FACULTY OF SCIENCE AND EDUCATION

DEPARTMENT OF COMPUTER STUDIES

FINAL YEAR PROJECT REPORT

A WEB-BASED CAMPUS MEDICAL UNIT INFORMATION MANAGEMENT SYSTEM

By

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(BU/UP/2023/1799)

This Final Year Project Report is submitted to the Faculty of Science and Education in Partial Fulfillment of the Requirement for the Award of the Degree of Bachelor of Science Education of Busitema University.

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ABSTRACT

The Busitema University Nagongera Campus Medical Unit relies on a manual, paper-based system to manage healthcare services, which has resulted in inefficiencies in patient registration, appointment scheduling, prescription management, referral processing, and health reporting. This study designed, developed, and implemented a web-based Campus Medical Unit Information Management System (CMUIMS) to automate and streamline these clinical workflows.

A mixed-methods research approach was adopted, combining qualitative interviews and observations with quantitative questionnaire data collection from 30 participants including students, university staff, a Lab Technician, and a Nurse. The Rapid Application Development (RAD) methodology guided the system development through iterative prototyping and continuous stakeholder engagement.

The system was developed using React and Tailwind CSS (frontend), Node.js and Express.js (backend), and SQLite (database). It supports role-based access for four user categories: System Admin, Lab Technician/Nurse (Medical Personnel), and Patients (Students and Staff). Key modules include patient self-registration, appointment booking and approval, Electronic Medical Records (EMR) management, prescription management, referral management, and automated health report generation with email notification capabilities.

Testing was conducted through unit testing, integration testing, user acceptance testing (UAT), and security testing. Results demonstrated that all core modules function correctly, with positive user feedback confirming improved efficiency, ease of use, and better record management. It is recommended that the university formally deploy the system, provide staff training, and explore integration with national digital health frameworks.

DECLARATION

I, ODERO EMMANUEL, Reg. No. BU/UP/2023/1799, do hereby declare that this Project Report is original and has not been submitted for any other degree award to any institution or university before.

Signed: .....

Date: 24TH AUGUST 2026

APPROVAL

This Project Report has been submitted with the approval of the following supervisors:

Dr. Nandutu Irene

Signed: ..... Date: 24/08/2026

Mr. Wambi Fred

Signed: ..... Date: 28/08/2026

DEDICATION

First of all, I would like to thank Almighty God for enabling me and always keeping me safe through my academics and above providing me with the ability to complete my project work with good health.

I dedicate this work is to my family; My mother; Mrs. Esther Atim and My Dad Mr. Ocen Joel their unwavering support and encouragement, Special dedication My aunt **Mrs. Rose Akullo Obong**, who works day and night in Health Centres to raise resources to see that I lack nothing during my studies and supported me with advice, finance and materials throughout my academic journey **"A Virtuous Nurse/Aunt"** to me. Not forgetting my follower **Ocoo Brian** who from my secondary has been special package to me.

I would like to extend special appreciations to my supervisors **Dr. Nandutu Irene and Mr. Wambi Fred** who guided me throughout the course of my final year project and that has turned out to be a success.

Finally, I would like to thank all who has helped me throughout my course especially The campus Nurse, my colleagues, **Angole Sharif A, Okello Emmanuel Kitara and others that I can't mention** as they have been of great help and positive influence to me reaching this milestone in my course and the entire students and staff of Busitema University Nagongera Campus who deserve a better, more efficient healthcare experience.

ACKNOWLEDGEMENT

First and foremost, I give thanks to God Almighty for the gift of life, good health, and the strength to complete this project.

I am profoundly grateful to my supervisors, Dr. Nandutu Irene and Wambi Fred, for their expert guidance, constructive criticism, and constant encouragement throughout the duration of this project.

I extend sincere thanks to the staff and students of the Busitema University – Nagongera Campus Medical Unit, particularly the Lab Technician and the Nurse, for their cooperation during data collection and requirements gathering.

I also thank the Department of Computer Studies, Faculty of Science and Education, Busitema University, for providing an enabling environment for this research. Finally, I acknowledge my colleagues and friends for their moral support and encouragement.

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ABBREVIATIONS / ACRONYMS

CMUIMS – Campus Medical Unit Information Management System

EMR – Electronic Medical Record

EHR – Electronic Health Record

HIS – Health Information System

ICT – Information and Communication Technology

RAD – Rapid Application Development

UAT – User Acceptance Testing

SQL – Structured Query Language

CSS – Cascading Style Sheets

API – Application Programming Interface

WHO – World Health Organization

DPPA – Data Protection and Privacy Act

DFD – Data Flow Diagram

UI – User Interface

STEM – Science, Technology, Engineering and Mathematics

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Healthcare delivery in higher education institutions plays a vital role in supporting the well-being of students and staff, ensuring a healthy campus environment conducive to learning and productivity. Campus Medical Units serve as primary healthcare facilities that provide medical services ranging from outpatient consultations and emergency care, pharmacy services, health education, disease prevention, and control. Effective management of health information within these units is therefore essential for maintaining quality healthcare delivery and institutional accountability.

Traditionally, the management of health information in many campus Medical Units across higher learning institutions has relied on manual and semi-manual approaches such as paper-based patient registration, handwritten medical records, physical prescription logs, and manual inventory tracking for pharmaceutical supplies. Patient records were collected, processed, and stored using paper-based filing systems a process that is time-consuming, inefficient, and error-prone. Healthcare providers often handled multiple patients daily, patient histories were retrieved manually, and communication between medical departments remained inconsistent. These practices frequently led to delayed service delivery, poor documentation, loss or misplacement of patient records, medication errors, and limited transparency in healthcare delivery. Information systems in developing countries are often data-based rather than performance-based, with incomplete and inaccurate data constraining their utility for management and decision-making (Bagherian & Sattari, 2022).

With rapid advancements in Information and Communication Technologies (ICT), healthcare institutions across Africa are increasingly expected to adopt automated information systems to enhance health administration and decision-making. The use of ICT has been identified as a crucial element in promoting the quality of health service delivery and accelerating the achievement of global development targets (Byaro et al., 2023; WHO, 2022). Health Information Systems enable healthcare facilities to efficiently collect, store, process, and disseminate patient data, thereby improving coordination, accountability, and service delivery. Within the healthcare sector, Electronic Medical Records (EMR) systems have been widely adopted to support patient care, monitoring, evaluation, and evidence-based clinical decision-making (World Health Organization, 2020). Uganda's Ministry of

Health launched the Health Information and Digital Health Strategic Plan 2020/21–2024/25, institutionalising the use of patient-level digital systems at the point of care as a national priority (Ministry of Health Uganda, 2020).

At Busitema University Nagongera Campus, the management of health information at the campus Medical Unit is still largely manual, presenting significant challenges in monitoring patient care, coordinating clinic operations, analysing health data, and maintaining accurate medical records. This research gap is the major motivation for this study.

1.2 Statement of the Problem

Currently, Busitema University Nagongera Campus Medical Unit relies on a manual, paper-based approach to manage healthcare services, including patient registration, consultation and appointment management, prescription processing, and referral management. Healthcare providers such as Lab Technicians and Nurses are required to handle all these processes manually, which is time-consuming, prone to error, and can lead to data loss or information gaps.

As a result, analysing patient data, monitoring disease trends, and generating timely health reports for decision-making and quality assurance becomes challenging. Studies across sub-Saharan Africa have consistently demonstrated that EHR implementation reduces data entry errors by 20–30% and enhances the accuracy of health records by 15–25% (Musie et al., 2025); yet the Nagongera campus clinic had not benefited from any such automated system. In the academic year 2024/2025, only 282 students registered for medical services at the unit, representing an estimate of less than 50% of the students enrolled at the Faculty of Science and Education. This gap is consistent with findings by Bagherian and Sattari (2022), who noted that manual systems in developing countries fail to capture the full extent of the patient population due to poor record management and limited access.

Therefore, this study proposed the design and development of an automated, web-based Campus Medical Unit Information Management System to streamline patient registration, consultation appointment management, prescription processing, referral management, and health reporting. Such a system enhances efficiency, improves healthcare delivery, ensures proper record management, and supports effective administration of health services at Busitema University Nagongera Campus.

1.3 Main Objective of the Study

The general objective of this study was to develop a web-based Campus Medical Unit Information Management System (CMUIMS) that supports better management, monitoring, and delivery of healthcare services at Busitema University Nagongera Campus.

1.4 Specific Objectives

1. To review the literature and gather requirements for the Campus Medical Unit Information Management System through literature review and stakeholder engagement.
2. To design an automated web-based Campus Medical Unit Information Management System.
3. To test the automated web-based Campus Medical Unit Information Management System.
4. To validate the proposed web-based Campus Medical Unit Information Management System prototype.

1.5 Justification/Rationale of the Study

Upon successful development and implementation of the automated web-based CMUIMS, the following benefits were anticipated and realised:

- **Improved Operational Efficiency:** The system streamlines patient registration, appointment scheduling, consultation, and healthcare processes, reducing patient wait times and improving healthcare service delivery. Research has shown that web-based healthcare systems using RAD methodology can reduce average registration time by approximately 40% while improving service efficiency at community health centres (Putri et al., 2023).
- **Enhanced Quality of Patient Care:** Medical staff now have immediate access to accurate and complete patient medical histories, enabling more informed clinical decisions and reducing the risk of medical errors.
- **Centralised and Secure Health Record Management:** A secure, centralised electronic health record repository eliminates fragmented paper files, reduces the risk of lost or misfiled records, and protects patient data confidentiality in compliance with the Uganda Data Protection and Privacy Act (2019).

- **Informed Decision-Making and Reporting:** Automated reporting tools enable university health officials to generate real-time insights into common ailments and clinic utilisation rates to support strategic planning.
- **Reduced Administrative Burden:** By automating routine clerical tasks, the system significantly reduces the manual workload for Medical Unit staff, allowing them to focus more on patient care.
- **Contribution to Knowledge:** The study contributes to academic literature on health information systems in campus healthcare settings in Uganda and sub-Saharan Africa.

1.6 Scope of the Study

1.6.1 Geographical Scope

The study was conducted at Busitema University Nagongera Campus, located in Nagongera Town Council, Tororo District, approximately 17 kilometres from Tororo town along the Tororo-Busolwe road.

1.6.2 Content Scope

The study focused on the design and development of a web-based Campus Medical Unit Information Management System to support the management of healthcare services at the campus Medical Unit. The system covers digital patient registration and management, appointment scheduling and consultation management, email notifications, Electronic Medical Records (EMR) management, diagnosis and prescription management, referral management, and automated health report generation. Pharmacy inventory management is out of scope.

1.6.3 Technological Scope

The system was developed using HTML5/React and Tailwind CSS (front-end), Node.js and Express.js (back-end), and SQLite (database management). Email services were handled through Node Mailer and Gmail. Password hashing used bcrypt.js, and version control was managed using Git and GitHub.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter presents a critical review of the literature relevant to the study's objectives. The purpose of this review is to establish a theoretical and empirical foundation for the design and implementation of the proposed Campus Medical Unit Information Management System (CMUIMS). The chapter examines health information systems, electronic medical records, campus clinic management systems, digital health in Uganda and sub-Saharan Africa, and identifies the research gap that this study addresses.

2.2 Health Information Systems

A Health Information System (HIS) is a combination of people, hardware, software, data, and procedures that interact to collect, process, store, and disseminate health information to support healthcare delivery, decision-making, coordination, and control within a healthcare organisation (O'Brien & Marakas, 2010). Health information systems are essential for improving healthcare efficiency, reducing operational costs, and enhancing the accuracy of patient data handling. ICT development has been identified globally as a tool for achieving operational and service-delivery efficiencies in the health sector (Byaro et al., 2023).

Tun and Madanian (2023) conducted a systematic review of Clinical Information System (CIS) implementation in developing countries and established that CIS usage reduces healthcare costs over time, improves the quality of medical care, and enhances clinical efficiency. Their review identified key success factors including strong user involvement, organisational readiness, and adequate technical infrastructure all of which are particularly relevant to the design of a campus-level health information system.

Campus Medical Unit Management Systems are specialised health information systems designed to support the administration and delivery of healthcare services within educational institutions, integrating functionalities such as patient registration, appointment scheduling, consultation management, prescription processing, and health reporting (Rosenberg et al., 2001). Bagherian and Sattari (2022) found that information systems in developing countries are often data-driven rather than performance-driven, with incomplete and inaccurate data constraining their utility for management decision-making.

2.3 Electronic Medical Records

Electronic Medical Records (EMRs) are digital versions of patients' paper charts and contain each patient's medical and treatment history within a single healthcare facility. EMRs include patient demographics, progress notes, diagnoses, medications, vital signs, immunisations, laboratory results, and radiology reports (World Health Organization, 2020). EMR systems have revolutionised healthcare delivery by providing healthcare providers with immediate access to accurate and complete patient information.

Research from multiple sub-Saharan African countries demonstrates that EHR systems significantly improve data management practices and patient care outcomes. Musie et al. (2025), in a scoping review of a decade of EHR design and implementation in sub-Saharan Africa, found that EHR implementation has been associated with a 20–30% reduction in data entry errors and a 15–25% enhancement in the accuracy and accessibility of patient records. Studies from Ghana, Rwanda, Nigeria, South Africa, Burundi, Ethiopia, and Gabon documented a 30% reduction in data entry errors and a 25% increase in data retrieval efficiency. Further, research from Rwanda, Kenya, Gabon, Nigeria, and Ethiopia reported a 20% improvement in patient follow-up rates and a 15% decrease in duplicate testing after EHR adoption.

The design model for the proposed CMUIMS is informed by these findings, incorporating a multi-module web-based approach consistent with evidence-based best practices in the sub-Saharan African context. Fauzi et al. (2023) found that RAD is the dominant methodology in healthcare information system development due to its incremental, prototyping-driven approach and continuous stakeholder engagement. Putri et al. (2023) further demonstrated that RAD-built systems using Node.js, Express, and SQLite achieved System Usability Scale scores exceeding the 'Very Good' threshold of 80, reducing average registration time by approximately 40%.

2.4 Digital Health in Uganda and Sub-Saharan Africa

Uganda has made significant strides in digital health policy in recent years. The Ministry of Health launched the Health Information and Digital Health Strategic Plan 2020/21–2024/25, providing strategic direction for health information management and digitisation of the national Health Information System (Ministry of Health – Uganda, 2020). In May 2023, an updated National Health Information and Digital Health Strategic Plan was launched, aimed at accelerating access to quality-assured data, institutionalising patient-level digital systems,

and fostering effective collaborative mechanisms within the health sector by 2025 (Ministry of Health Uganda, 2023).

Despite these policies, Uganda's digital health landscape remains challenged by fragmented systems, variable data quality, and digital health projects that fail to integrate with broader health system functions. Karamagi et al. (2022) documented that infrastructure limitations, high staff turnover, and insufficient technical capacity remain persistent barriers across sub-Saharan Africa. Alunyu, Amiyo, and Nabukenya (2024) found that most resource-constrained countries apply international digital health standards with little regard for contextual fitness, and demonstrated that localised design and contextual standards are essential for health information systems operating within Ugandan institutions.

2.5 Web-Based Systems and Campus Health Management

Automated Campus Medical Unit Information Management Systems offer numerous advantages over manual approaches, including improved accuracy of patient records, real-time access to health information, enhanced communication among healthcare stakeholders, secure storage of medical documents, and efficient reporting mechanisms (Alruwais, Wills & Wald, 2018). Web-based systems are favoured for campus healthcare management due to their accessibility, platform independence, ease of maintenance, and suitability for resource-constrained settings.

Mussi et al. (2023), in a study of large-scale implementation of a health information system in Brazilian university hospitals, found that implementation outcomes were linked to improvements in planning, control, decision-making, transparency, optimization of resources, professional productivity, patient information security, and safety and quality of care.

2.6 Research Gap

Despite the documented benefits of health information systems and electronic medical records, many universities in Uganda and sub-Saharan Africa continue to rely on manual, paper-based approaches to manage campus healthcare services. The existing literature does not adequately address the design and implementation of campus-level health information systems in Ugandan higher education institutions, particularly at smaller regional campuses such as Busitema University Nagongera Campus.

This study fills this gap by designing and implementing a web-based Campus Medical Unit Information Management System tailored to the specific operational context, healthcare challenges, and user needs of Busitema University Nagongera Campus. Drawing on best practices from sub-Saharan African EHR implementations, Uganda's national digital health strategy, and contextualised design principles validated for Ugandan institutions (Alunyu et al., 2024; Alunyu et al., 2025), the system provides a practical, scalable solution that can potentially be adopted by other campuses and similar institutions across Uganda.

CHAPTER THREE: METHODOLOGY

3.1 Introduction

This chapter describes the research design and development approach, study area and population, sampling techniques, data collection methods, and data analysis procedures. Together, these elements form a comprehensive methodology that guided the design and implementation of the proposed Campus Medical Unit Information Management System (CMUIMS) for Busitema University Nagongera Campus.

3.2 Research Design and Development Approach

This study adopted both qualitative and quantitative research designs through a mixed-methods approach. Das (2022) explains that qualitative research follows an inductive framework to explore and gain an in-depth understanding of phenomena, while a mixed-methods design systematically combines quantitative and qualitative methods for a comprehensive understanding of the issue. In this study, qualitative methods were used to explore the underlying reasons, motivations, and processes behind stakeholder experiences and requirements through interviews and observations. Quantitative methods involved collecting and analysing numerical data from questionnaires to identify patterns and frequencies in current healthcare management challenges.

The system development followed the Rapid Application Development (RAD) methodology. RAD is an incremental software development model that focuses on rapid development through short, iterative cycles that incorporate active user feedback and prototyping, thereby improving system fit and user satisfaction (Fauzi et al., 2023). Compared to the linear Waterfall model, RAD offers greater flexibility and adaptability to changing needs, making it particularly suitable for healthcare information system development where requirements evolve through iterative engagement with users (Tun & Madanian, 2023).

3.3 Study Area and Population

The study was conducted at Busitema University Nagongera Campus, located in Nagongera Town Council, Tororo District, in Eastern Uganda, approximately 17 kilometres from Tororo Town along the Tororo-Busolwe road. The campus hosts the Faculty of Science and

Education and has a significant student and staff population that relies on the campus clinic for primary healthcare.

The study population consisted of students, Medical Unit staff (Lab Technician and Nurse), and university staff at Busitema University Nagongera Campus who are directly involved in or beneficiaries of campus medical healthcare services. The research involved a total of thirty (30) participants: a Lab Technician, a Nurse, four staff members, and twenty-four students.

Table 3-1. Sample size of participants

Participants	**Male**	**Female**	**Total**
Lab Technician	1	0	1
Nurse	0	1	1
Staff	2	2	4
Students	12	12	24
Total	15	15	30

3.4 Sampling Techniques

A simple random sampling method was used to select participants from the student and staff population, ensuring that every eligible individual had an equal chance of being included. Andrade (2021) explains that random sampling improves the generalizability of findings to the broader population. In addition, purposive sampling was applied for selecting the Lab Technician and the Nurse, based on their roles and direct involvement in campus Medical Unit operations. Campbell et al. (2020) explain that purposive sampling matches the sample to the aims and objectives of the research, improving the rigour of the study.

3.5 Data Collection Methods and Instruments

3.5.1 Interviews

Face-to-face interviews were conducted with the Lab Technician and Nurse to obtain in-depth insights into the current campus medical healthcare processes, pain points, and requirements for the proposed CMUIMS. Das (2022) confirms that interviews are the predominant qualitative data collection method in health research, providing rich, reliable information and allowing the researcher to probe and follow up on important points.

3.5.2 Questionnaires

Structured questionnaires were administered to students to gather information about their experiences with the campus Medical Unit, challenges faced, and expectations for an improved system. Kwok et al. (2022) note that quantitative data collection instruments including questionnaires are standard for collecting minimum datasets in health research.

3.5.3 Observation

Selected clinic sessions were attended to observe patient registration, consultation processes, prescription handling, and healthcare operations. This method captured contextual nuances that may not be fully expressed in interviews or questionnaires, and was particularly important for identifying informal workflows.

3.5.4 Document Analysis

Existing records, registration logs, and health reports from the campus Medical Unit were reviewed to understand current data management practices and identify key system requirements. Document analysis is recognised as a critical method in health information systems research for understanding the baseline state of health data management (Kakudate et al., 2024).

3.6 Data Analysis Methods

3.6.1 Qualitative Data Analysis

Data collected through interviews and observations were analysed using thematic analysis. Das (2022) confirms that thematic analysis is one of the most common qualitative analysis approaches in health research, involving coding and categorising data into themes to identify patterns, common challenges, and user needs.

3.6.2 Quantitative Data Analysis

Data collected through questionnaires were analysed using descriptive statistics. Data were organised into structured formats such as tables, charts, and graphs using MS Excel. Khoa et al. (2023) recommend the use of descriptive statistics as the primary analytical approach in mixed-methods health research studies where the goal is to describe patterns and distributions.

3.7 Limitations/Anticipated Constraints

The study anticipated limited access to some Medical Unit records due to patient confidentiality requirements, and a small purposively-selected clinical staff sample (one Lab Technician and one Nurse) reflecting the actual staffing of the unit. These constraints did not prevent the study from being carried out and were addressed by triangulating interview, questionnaire, observation and document-analysis data.

CHAPTER FOUR: FIELD STUDY RESULTS AND SYSTEM DESIGN

4.1 Introduction

This chapter presents the results of the field study, including background information on the current system, its strengths and weaknesses, the system requirements gathered from stakeholders, and the overall system design. This forms the foundation for the implementation described in Chapter Five.

4.2 Background Information of the Organisation (Current System)

The Busitema University Nagongera Campus Medical Unit is the primary healthcare facility for students and staff of the Faculty of Science and Education. It is staffed by a Lab Technician and a Nurse, who are responsible for providing outpatient consultation, basic laboratory services, prescription management, and patient referrals to higher-level facilities when necessary.

Prior to this study, all operations at the Medical Unit were managed manually. Patients were registered using paper forms, appointments were scheduled verbally or through physical attendance, medical records were maintained in physical files, prescriptions were written by hand, and referrals were documented on paper letters. Health reports were compiled manually at the end of each month using aggregate counts from the paper records.

4.3 Strengths and Weaknesses of the Current System

4.3.1 Strengths of the Current System

- Simple to operate and requires no technical training for basic record-keeping.
- No reliance on electricity or internet connectivity for basic operations.
- Familiarity among existing Medical Unit staff with current workflows.

4.3.2 Weaknesses of the Current System

- High risk of patient record loss, misplacement, or damage.
- Inefficiency in retrieving patient histories due to manual filing systems.
- No mechanism for tracking appointment statuses or referral outcomes.
- Limited capacity to generate analytical health reports for decision-making.

- Lack of privacy and confidentiality in paper-based records.
- Duplication of data entry and high administrative workload for Medical Unit staff.

4.4 System Requirements

4.4.1 Functional Requirements

Table 4-1. Functional requirements

Req. No.	Requirement Description	User Role
FR01	Patient self-registration via web portal	Patient
FR02	Appointment booking and approval workflow	Patient, Medical Staff
FR03	Email notification on appointment booking and approval	Health Personnel and Patients
FR04	Electronic Medical Records (EMR) creation and management	Medical Staff
FR05	Prescription creation, management, and printing	Medical Staff
FR06	Patient referral initiation, tracking, and documentation	Medical Staff, Admin
FR07	Automated health report generation	Admin, Medical Staff
FR08	User management and role-based access control	System Admin
FR09	Patient dashboard for viewing appointment history	Patient

4.4.2 Non-Functional Requirements

Table 4-2. Non-functional requirements

Category	Description
Security	Role-based access, password hashing (bcrypt.js), SQL injection protection
Performance	System responses within 3 seconds for standard operations
Usability	Intuitive, mobile-responsive UI achievable without technical training
Reliability	System uptime of at least 99% during clinic working hours
Scalability	Designed to accommodate growth in users and records
Compliance	Adherence to Uganda Data Protection and Privacy Act (2019)

4.5 System Design

4.5.1 System Architecture

The CMUIMS follows a three-tier web architecture comprising a frontend React application, a Node.js/Express.js RESTful API backend, and an SQLite database. The frontend communicates with the backend via HTTP REST API calls. The backend processes business logic, manages authentication, and interacts with the SQLite database for data persistence.

4.5.2 Context Diagram

The Context Diagram provides a high-level view of system interactions with external entities (patients, medical personnel, and administrators), defining system boundaries and information flow. The System Admin manages users, reviews referrals, and generates reports. The Lab Technician and Nurse review appointments, update medical records, create referrals, and issue prescriptions. Patients self-register, book appointments, and view their medical history.

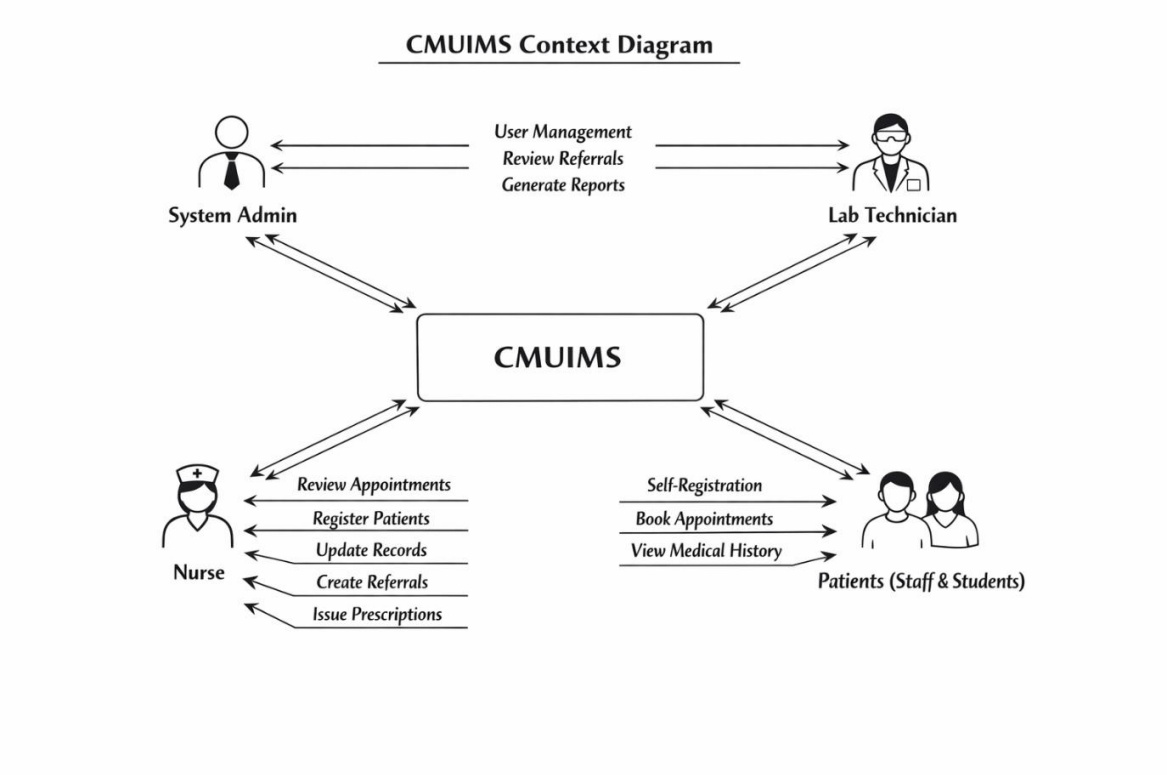

Figure 4-1. Context Diagram of the CMUIMS

4.5.3 Data Flow Diagram

The Data Flow Diagram depicts internal system processes in detail, including patient registration, appointment scheduling, EMR management, prescription processing, and report generation, guiding the development of efficient data pathways between the system's users and the central database.

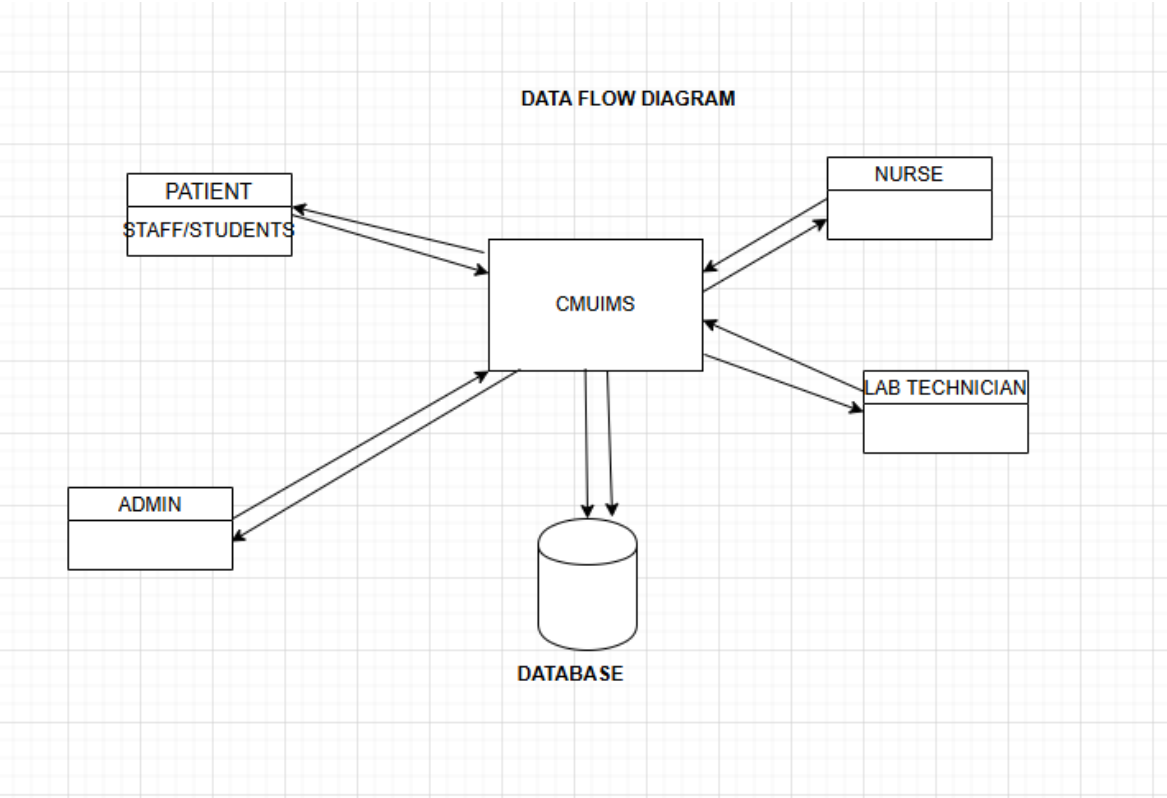

Figure 4-2. Data Flow Diagram of the CMUIMS

4.5.4 Use Case Diagram

The Use Case Diagram models the various functions that users will perform within the system:

- **System Admin:** Manages system users, reviews referrals, generates reports.
- **Lab Technician:** Reviews appointments, updates lab results, creates referrals, registers patients.
- **Nurse:** Reviews appointments, registers patients, updates medical records, creates referrals, issues prescriptions.
- **Patient (University Staff and Students):** Self-service registration, appointment booking, viewing medical history.

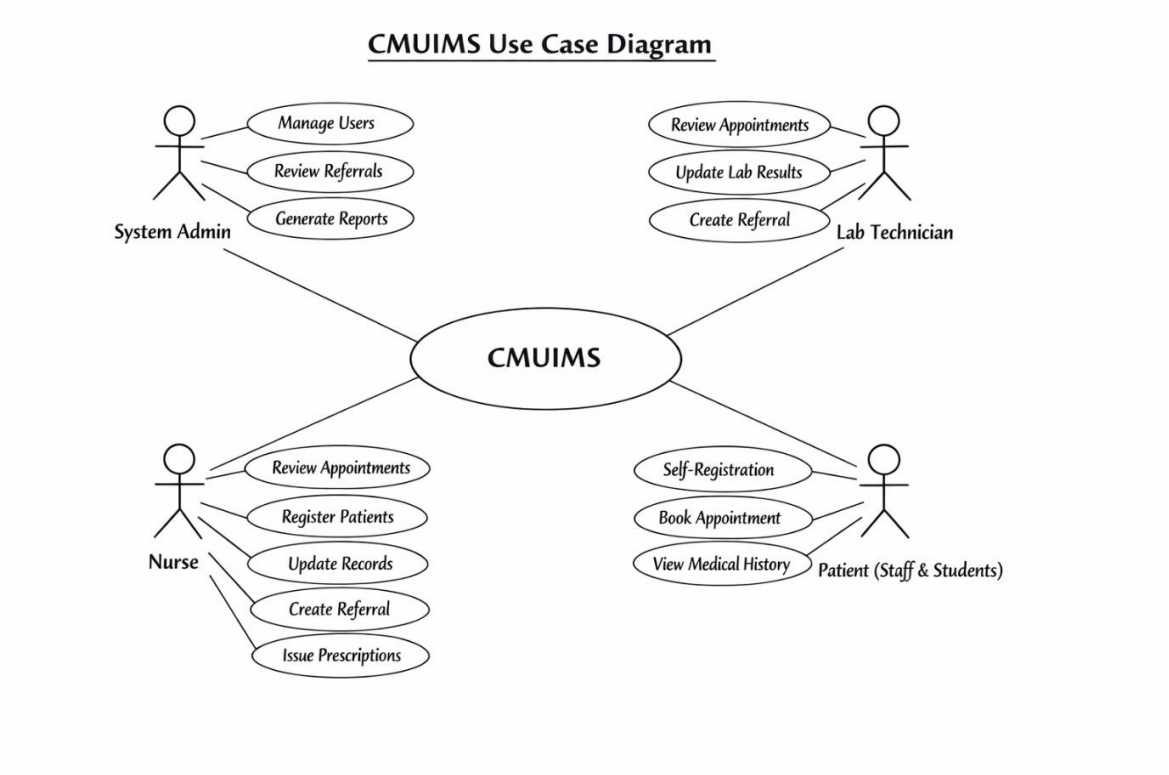

Figure 4-3. Use Case Diagram of the CMUIMS

4.5.5 Entity Relationship Design

The database design incorporates key entities including Users, Patients, Appointments, Medical Records, Prescriptions, Lab Results, and Referrals. Relationships between these entities ensure referential integrity and support the functional requirements of the system. SQLite was selected as the database engine for its lightweight, serverless nature and suitability for the deployment context.

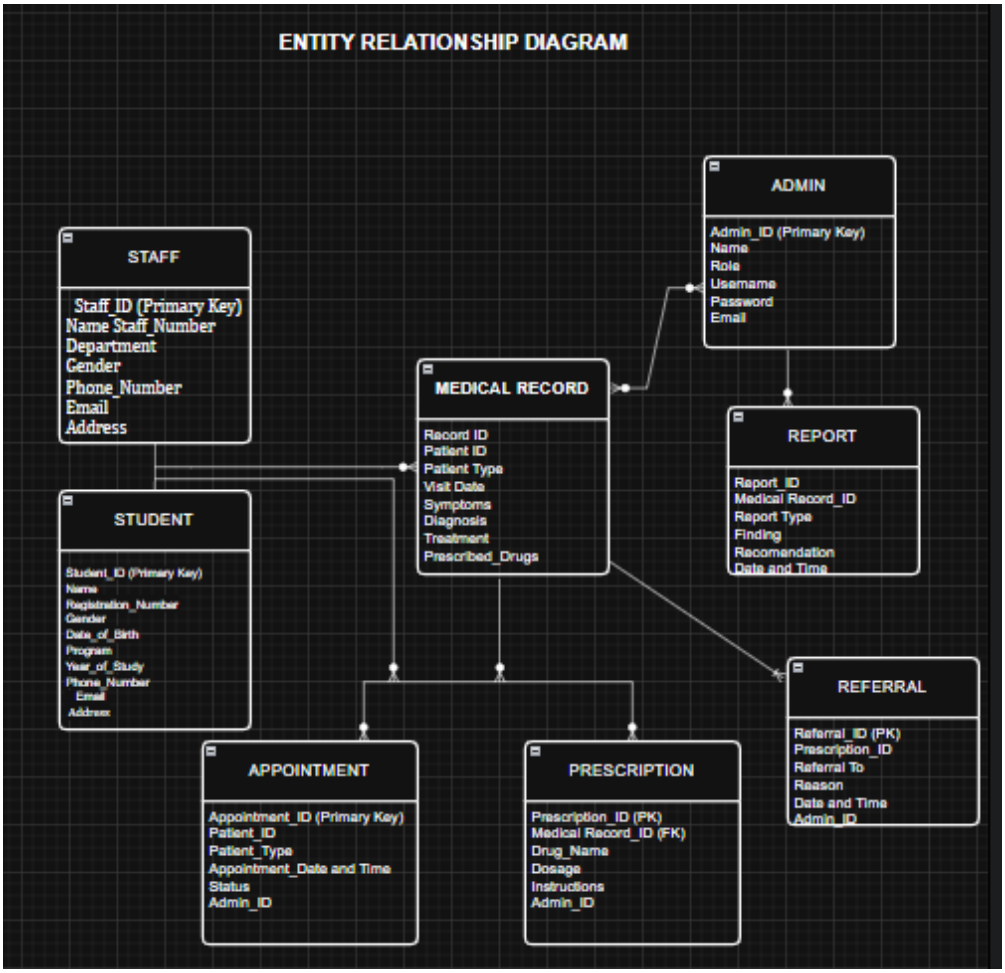

Figure 4-4. Entity Relationship Diagram of the CMUIMS

CHAPTER FIVE: IMPLEMENTATION AND TESTING

5.1 Introduction

This chapter presents the implementation of the CMUIMS, building the system as designed in Chapter Four, step by step as represented by the use-case diagrams. Each module is introduced with design considerations, followed by a screenshot of the implemented interface and an explanation of how that module works. The chapter also presents the testing activities conducted to validate the system.

5.2 Security and Authentication

The CMUIMS implements a secure, role-based authentication system. All user passwords are hashed using bcrypt.js before storage in the database, ensuring that plaintext passwords are never stored. JWT (JSON Web Tokens) are used for session management. Users are assigned one of four roles System Admin, Lab Technician, Nurse, or Patient and the system enforces role-based access control (RBAC) so that each user can only access features and data relevant to their role. Protection against SQL injection and cross-site scripting was implemented throughout the backend API, consistent with the requirements of the Uganda Data Protection and Privacy Act (2019).

Figure 5-1 below shows the CMUIMS login interface, which provides a secure sign-in form with email and password fields. New patients can create an account via the self-registration link.

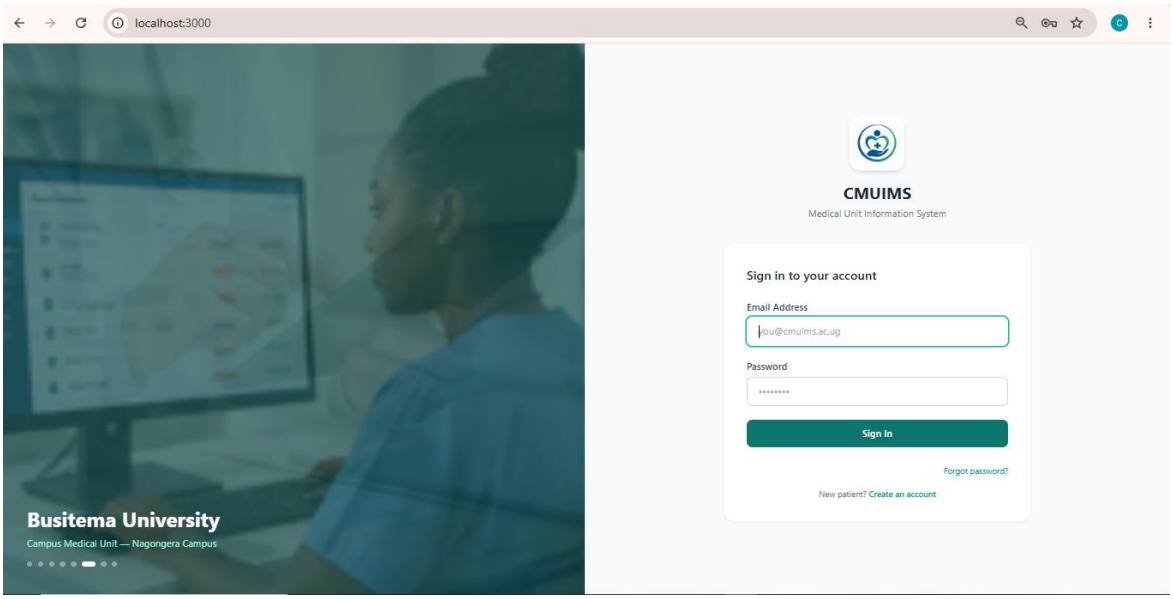

Figure 5-1. CMUIMS Login Interface

5.3 Admin Dashboard

The Admin Dashboard (Figure 5-2) provides the System Administrator and administrative staff with a comprehensive overview of system activity. It displays summary statistics including Total Patients, Total Appointments, Total Referrals, and Pending Referrals. The Staff Activity panel shows individual contributions of Medical Unit staff appointments handled, EMRs created, and referrals initiated enabling performance monitoring. Quick Action buttons allow the admin to directly navigate to user management, referral review, and report generation modules.

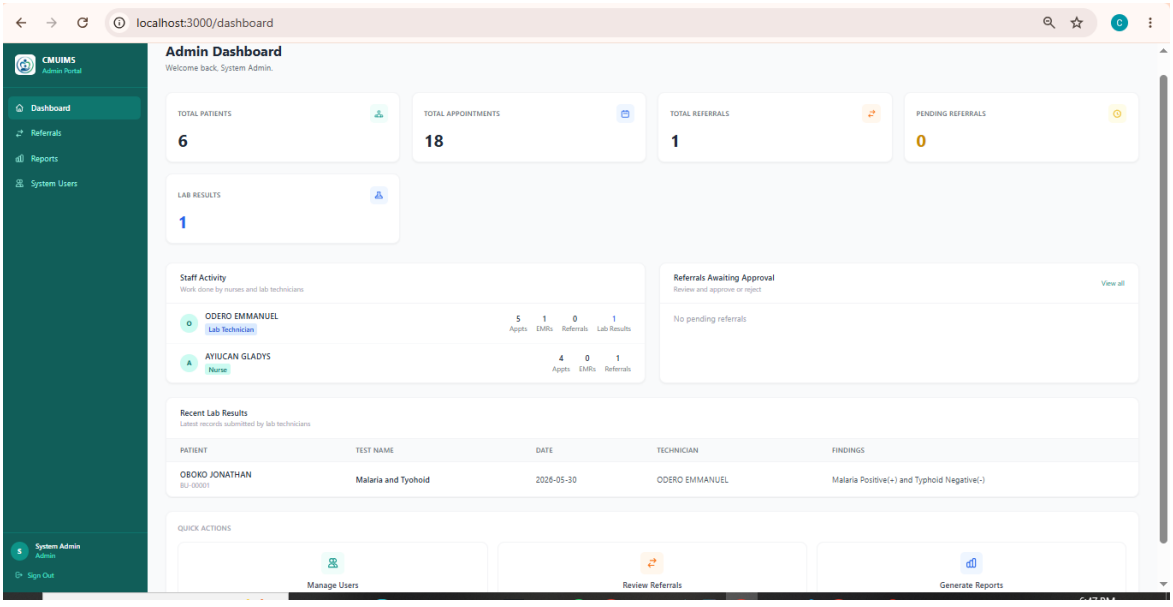

Figure 5-2. Admin Dashboard

5.4 Lab Technician Dashboard

The Lab Technician Dashboard (Figure 5-3) is the primary working interface for the Lab Technician. It provides the same summary statistics as the admin view but is tailored to the medical staff workflow. The navigation sidebar gives access to Patients, Appointments, Medical Records, Lab Results, Referrals, and My Reports.

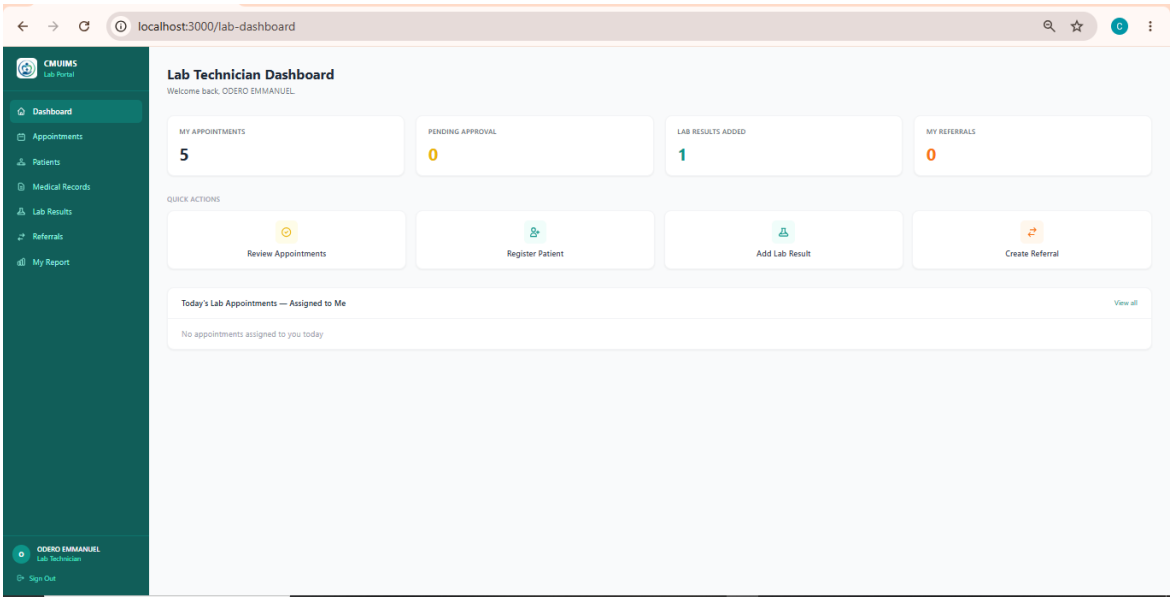

Figure 5-3. Lab Technician Dashboard

5.5 Nurse Dashboard

The Nurse Dashboard (Figure 5-4) is the primary working interface for the Nurse. It provides the same summary statistics as the admin view but is tailored to the Nurse workflow. The navigation sidebar gives access to Patients, Appointments, Medical Records, Prescriptions, Referrals, and My Reports.

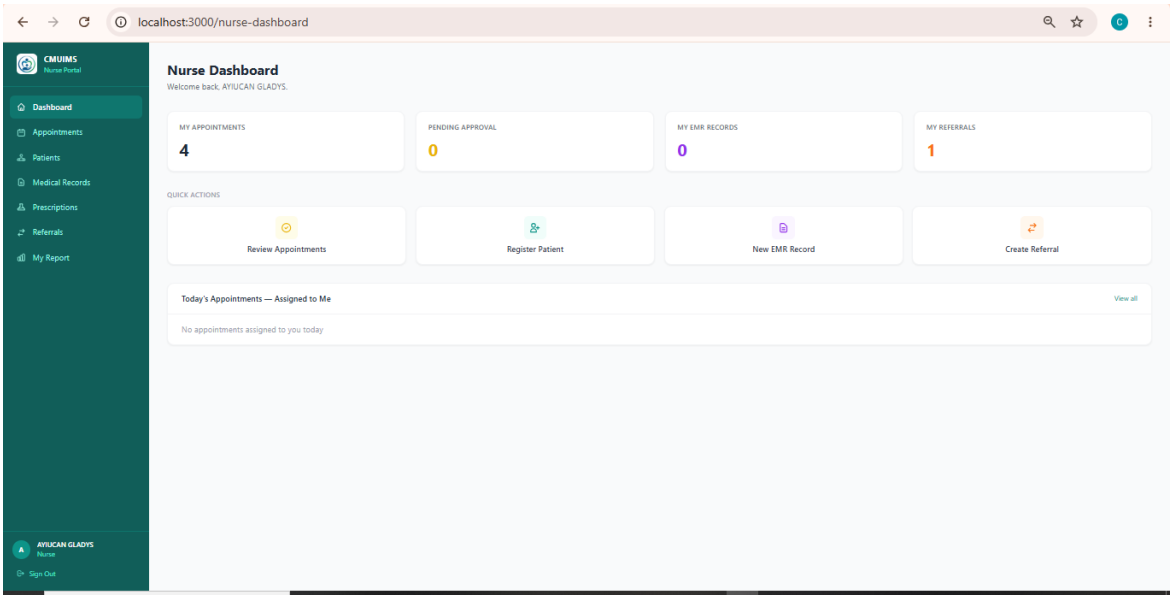

Figure 5-4. Nurse Dashboard

5.6 Patient Dashboard

The Patient Dashboard (Figure 5-5) is the self-service portal available to registered students and staff. Upon login, patients can view their appointment statistics (Total Appointments, Pending, Approved, Completed), their personal details including Patient Number, Category (Student), University ID, and Email. The My Appointments section lists all booked appointments with date, provider, reason, and real-time status (Approved / Pending), Prescriptions, and Lab Results, and Referrals. The Book Appointment button in the top right enables patients to request new appointments.

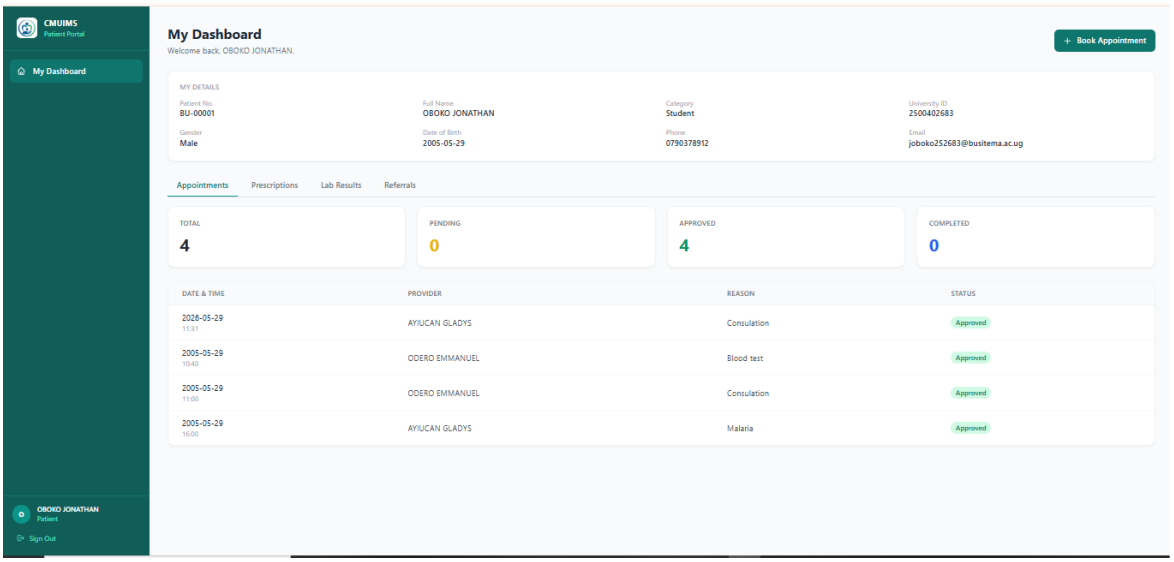

Figure 5-5. Patient Dashboard

5.7 Appointment Booking Module

The Appointment Booking Module (Figure 5-6) allows patients to submit appointment requests directly from the patient portal. The booking form captures the healthcare provider, preferred date and time (within 08:00–17:00), the reason or chief complaint, and a detailed description of symptoms. Upon submission, the request is sent to the selected provider for approval, who receives an email notifying them of the appointment made by the patient, and the patient receives an email notification once the appointment is approved. This module eliminates the need for walk-in queues and manual scheduling, improving efficiency for both patients and medical staff.

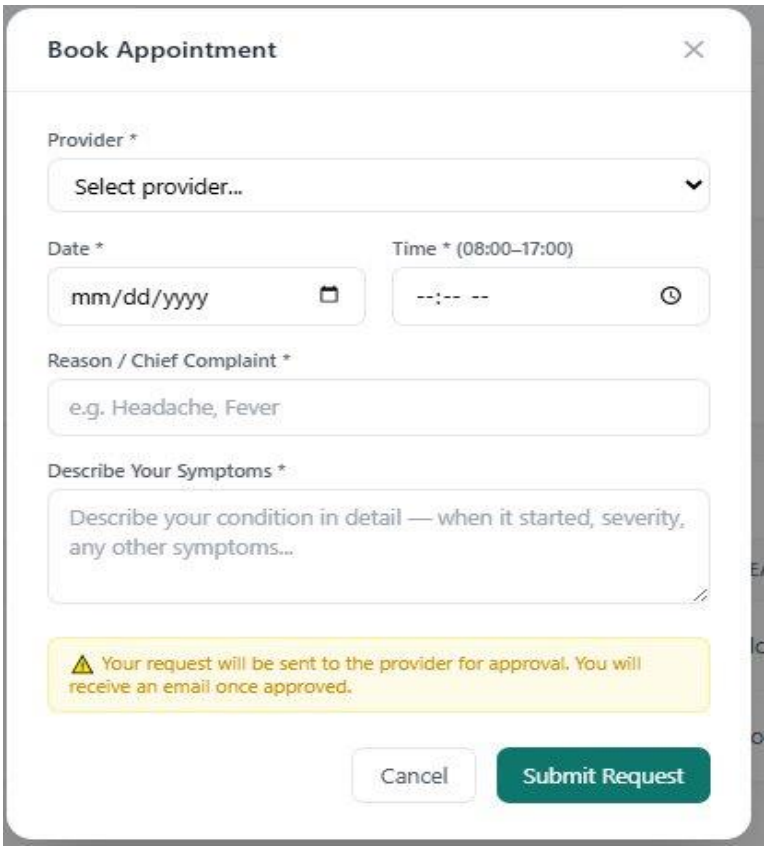

Figure 5-6. Appointment Booking Module

5.8 Prescription Module

The Prescription Module (Figure 5-7) enables Medical Personnel (Nurse) to create and print prescriptions for patients. The New Prescription form allows the Medical Staff to select the patient from a dropdown, set the prescription date, add clinical notes, and specify one or more medications including Drug Name, Dosage, Frequency, Duration, and Quantity via an Add Drug function. Completed prescriptions can be saved and printed for patient use. This

module replaces handwritten prescription pads and ensures that prescription records are stored digitally for future reference.

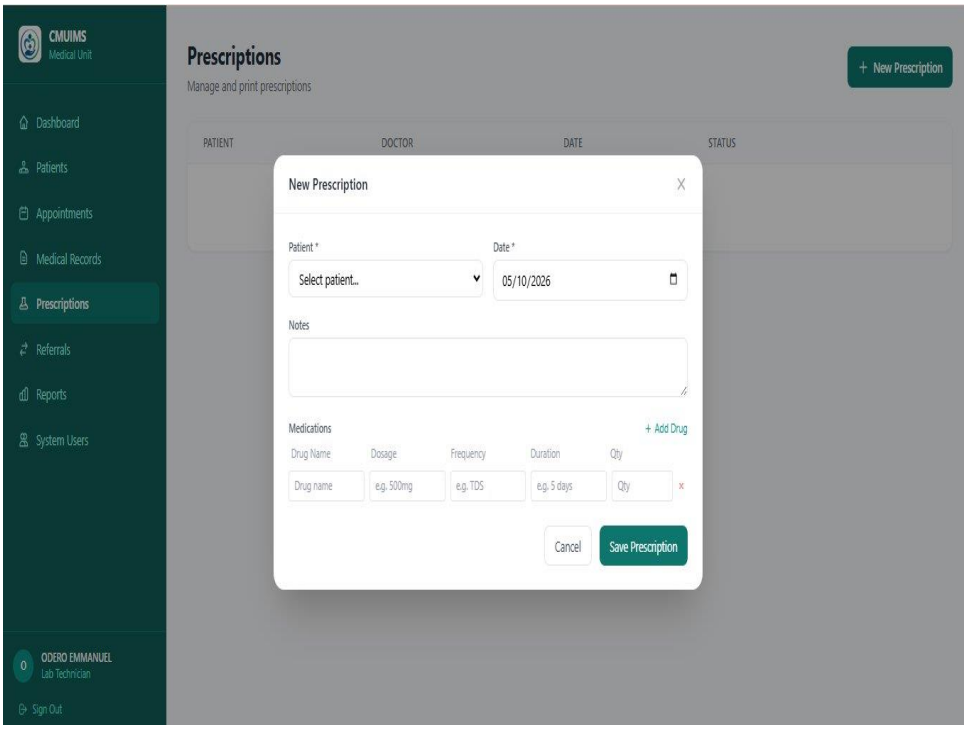

Figure 5-7. Prescription Module

5.9 Referral Module

The Referral Module (Figure 5-8) supports the initiation, tracking, and documentation of patient referrals to external healthcare facilities. Medical Personnel can create a new referral by selecting the patient, setting the referral date and urgency (Routine or Emergency), specifying the receiving hospital or specialist (e.g., Mbale Regional Referral Hospital), and providing the reason for referral. The referral list displays all referrals with their current status (e.g., Accepted), patient ID, and urgency level. The System Admin can review and approve or reject referrals from the admin panel.

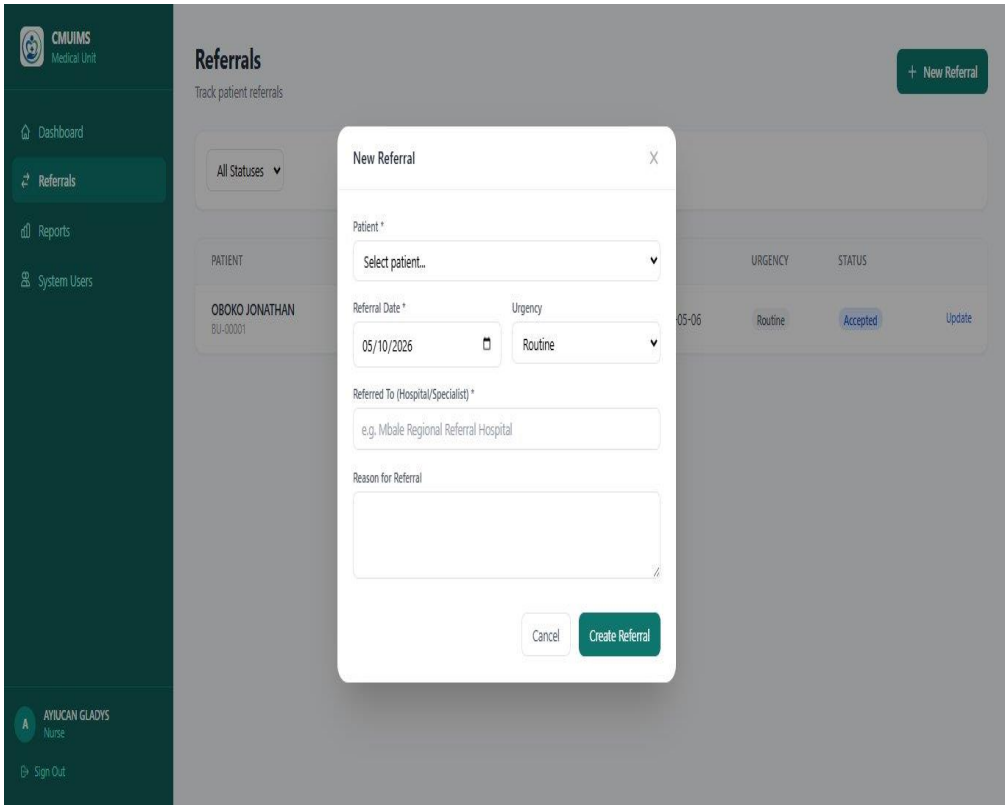

Figure 5-8. Referral Module

5.10 Health Report Generation Module

The Health Report Generation Module (Figure 5-9) allows Medical Personnel to view electronic medical records (EMRs) for all patients that they have worked on. The interface displays patient records filtered by provider (admin page), showing the patient's name, patient number (e.g., BU-00001), date, attending doctor, diagnosis (e.g., high stage of malaria), and presenting complaint. Records can be filtered by patient for focused review. This module ensures that health records are centrally stored, easily retrievable, and available to support clinical decisions.

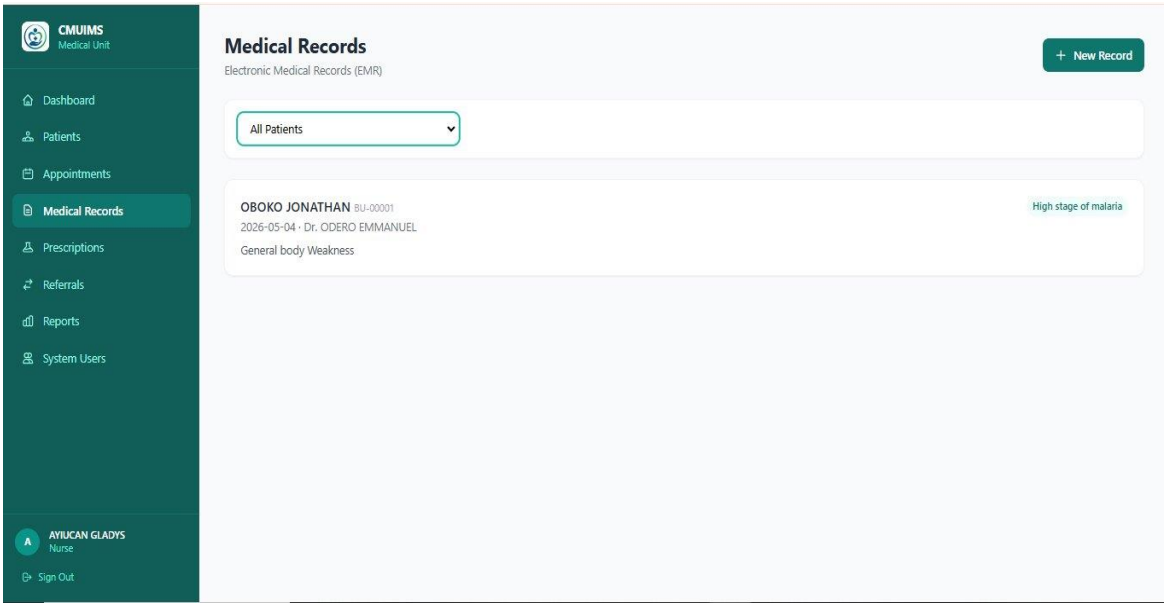

Figure 5-9. Health Report Generation Module

5.11 Report Generation Module

The Report Generation Module (Figure 5-10) provides administrators and medical personnel with an analytical overview of system activity across a selected date range. It displays aggregate statistics: Total Patients, Total Appointments, Completed Visits, and Total Referrals. An Appointments by Status breakdown shows Approved and Pending. A Patients by Category chart shows the distribution of registered patients by category. The Staff Activity Report presents appointment, EMR, and referral counts per staff member, enabling performance review. Reports can be exported using the Print Report button.

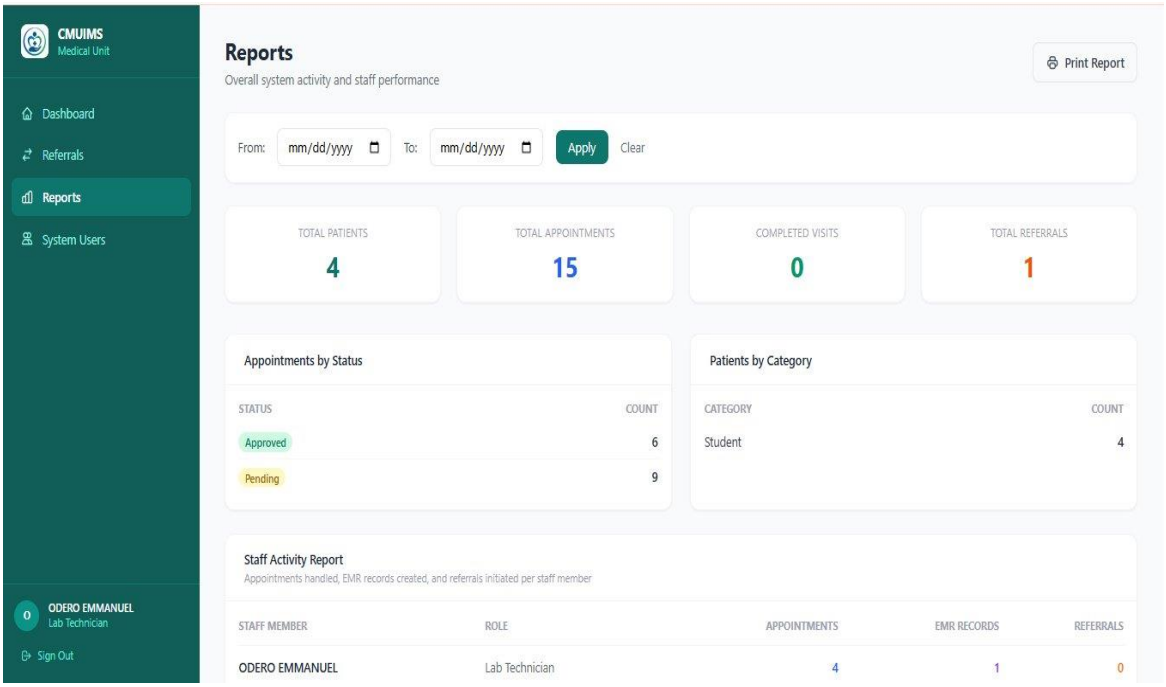

Figure 5-10. Report Generation Module

5.12 System Testing

The developed CMUIMS underwent rigorous testing across four dimensions to ensure full functionality, performance, and alignment with user needs:

5.12.1 Unit Testing

Individual features including user login, patient registration, appointment booking, EMR creation, prescription management, referral creation, and report generation were tested in isolation using structured test cases. All core functions passed unit testing, with expected outputs confirmed for valid inputs and appropriate error handling for invalid inputs.

5.12.2 Integration Testing

Integration testing ensured seamless interaction between modules: patient registration and appointment scheduling; consultation recording and prescription management; and prescription processing, referral, and reporting modules.

5.12.2.1 Email Integration Performance

The Node Mailer API was tested using Postman to confirm that all endpoints returned correct status codes and data structures. When an appointment is made by the patient, the health worker receives an email alert and reviews the appointment, taking an action of

approving, deleting, or editing; on confirming an action, the patient receives an email with feedback on the health worker's action.

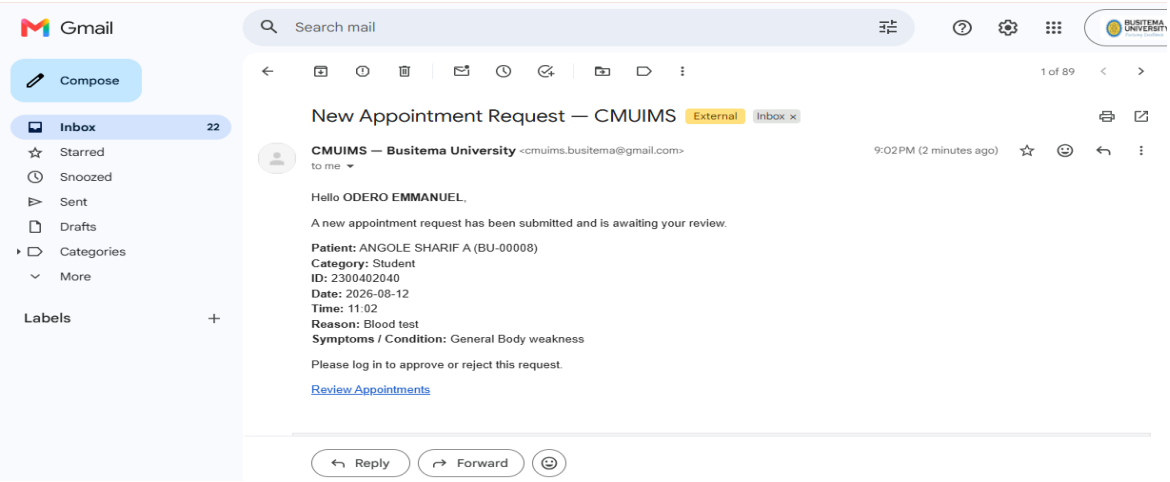

Figure 5-11-1. Email Integration Performance – Alert Notifications for Health Worker

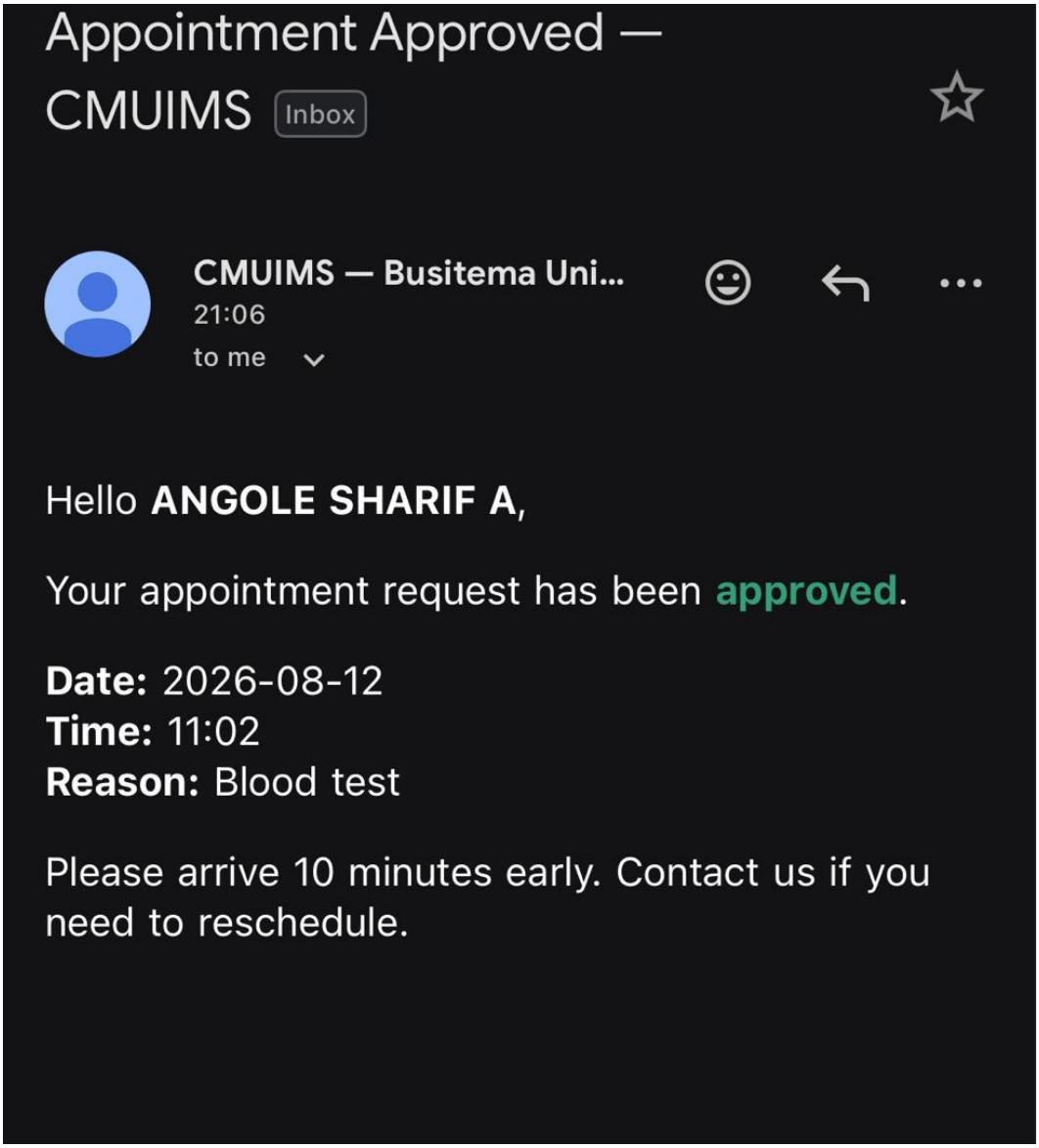

Figure 5-11-2. Email Integration Performance – Alert Notifications for the Patient

5.12.3 User Acceptance Testing (UAT)

UAT was conducted with representative stakeholders including a patient, a nurse, a lab technician, and the system administrator. Participants were asked to complete defined tasks within the system and provide feedback on ease of use, completeness, and overall satisfaction. Feedback was positive, with users noting the system's intuitive interface, an email alert on receiving appointment and upon approval of appointment, reduced administrative workload, and improved record accessibility. Minor UI suggestions from participants were incorporated.

5.12.4 Security Testing

Security testing confirmed that role-based access control correctly prevented unauthorized access to restricted modules. Password hashing was verified using bcrypt.js. API endpoints were tested for SQL injection and cross-site scripting vulnerabilities, with all identified risks mitigated. Session management using JWT tokens was confirmed to expire appropriately after logout.

CHAPTER SIX: DISCUSSION, CONCLUSION, RECOMMENDATIONS, LIMITATIONS AND FUTURE WORK

6.1 Introduction

This chapter discusses the results of the study in relation to the objectives set out in Chapter One, draws conclusions from the findings, provides recommendations for stakeholders, and identifies the limitations of the study and areas for future work.

6.2 Discussion of Results

6.2.1 Determination of Requirements for the System

The first objective was to review literature and gather requirements for the CMUIMS through stakeholder engagement. This was achieved through face-to-face interviews with the Lab Technician and Nurse, structured questionnaires administered to 24 students, observation of clinic operations, and document analysis of existing health records. The requirements gathered are presented in Chapter Four, Section 4.4. This approach is consistent with Kakudate et al. (2024), who confirmed that mixed-methods approaches to requirements gathering combining interviews, observation, and document analysis are best suited to capturing both the technical and human dimensions of health information system design. The requirements gathering confirmed that the manual system was inefficient, error-prone, and incapable of supporting timely health reporting, thereby validating the need for an automated system.

6.2.2 System Design

The second objective was to design an automated web-based CMUIMS. The system design was guided by established modelling tools including a Context Diagram, Data Flow Diagram, and Use Case Diagram as presented in Chapter Four, Section 4.5. The design incorporates a three-tier web architecture with a React/Tailwind frontend, Node.js/Express backend, and SQLite database, consistent with the technology stack validated by Putri et al. (2023) for RAD-based healthcare systems in community health centres. The multi-module design covering patient registration, appointment scheduling, EMR management, prescription management, referral management, and report generation aligns with best practices documented in sub-Saharan African EHR implementations (Musie et al., 2025).

6.2.3 Implementation and Testing

The third objective was to implement and test the CMUIMS. The system was successfully implemented with all specified functional modules operational, as presented in Chapter Five. Unit testing, integration testing, UAT, and security testing were conducted systematically. Results confirmed that all core functionalities work as intended, API endpoints return correct responses, and the system enforces role-based access control effectively. UAT feedback from stakeholders was positive, indicating high usability and satisfaction with the system's interface and functionality. This is consistent with Tun and Madanian's (2023) finding that iterative UAT with ongoing stakeholder engagement is the strongest predictor of long-term system adoption in developing-country healthcare settings.

6.2.4 Evaluation and Validation

The fourth objective was to evaluate and validate the proposed CMUIMS prototype. Validation was achieved through UAT with Medical Unit staff and patients, confirming that the system meets the identified functional and non-functional requirements. Security validation confirmed compliance with the Uganda Data Protection and Privacy Act (2019). The automated health report generation module was validated as capable of producing accurate summaries of patient visits, appointment statistics, and staff activity, fulfilling the objective of supporting evidence-based decision-making at the Medical Unit.

6.3 Conclusion

This study successfully designed, developed, and implemented a web-based Campus Medical Unit Information Management System (CMUIMS) for Busitema University – Nagongera Campus. The system addresses the documented inefficiencies of the manual healthcare management approach by providing an integrated, multi-module digital solution covering patient registration, appointment scheduling and management, Electronic Medical Records, prescription management, referral management, and automated health reporting.

The RAD methodology proved effective for iterative development, enabling continuous stakeholder feedback to guide the system design and implementation. The technology stack React, Tailwind CSS, Node.js, Express.js, and SQLite was appropriate for the resource-constrained campus setting and delivered a performant, scalable, and user-friendly system. All four specific objectives of the study were successfully achieved, and the system was validated through comprehensive testing to meet functional, security, and usability requirements.

The CMUIMS represents a practical contribution to campus healthcare digitisation in Ugandan higher education institutions and demonstrates that locally designed, context-sensitive health information systems can effectively address the healthcare management challenges faced by small regional campuses.

6.4 Recommendations

- Busitema University administration should formally adopt and deploy the CMUIMS for routine use at the Nagongera Campus Medical Unit, providing the necessary hardware infrastructure including computers, reliable internet connectivity, and backup power.
- A structured training programme should be developed for Medical Unit staff (Lab Technician, Nurse) and students to ensure effective adoption and utilisation of all system modules.
- The university should explore integration of the CMUIMS with Uganda's national digital health infrastructure, including DHIS2 and the national EMR ecosystem, to improve data interoperability and enable population-level health reporting.
- A formal data governance policy should be established for the Medical Unit, outlining data ownership, access rights, retention periods, and breach response procedures, consistent with the Uganda Data Protection and Privacy Act (2019).
- Future procurement processes for campus health information systems at other Busitema University campuses should consider the CMUIMS as a replicable, cost-effective model.

6.5 Limitations and Future Work

The following limitations were encountered during the study:

- The system was developed and tested in a pilot environment with a limited number of patients and appointments, which may not fully reflect real-world load conditions at scale.
- The study was conducted at a single campus, limiting the generalisability of the findings to other campuses with different infrastructure and user profiles.

- Pharmacy inventory management was intentionally excluded from the scope of this study.

The following areas are recommended for future work:

- Integration of a pharmacy inventory management module to provide a comprehensive end-to-end healthcare management solution.
- Development of a mobile application version of the CMUIMS to improve accessibility for students who primarily use smartphones.
- Formal evaluation of system impact on clinic utilisation rates and patient satisfaction following full deployment over an academic year.

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APPENDICES

Appendix A: Project Budget

Table A-1. Project budget

Item	**Description**	**Estimated Cost (UGX)**
Stationery	Printing, photocopying, binding	120,000
Data Collection	Transport to Nagongera Campus, airtime, internet	100,000
Software Tools	VS Code, IntelliJ, SQLite, Git	80,000
Internet	Research, development, testing	300,000
Contingency	Unexpected expenses	100,000
Total		700,000

Appendix B: Work Plan and Timeline

Table B-1. Work plan and timeline

Phase	**Activity**	**Week(s)**
Phase 1	Literature review and requirements gathering	2
Phase 2	System analysis and design	2
Phase 3	System implementation (development)	1
Phase 4	System testing and validation	1
Phase 5	Documentation and report writing	2

Appendix C: Interview Guide

The following guiding questions were used during face-to-face interviews with the Medical Unit staff:

1. How do you currently register patients at the Medical Unit?

   ……

   ……

2. What challenges do you face with the current manual record-keeping system?

   ……

   ……

3. How are patient medical histories retrieved during consultations?

   ……

   ……

4. How are prescriptions and referrals managed?

   ……

   ……

5. What features would you consider most important in an automated system?

   ……

   ……

Appendix D: Student Questionnaire Summary

The following questionnaire was administered to 24 students to gather information about their experiences with the campus Medical Unit. Please circle or tick your preferred response.

1. How many times have you visited the campus Medical Unit this academic year?

   ☐ Never ☐ 1–2 times ☐ 3–5 times ☐ More than 5 times

2. How would you rate the quality of healthcare services at the Medical Unit?

   ☐ Very Poor ☐ Poor ☐ Average ☐ Good ☐ Excellent

3. Have you ever experienced delays in receiving medical services at the unit?

   ☐Yes ☐ No

4. Have you ever experienced the loss or misplacement of your medical records?

   ☐ Yes ☐ No

5. Would you prefer an online system where you can book appointments and view your medical history?

   ☐ Yes ☐ No ☐ Not sure

6. Any additional comments or suggestions for improving healthcare services at the Medical Unit:

   .....

   .....

   .....

   .....

Thank you for your co-operation!