, identify pain points, and gather requirements for the proposed system.

- Participants*: 5 lecturers, 2 technologists, 1 administrator, and the HOD (n=9).
- Duration*: 30-45 minutes per interview.
- Recording*: Audio-recorded with consent; transcribed verbatim.
- Interview Guide*: Covered topics including current challenges, desired features, security concerns, and integration requirements.

2) Structured Questionnaires

A structured questionnaire was administered to students to quantify the challenges experienced with the manual system and elicit expectations for the digital system.

Questionnaire Design:

- Section A*: Demographic Information (5 items).
- Section B*: Current Logbook System Challenges (12 items, 5-point Likert scale).
- Section C*: Desired System Features (15 items, 5-point Likert scale).
- Section D*: Open-ended feedback (3 items).

Validity and Reliability:

- Content Validity*: Validated by three experts in educational technology and software engineering.

- Reliability*: Pilot-tested with 30 students; Cronbach's Alpha = 0.87 (acceptable threshold: ≥ 0.70).

3) Document Analysis

Existing paper-based logbook records, laboratory manuals, course outlines, and departmental policies were reviewed to understand documentation standards, record-keeping requirements, and assessment criteria.

3.3.2. System Evaluation Phase

1) User Acceptance Testing (UAT)

UAT was conducted with a representative sample of end-users to evaluate the system's functionality, usability, and performance against predefined criteria.

UAT Procedure:

- Orientation Session* (30 minutes): Participants were briefed on system features and functionalities.
- Guided Task Execution* (60 minutes): Participants performed specific tasks (login, course registration, report submission, report viewing).
- Independent Exploration* (30 minutes): Participants explored the system freely.
- Feedback Collection* (30 minutes): Completion of evaluation instruments.

UAT Participants: 50 students and 10 staff members (randomly selected from the larger sample).

2) System Usability Scale (SUS)

The SUS [16] was administered to measure perceived usability. The SUS consists of 10 items rated on a 5-point Likert scale, yielding a score from 0 to 100.

SUS Score Interpretation:

- 80: Excellent.
- 68-80: Good.
- 50-67: OK.
- <50: Poor.

3) Performance Testing

Automated and manual performance tests were conducted to evaluate system responsiveness, scalability, and reliability.

Performance Metrics:

Table 3. Performance Metrics.

Metric	Target	Measurement Tool
Page Load Time	<3 seconds	Google PageSpeed Insights
Concurrent Users	≥ 100	Apache JMeter
Database Query Response	<500ms	MySQL Query Profiler
System Uptime	$\geq 99\%$	Server Monitoring Logs
Error Rate	<1%	Error Logs Analysis

4) Pre- and Post-Implementation Surveys

A quasi-experimental design was employed to compare user satisfaction and efficiency before and after system implementation.

a) *Pre-Implementation Survey*: Assessed satisfaction with the manual system.

b) *Post-Implementation Survey*: Assessed satisfaction with the digital system (administered 4 weeks after deployment).

5) Focus Group Discussions

Two focus group discussions were conducted (one with students, one with staff) to gather in-depth qualitative feedback on system usability, challenges encountered, and suggestions

for improvement.

1) *Student Focus Group*: 10 participants, 60 minutes.

2) *Staff Focus Group*: 6 participants, 60 minutes.

3.4. System Development Methodology

3.4.1. Development Approach

The system was developed using the *Agile Software Development Methodology* with Scrum framework, chosen for its iterative nature, flexibility, and emphasis on continuous stakeholder feedback [18].

Development Sprints:

Table 4. *Development Sprints.*

Sprint	Duration	Deliverables
Sprint 1	2 weeks	User Authentication Module
Sprint 2	2 weeks	Student Registration & Course Module
Sprint 3	2 weeks	Report Submission Module
Sprint 4	2 weeks	Lecturer Supervision Module
Sprint 5	2 weeks	Admin Management Module
Sprint 6	2 weeks	Reporting & Analytics Module

3.4.2. Development Tools and Technologies

Table 5. *Development Tools and Technologies.*

Category	Technology	Purpose
Frontend	HTML5, CSS3, JavaScript	User Interface
Backend	PHP 7.4	Server-side Logic
Database	MySQL 8.0	Data Storage
Web Server	Apache (XAMPP)	Application Hosting
Version Control	Git/GitHub	Code Management
IDE	Visual Studio Code	Development Environment
Testing	PHP Unit, Selenium	Automated Testing

3.4.3. System Architecture

The system follows a *three-tier client-server architecture*:

- 1) *Presentation Layer*: Web browser interface for users.
- 2) *Application Layer*: PHP-based business logic.
- 3) *Data Layer*: MySQL relational database.

3.5. Testing Procedure

3.5.1. Testing Levels

- 1) Unit Testing

Individual components (functions, classes, modules) were

tested in isolation using PHP Unit.

- a) *Scope*: 45 unit tests covering all critical functions.
- b) *Pass Rate Required*: 100%.
- c) *Tools*: PHP Unit 9.0.

2) Integration Testing

Testing of interactions between integrated modules to identify interface defects.

- a) *Approach*: Bottom-up integration.
- b) *Test Cases*: 28 integration test scenarios.
- c) *Tools*: Selenium WebDriver.

3) System Testing

End-to-end testing of the complete system against requirements.

- a) *Test Cases*: 52 system test cases.
- b) *Coverage*: All functional requirements.
- c) *Environment*: Staging server mirroring production.

4) User Acceptance Testing (UAT)

Real users tested the system in a controlled environment.

- a) *Participants*: 50 students, 10 staff.
- b) *Duration*: 2 weeks.
- c) *Criteria*: 90% task completion rate, ≥ 70 SUS score.

3.5.2. Testing Matrix

Table 6. Testing Matrix.

Test Type	Objective	Method	Success Criteria
Unit	Verify individual components	Automated	100% pass
Integration	Verify module interactions	Automated/Manual	95% pass
System	Verify end-to-end functionality	Manual	90% pass
UAT	Verify user acceptance	Manual	≥ 70 SUS
Performance	Verify system responsiveness	Automated	<3s load time
Security	Verify access controls	Manual/Automated	No vulnerabilities

3.5.3. Black Box Testing

Black box testing was conducted to evaluate system functionality without examining internal code structure. Test cases were designed based on functional requirements.

Sample Black Box Test Cases:

Table 7. Sample Black Box Test Cases.

Test ID	Input	Expected Output	Actual Output	Status
TC-001	Valid login credentials	Redirect to dashboard	Redirect to dashboard	Pass
TC-002	Invalid password	Error message displayed	Error message displayed	Pass
TC-003	Submit empty report	Validation error	Validation error	Pass
TC-004	View submitted report	Report displayed	Report displayed	Pass

3.5.4. White Box Testing

White box testing examined internal code logic, paths, and branches.

- 1) *Code Coverage Target*: $\geq 80\%$.
- 2) *Tools*: X debug, PHP Unit Coverage.
- 3) *Focus Areas*: Authentication logic, data validation, database queries.

3.6. Evaluation Criteria

3.6.1. Quantitative Evaluation Metrics

Table 8. Quantitative Evaluation Metrics.

Metric	Description	Target	Measurement
Functionality	Feature completeness	100%	Requirements traceability matrix
Usability	Ease of use	SUS ≥ 70	SUS questionnaire
Performance	Response time	<3 seconds	Load testing
Reliability	System uptime	$\geq 99\%$	Monitoring logs
Security	Access control effectiveness	100%	Penetration testing
Efficiency	Time savings	$\geq 50\%$ reduction	Pre/post comparison

3.6.2. Qualitative Evaluation Criteria

- 1) User Satisfaction: Overall satisfaction with system features and experience.
- 2) Perceived Usefulness: Extent to which users believe the system enhances their work.
- 3) Perceived Ease of Use: Degree to which users find the system easy to use.
- 4) Feedback Quality: Quality and timeliness of feedback provided through the system.
- 5) Adoption Barriers: Challenges encountered during system use.

3.6.3. Technology Acceptance Model (TAM) Framework

The evaluation was guided by the Technology Acceptance Model [19], which posits that:

- 1) Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) influence Attitude Toward Use.
 - 2) Attitude and PU influence Behavioral Intention.
 - 3) Behavioral Intention influences Actual System Use.
- TAM Questionnaire Constructs:*

Table 9. TAM Questionnaire Constructs.

Construct	Items	Source
Perceived Usefulness	6	[19]
Perceived Ease of Use	6	[19]
Attitude Toward Use	4	[19]
Behavioral Intention	3	[19]

3.7. Data Analysis Methods

3.7.1. Quantitative Data Analysis

- 1) Descriptive Statistics
 - a) Frequencies, percentages, means, and standard deviations were computed for demographic data and questionnaire responses.
 - b) *Tools*: SPSS 26.0, Microsoft Excel.
- 2) Inferential Statistics
 - a) *Paired Sample T-Test*: To compare pre- and post-implementation satisfaction scores.
 - b) *Independent Sample T-Test*: To compare responses between different user groups.
 - c) *ANOVA*: To compare responses across academic levels.
 - d) *Significance Level*: $p < 0.05$.
- 3) Correlation Analysis
 - a) *Pearson Correlation*: To examine relationships between TAM constructs.
 - b) *Regression Analysis*: To identify predictors of system adoption.

3.7.2. Qualitative Data Analysis

- 1) Thematic Analysis

Interview and focus group transcripts were analyzed using Braun and [4] six-phase thematic analysis approach:

- a) Familiarization with data.
- b) Generating initial codes.
- c) Searching for themes.
- d) Reviewing themes.
- e) Defining and naming themes.
- f) Producing the report.

- 2) Content Analysis

Open-ended questionnaire responses were analyzed using content analysis to identify recurring patterns and categories.

3) Triangulation

Findings from quantitative and qualitative data sources were triangulated to enhance validity and provide comprehensive insights.

3.7.3. Data Quality Assurance

Table 10. Strategies for Ensuring Data Quality.

Aspect	Strategy
Credibility	Member checking, triangulation
Transferability	Thick description of context
Dependability	Audit trail, peer review
Confirmability	Reflexivity, negative case analysis

3.8. Ethical Considerations

3.8.1. Ethical Approval

Ethical approval was obtained from the Research Ethics Committee of Niger State Polytechnic, Zungeru, prior to data collection.

3.8.2. Informed Consent

All participants were provided with an information sheet explaining:

- 1) Purpose of the study.
- 2) Voluntary nature of participation.
- 3) Right to withdraw at any time.
- 4) Data confidentiality measures.
- 5) Contact information for queries.

Written informed consent was obtained from all participants.

3.8.3. Confidentiality and Anonymity

- 1) Personal identifiers were removed from all data.
- 2) Data was stored on password-protected servers.
- 3) Access limited to research team members.
- 4) Data will be retained for 5 years post-publication.

3.8.4. Data Security

- 1) All data collected through the system is encrypted using AES-256.
- 2) User passwords are hashed using bcrypt.
- 3) Regular backups are performed to prevent data loss.

3.9. Limitations of the Methodology

- 1) *Single Institution Focus:* The study was conducted at one institution, limiting generalizability.
- 2) *Self-Reported Data:* Questionnaire responses may be subject to social desirability bias.
- 3) *Short Evaluation Period:* Long-term adoption patterns were not assessed.
- 4) *Sample Size:* Despite adequate power, larger samples could enhance statistical validity.

Technological Infrastructure: Results may vary in contexts with different IT infrastructure

3.10. Architectural Design

The architectural design of this system includes defining the structure and components of the software application. The system consists of modules for user authentication, logbook entry, search functionality, and administrative controls. The architecture was designed to ensure scalability, security, and ease of use for both students and departmental members.

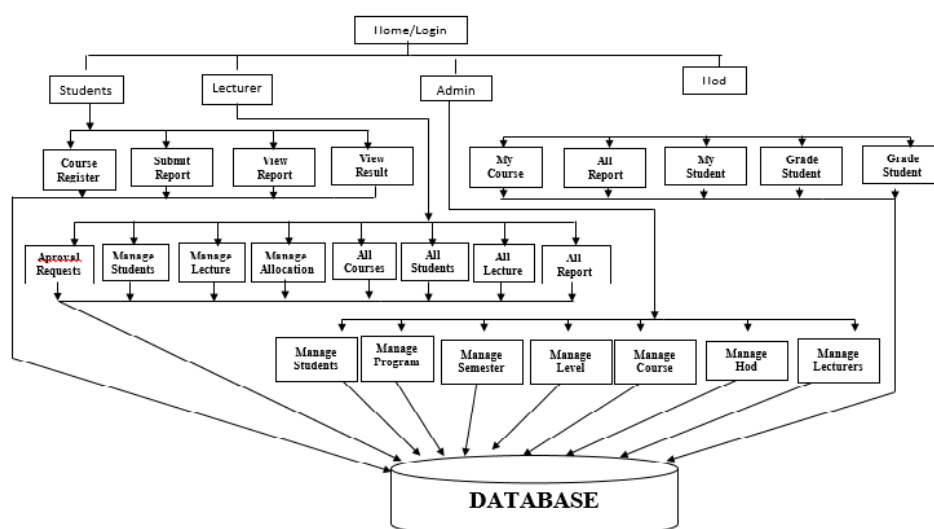


Figure 1. Architectural Design.

Figure 1 demonstrate a *client-server architecture*. Users interact with the system through a web interface, while the application server processes requests and communicates with the database.

The major users are:

- 1) Students.
- 2) Lecturers.
- 3) Administrators.
- 4) HODs.

Each user is provided with appropriate privileges after successful authentication.

3.10.1. Abstract Specification

The abstract specification of the Electronic Laboratory Logbook Management System defines the system's input and output requirements, ensuring that all functionalities are clearly outlined and understood.

3.10.2. Input Specification

The system accepts inputs such as student ID, date of experiment, experiment title, apparatus used, and observations recorded during the experiment. Additionally, departmental members input assessment grades for student logbook entries.

The major inputs required by the system are *student information, lecturer information, course information, programme information, report information, assessment information, result information, and user login information*.

The system may require the following fields:

Table 11. Input Specification.

Input Field	Description
Student ID	Unique identification number of the student
Matriculation Number	Official student registration number
Full Name	Student's complete name
Gender	Gender of the student
Date of Birth	Student's date of birth
Department	Department where the student is registered
Programme	Student's academic programme
Academic Level	Current level of study
Phone Number	Student's contact number
Email Address	Student's email address
Username	Login identification
Password	Student's authentication password

The system validates the information before storing it in the database.

3.10.3. Output Specification

The system generates outputs including a digital logbook for each student, summarizing their completed experiments and corresponding grades. Notifications were sent to students for pending approvals or feedback on their logbook entries.

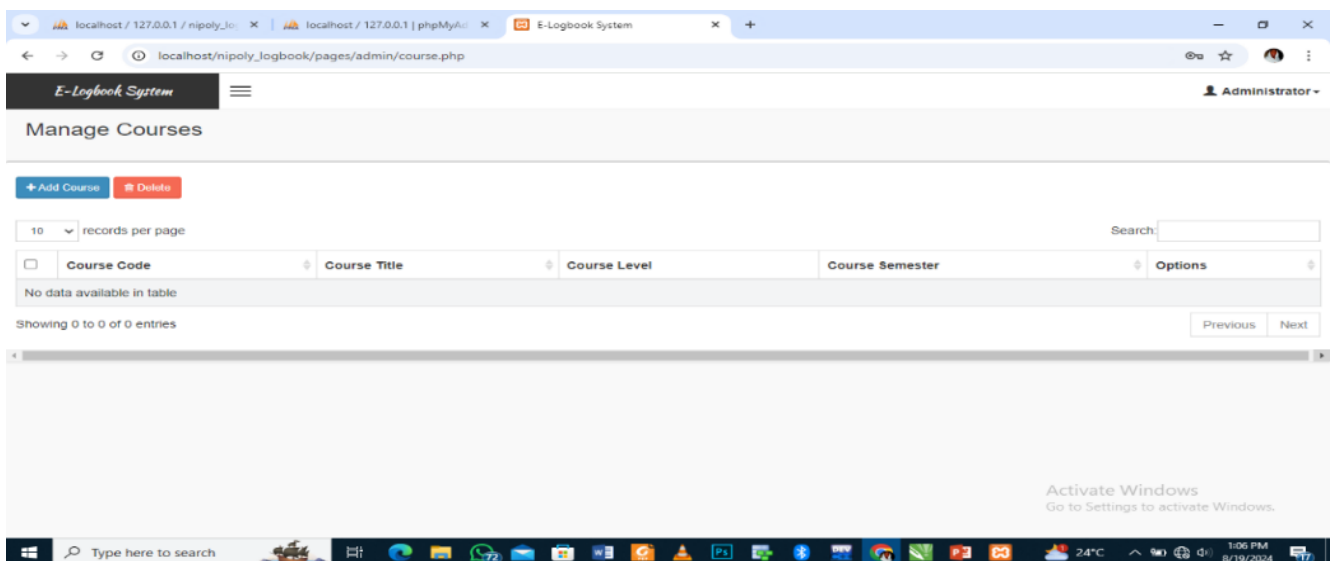


Figure 2. Student Module entries output.

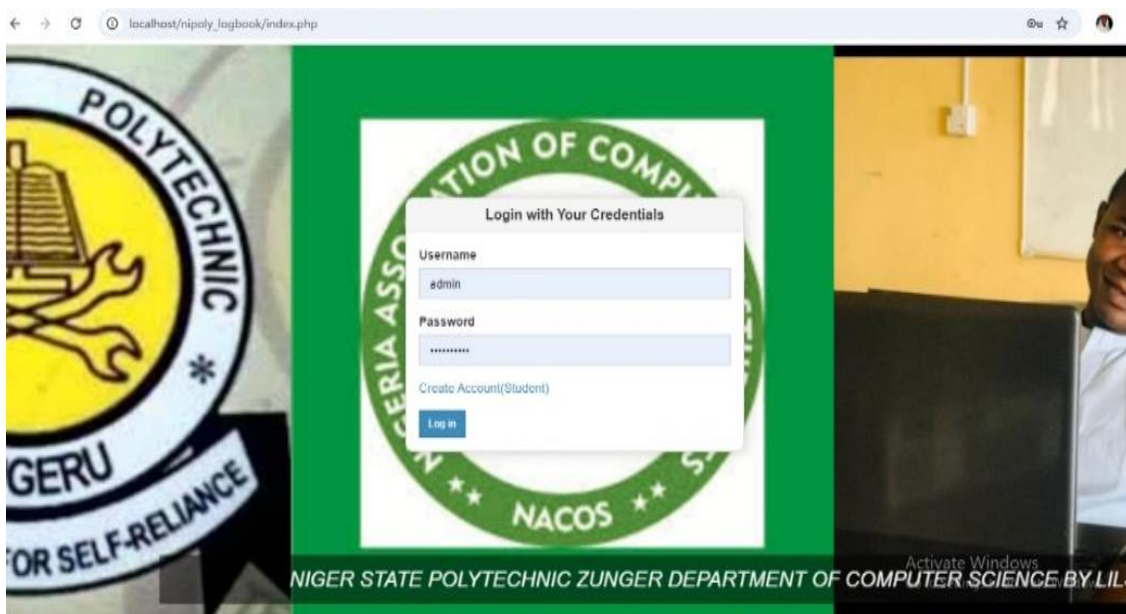


Figure 3. Login page.

3.10.4. Interface Design

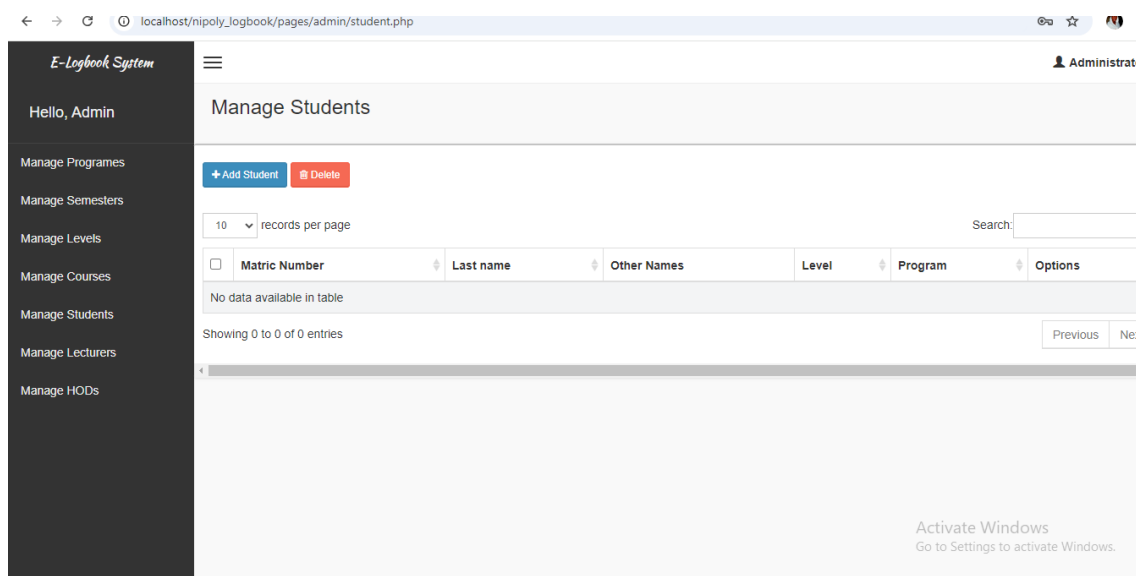


Figure 4. Interface design.

The user interface design focuses on creating a user-friendly experience for both students and departmental members. The interface were to be intuitive, featuring easy navigation, clear data entry forms, and interactive elements to enhance usability.

3.10.5. Data Structure Design

The data structure design was defined how information is stored and organized within the system. Student details, experiment logs, assessment grades, and administrative data was

be stored in a relational database, ensuring data consistency and integrity.

3.10.6. Algorithm Designs

Algorithm design involves outlining the logic and processes that drive the system's functionalities. This includes algorithms for searching, sorting, and filtering logbook entries, as well as authentication algorithms to verify user access permissions.

The *Architectural Design* represents the workflow of an *Academic/School Management System* in which students, lecturers, Instructors, Technologist administrators, and Heads of Department (HODs) interact with different system functions, while all information is ultimately stored in and retrieved from a central database.

- 1) *Home/Login*: The workflow begins at *Home/Login*. Every user must access the system through the login interface. After authentication, the system determines the user's role and directs the user to the appropriate functions.

There are four major categories of users:

- a) *Students*.
- b) *Lecturers/Instructors/Technologist*.
- c) *Admin*.
- d) *HOD (Head of Department)*.

This role-based structure ensures that users can only access functions relevant to their responsibilities.

- 2) *Student Workflow*: When a *Student* logs into the system, the student is provided with functions such as:
 - a) *Course Register*- The student can register for courses offered during a particular semester. The selected courses are processed and stored in the database.
 - b) *Student* → *Course Register* → *Database*
 - c) *Submit Report*- Students can submit Practical reports, attachment or other required documents electronically through the system.
 - d) *Student* → *Submit Report* → *Database*
 - e) *View Report*- The student can retrieve previously submitted reports or reports made available by lecturers/Instructor/Technologist/administrators.
 - f) *Database* → *View Report* → *Student*
 - g) *View Result*- Students can view their practical scores after lecturers/Instructor/Technologist and relevant authorities have entered and approved the scores.

Database → *View Result* → *Student*

Therefore, the student workflow is mainly concerned with *course registration, report submission, report viewing, and result viewing*.

- 3) *Lecturer Workflow*: The *Lecturer* section provides academic staff with functions related to teaching, assessment, and student records.

The lecturer can interact with functions such as:

- a) *Submit/View Reports*.
- b) *View Results*.
- c) *Manage or provide academic information*.
- d) *Access information concerning assigned courses and students*.

The lecturer's activities generate or retrieve information from the central database.

For example:

Lecturer → *Academic Report/Result* → *Database*

and

Database → *Student/Course Information* → *Lecturer*

The lecturer therefore acts as one of the major sources of

academic information in the system.

- 4) *Admin Workflow*: The *Admin* has broader access because the administrator is responsible for managing the overall academic system. The design shows several administrative functions:

- a) *Approval Requests*: The administrator handles requests submitted through the system, such as course-related or student-related approval requests.

- b) *Manage Students*: The administrator can:

- 1) Add students.
- 2) Edit student information.
- 3) Update student records.
- 4) Delete or deactivate records where necessary.
- 5) View student information.

- c) *Manage Lecture*: This function allows the administrator to manage lecture/course-related information.

- d) *Manage Allocation*- The administrator can allocate:

Lecturers to courses.

Courses to programmes/classes.

Other academic responsibilities.

- e) *All Courses*- The administrator can view and manage the complete list of courses in the institution.

- f) *All Students*- This provides access to the complete student database.

- g) *All Lectures*- The administrator can view information relating to lectures/courses.

- h) *All Reports*- The administrator can access reports generated or submitted within the system. Thus, the Admin functions provide *centralized management and control of academic information*.

- 5) *HOD Workflow*: The *HOD* has functions specifically related to departmental academic administration. The architectural diagram identifies functions such as:

- a) *My Course*- The HOD can view courses belonging to or handled by the department.

- b) *All Report*- The HOD can access reports associated with the department.

- c) *My Student*- The HOD can view students within the department.

- d) *Grade Student*- The HOD can participate in or manage student grading/assessment activities.

The HOD therefore serves as a *departmental supervisory level* between lecturers/students and the wider administrative system.

- 6) *System Management Layer*: Below the user functions, the diagram contains another important layer consisting of:

- a) *Manage Students*.

- b) *Manage Program*.

- c) *Manage Semester*.

- d) *Manage Level*.

- e) *Manage Course*.

- f) *Manage HOD*.

- g) *Manage Lecturers*.

This represents the *core administrative management layer*

of the application.

Manage Students: Maintains student records and links students to their programmes and levels.

Manage Program: Maintains programmes offered by the institution, such as Computer Science, Computer Engineering, etc.

Manage Semester: Controls academic sessions/semesters such as:

- a) First Semester.
- b) Second Semester.

Manage Level- Maintains academic levels such as:

- a) ND I.
- b) ND II.
- c) HND I.
- d) HND II.

Manage Course: Maintains course codes, course titles, credit units, programmes, and other course information.

Manage HOD: Maintains information about Heads of Departments and their departmental assignments.

Manage Lecturers: Maintains lecturer information and their relationships with courses, departments, and programmes.

7) **Central Database:** At the bottom of the architecture is the **DATABASE**, which is the central storage component of the system. Almost every major operation connects to this database. The database stores information such as:

- a) Student records.
- b) Lecturer records.
- c) HOD records.
- d) Programme information.
- e) Course information.
- f) Semester information.
- g) Level information.
- h) Course registration.
- i) Student reports.
- j) Grades/results.
- k) Allocation information.
- l) Approval requests.

The database therefore serves as the *central repository from which information is stored, updated, and retrieved*.

8) **Flow Chart:** The complete workflow can be summarized as demonstrated in the [Figure 4](#) below:

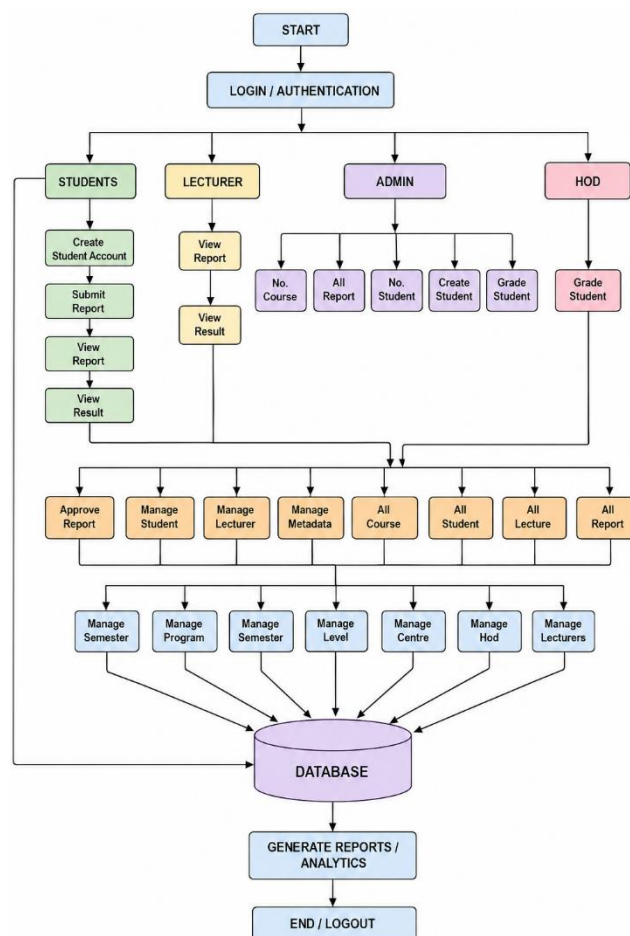


Figure 5. Flow Chart.

9) **Relationship Between the Different Users:** The architecture can also be understood as a role-based academic information flow:

Table 12. Relationship Between the Different Users.

User	Major Responsibilities
Student	Register courses, submit reports, view reports and results
Lecturer	Handle academic/lecture activities, reports and results
HOD	Supervise departmental courses, students, reports and grading
Admin	Manage students, lecturers, courses, programmes, allocation and reports
Database	Store and retrieve all system information

The architectural design follows a *centralized, role-based academic management workflow*. Users first authenticate

through the *Home/Login* interface. The system then directs each user to functions based on their role. Students mainly interact with registration, reports, and results; lecturers handle academic activities; HODs supervise departmental academic activities; and administrators manage the broader institutional records. All these activities communicate with the *central database*, making it possible to maintain consistent student, course, lecturer, programme, result, and administrative information throughout the system.

4. System Implementation and Documentation

4.1. System Implementation

The system implementation phase involves the actual coding and development of the electronic laboratory logbook management system. This phase is critical to the success of the study, as it translates the design specifications into a working system.

The system was implemented using a combination of programming languages, including PHP, SQL, JavaScript, HTML, and CSS.

4.2. Choice of Programming Language

The choice of programming language was based on the following factors:

- 1) *PHP*: PHP (Hypertext Preprocessor) is a server-side scripting language that is widely used for web development. It was chosen for its ease of use, flexibility, and ability to interact with databases.
- 2) *SQL*: SQL (Structured Query Language) is a standard language for managing relational databases. It was chosen for its ability to store, manipulate, and retrieve data efficiently.
- 3) *JavaScript*: JavaScript is a client-side scripting language that is used to add interactivity to web pages. It was chosen for its ability to create dynamic web pages and respond to user interactions.
- 4) *HTML*: HTML (Hypertext Markup Language) is a standard markup language used to create web pages. It was chosen for its ability to structure and format content on the web.
- 5) *CSS*: CSS (Cascading Style Sheets) is a styling language used to control the layout and appearance of web pages. It was chosen for its ability to separate presentation from content and improve the user experience.

4.3. System Requirement

The system requires the following hardware and software components:

4.3.1. Installation Requirement

The system requires a web server, such as Apache or IIS, to host the application. Additionally, a database management system, such as MySQL, is required to store and manage data.

4.3.2. Hardware Requirement

The system requires a minimum of:

- 1) 2 GB RAM.
- 2) 1 GHz processor.
- 3) 500 MB hard disk space.

4.3.3. Software Requirement

The system requires:

- 1) PHP 7.4 or higher.
- 2) MySQL 8.0 or higher.
- 3) JavaScript enabled web browser (e.g. Google Chrome, Mozilla Firefox).
- 4) HTML5 and CSS3 compatible web browser.

4.4. Process of Installation

The system was installed on a local machine using the following steps:

- 1) Install XAMPP (a web server package that includes Apache, MySQL, PHP, and Perl) on the local machine.
- 2) Create a new database in MySQL and import the database schema.
- 3) Upload the system files to the web server.
- 4) Configure the system settings, such as database connection and user authentication.

4.5. System Testing

The system was tested using black box testing, white box testing, and user acceptance testing. The testing process involved:

- 1) Unit testing: testing individual components of the system.
- 2) Integration testing: testing the interaction between components.
- 3) System testing: testing the entire system.
- 4) User acceptance testing: testing the system with real users.

4.6. System Change Over

The system changes over process involved:

Training users on the new system.

Migrating data from the old system to the new system.

Testing the system with real data.

Deploying the system to production.

4.7. System Documentation

The system documentation includes:

- 1) User manual: a guide for users on how to use the system.
- 2) Technical manual: a guide for developers on how to

maintain and update the system.

- 3) **System design document:** a document that outlines the system architecture and design.

5. Summary, Conclusion, and Recommendation

5.1. Summary

The implementation of the Electronic Laboratory Logbook Management System at the Computer Science Department of Niger State Polytechnic, Zungeru, aimed to enhance the efficiency and effectiveness of managing laboratory activities. The study involved the development of a web-based application that streamlined the process of recording, monitoring, and evaluating laboratory tasks.

The system provides features such as user authentication, task assignment, progress tracking, and report generation. Throughout the development process, various technologies including HTML, CSS, JavaScript, PHP, and MySQL were utilized to ensure the system's functionality and reliability.

User acceptance testing was conducted to gather feedback from students and staff members, which helped in identifying areas for improvement and refining the user interface. The feedback received was mostly positive, with users appreciating the system's user-friendly interface and the time-saving benefits it offered.

The successful implementation of the Electronic Laboratory Logbook Management System marks a significant milestone in enhancing the educational experience within the Computer Science Department. Moving forward, continuous support, training, and updates will be crucial to ensure the system's ongoing success and relevance.

5.2. Conclusion

In conclusion, the Electronic Laboratory Logbook Management System developed for the Computer Science Department of Niger State Polytechnic, Zungeru, has demonstrated significant potential in improving the efficiency and effectiveness of laboratory management processes. The system's functionality, user-friendly interface, and ability to streamline tasks underscore its value in facilitating a more organized and structured approach to recording and monitoring laboratory activities.

The positive feedback received during user acceptance testing reaffirms the system's utility and user-centric design. Despite the successful implementation, there is always room for improvement and optimization based on user feedback and evolving technological trends.

5.3. Recommendation

- 1) *Continuous Monitoring and Evaluation:* Regular monitoring and evaluation of the system's performance and

user feedback were to be essential to identify areas for enhancement and ensure its continued relevance.

- 2) *User Training and Support:* Providing comprehensive training to students and staff on how to effectively utilize the system to maximize its benefits and promote widespread adoption.
- 3) *Security Measures:* Implementing robust security measures to safeguard the integrity of data stored within the system is paramount to protect sensitive information and maintain user trust.
- 4) *Integration with Academic Curriculum:* Integrating the Laboratory Logbook Management System into the academic curriculum was further emphasize its importance and encourage its consistent use among students and departmental.

Abbreviations

AES-256	Advanced Encryption Standard with 256-bit Key
ANOVA	Analysis of Variance
BM@N	Baryonic Matter at Nuclotron
CSS	Cascading Style Sheets
CSS3	Cascading Style Sheets Version 3
DLIS	Digital Laboratory Information System
DOI	Digital Object Identifier
e-Log	Electronic Logbook
e-logbook	Electronic Logbook
ELLMS	Electronic Laboratory Logbook Management System
ESPRES	Electronic Logbook System for Postgraduate Research (Expansion Not Stated in the Source)
FreeIPA	Free Identity, Policy, and Audit
HND	Higher National Diploma
HND I	Higher National Diploma Level I
HND II	Higher National Diploma Level II
HOD	Head of Department
HTML	Hypertext Markup Language
HTML5	Hypertext Markup Language Version 5
IDE	Integrated Development Environment
IIS	Internet Information Services
IoT	Internet of Things
IT	Information Technology
JINR	Joint Institute for Nuclear Research
Moodle	Modular Object-Oriented Dynamic Learning Environment
MySQL	My Structured Query Language (Relational Database Management System)
ND	National Diploma
ND I	National Diploma Level I
ND II	National Diploma Level II
NICA	Nuclotron-Based Ion Collider Facility
ORCID	Open Researcher and Contributor ID
PEOU	Perceived Ease of Use

PHP	Hypertext Preprocessor
PU	Perceived Usefulness
SQL	Structured Query Language
SPSS	Statistical Package for the Social Sciences
STEM	Science, Technology, Engineering, and Mathematics
SUS	System Usability Scale
TAM	Technology Acceptance Model
UAT	User Acceptance Testing
UTAUT	Unified Theory of Acceptance and Use of Technology
XAMPP	Cross-Platform Apache, MySQL/MariaDB, PHP, and Perl

Author Contributions

Shehu Hamidu: Conceptualization, Data curation, Formal Analysis, Project administration, Software, Validation, Writing – original draft

Ibrahim Umar Kontagora: Conceptualization, Methodology, Supervision, Validation, Writing – review & editing

Adamu Isah Dagah: Data curation, Investigation, Resources, Writing – review & editing

Usman Ubandawaki: Formal Analysis, Investigation, Validation, Writing – review & editing

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Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] A. Abdulazeem and A. Omer, "Using Logbooks to Enhance Students' Learning: Lessons From a Mixed-methods Study in an Undergraduate Surgical Rotation," vol. 16, no. 3, pp. 409-429, 2021, <https://doi.org/10.18502/sjms.v16i3.9701>
- [2] S. Barteit *et al.*, "Electronic logbooks (e-logbooks) for the continuous assessment of medical licentiates and their medical skill development in the low-resource context of Zambia: A mixed-methods study," no. November, pp. 1-13, 2022, <https://doi.org/10.3389/fmed.2022.943971>
- [3] M. N. Mokhtar, S. A. Suhaini, F. H. Abdullah, R. Teo, and A. Izaham, "A survey of anaesthetic training logbook management among postgraduate students," 2024. <https://doi.org/10.1186/s12909-024-05859-4>
- [4] U. Ramnarain, A Systematic Review of Research on the Integration of Real and Virtual Laboratories for Inquiry-Based Learning. Springer Nature Switzerland, 2026. <https://doi.org/10.1007/978-3-032-13788-3>
- [5] P. Id *et al.*, "A Review of Electronic Engineering Logbooks Throughout the Electrical Engineering Curriculum A Review of Electronic Engineering Logbooks Throughout the Electrical Engineering Curriculum," 2016.
- [6] S. G. Higgins and M. M. Stevens, "laboratory notebooks in an academic," vol. 17, no. February, pp. 179-189, 2022, <https://doi.org/10.1038/s41596-021-00645-8>
- [7] W. Hussain, W. Ishak, F. M. Yamin, S. Nur, and A. Abdullah, "A Digital Logbook Model for Student Activities Management During Industrial Training," pp. 9-12, 2025.
- [8] W. Setyonugroho, N. Risdiana, A. A. Ch, M. Dian, S. Taher, and A. Khanif, "Exploring the usage of conventional logbooks during the clinical learning practice: A phenomenological study," vol. 11, no. 2, pp. 124-132, 2023.
- [9] A. A. Adekunle, B. L. Abolore, G. Mutiu, and A. M. Olalekan, "Design and Implementation of a Web-Based Laboratory Management System for Efficient Resource Tracking," vol. 13, no. 2, pp. 19-24, 2024.
- [10] W. Wu, H. Yu, X. Chen, M. Wei, V. Papaspyros, and G. Theraulaz, "Laboratory management: digital laboratory information system (DLIS) concept Laboratory management: digital laboratory information system (DLIS) concept," 2018, <https://doi.org/10.1088/1757-899X/434/1/012286>
- [11] M. Arif, H. Samed, R. Mokhtar, N. Isa, M. A. Rahman, and A. Suhaimi, "Designing an Electronic Logbook System for Monitoring Postgraduate Research Students Progress," vol. 4, no. 3, pp. 45-53, 2022.
- [12] Rahimi, M., Rosman, M., Arshad, I. H., Abdullah, N., Idayu, A., Shukry, M., Alias, N. R., Nur, N., Nik, I., & Fadzil, F. H. (2023). *Volume 7 2023* (Vol. 7). <https://doi.org/10.55057/ijbtlm.2022.4.3.5>
- [13] S. Mirici, "Virtual Laboratories and Simulation-Based Learning: Transforming STEM Education in Secondary Schools," vol. 1, no. 2, pp. 9-19, 2025.
- [14] V. Dao, T. Nguyen, and V. Bui, "Development of a laboratory-based learning model via digital platform environment".
- [15] K. V. Gertsenberger, A. A. Moshkin, A. I. Chebotov, K. Gertsenberger, A. Moshkin, and A. Chebotov, "DEVELOPMENT OF THE ELECTRONIC LOGBOOK FOR THE BM @ N EXPERIMENT AT NICA," pp. 175-179, 2019.
- [16] L. Stroud, E. Green, and J. Cronje, "A Revision Process That Bridges Qualitative and Quantitative Assessment," pp. 436-444, 2020, <https://doi.org/10.4236/psych.2020.113029>
- [17] E. E. Ikechukwu, "Assessment of the Activities of Scavengers in Obio / Akpor Local Government, Rivers State, Nigeria," no. March, pp. 272-280, 2015.
- [18] K. Schwaber and J. Sutherland, "The Scrum Guide," no. November, 2020.
- [19] P. Dany, B. Kenfack, and C. Njei, "Reinforcing of Citizen's Trust in E-Government: The Cameroon's Case," pp. 77-109, 2024, <https://doi.org/10.4236/jcc.2024.121006>