Development of a Computerized Hospital Laboratory Operations' Support System

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Certification

This is to certify that this study was conducted under my supervision by Abiodun Timothy ADEGBIJI with Matric Number (LCU/PG/MSC/CIS/15/0001) for the award of Master of Science Degree (MSc) in Computer Science, Faculty of Natural and Applied Sciences, Lead City University, Ibadan, Oyo State, Nigeria and that this work has not been previously submitted.

Dr. R. A. Badru **(Supervisor)**	**Date**
Dr. W. Sakpere **(Head of Department** **Computer Science)**	**Date**

Dedication

I dedicate this project to God almighty who without a doubt has shown me his grace, protected me from the first day till this day, I am forever indebted to God, so therefore all glory belongs to God.

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I alone stand responsible for errors, if any found in the work

Thank you all.

Abstract

Manual hospital laboratory operation system is characterized with lack of prompt retrieval of Information which result in time wastage, loss of information, misplacement and misallocation of results. To proffer solution to the aforementioned problems, the research study developed a computerized hospital laboratory operation support application which is aimed at using information technology to solve the problems associated with manual method of Hospital Laboratory Information System. The system is a web based model built on laravel 7.29 and a WAMP (Windows, Apache, MySQL, PHP) server. A total of 4 laboratories were visited (2 government owned and 2 private laboratories) to collect various types of tests being carried out in the laboratories through ethical approval using the conventional and the developed systems. During the implementation of the developed system at Oyo state hospital management laboratory in Oyo and Ibadan, the system was installed unto the hospital laboratories' database and subsequently utilized for registration of patients data and processed data. The result obtained showed that 65% of the respondents who were tested with the developed system used between 30-45 minutes and 48% used between 46- 60minutes while 88% that used the manual system used between 2-8hours before the result was ready.The adoption of this research will greatly allow prompt release of test results retrieval of Information, reduce patient test time wastage, give accurate laboratory test result, reduce loss of vital information, reduce misplacement of test results and reduce misallocation of test results to the barest minimum, if not totally eradicated.

Keywords: Computerized, information technology, Hospital, Laboratory, Laravel

Word Count:250

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List of Abbreviations

Abbreviation	Meaning
HIS	Health Information System
EMR	Electronic Medical Record
RPM	Remote Patient Monitoring
EMR	Electronic Medical Record
EHR	Electronic Health Record
MPI	Master Patient Index
CDS	Clinical Decision Support
HIE	Health Information Exchange
CMS	Computerized Management Systems
LIS	Laboratory information systems
HIS	Healthcare Information Systems
CHLOS	Computerized Hospital Laboratory Operations System
WHO	World Health Organization
ANSI	American National Standards Institute
LIMS	Laboratory Information Management System
GPS	Global Positioning Satellite
CML	Chemical Markup Language
ASP	Application Service Provider
RDLIMS	Relational Database Laboratory Information Management System
LDMS	Laboratory Data Management System
DBMS	Database Management System
RDB.	Relational Databases

SQL	Structured Query Language
NOS	Network Operating Systems
GUI	Graphical User Interface
OODB	Object-Oriented Database
RFID	Frequency Identification Devices

Appendices

Chapter One

Introduction

1.1 Background to the Study

Health Information System (HIS)

A health information system (HIS) is a database management system for medical records. Systems that collect, store, manage, and transmit a patient's electronic medical record (EMR), a hospital's operational management, or a system that supports healthcare policy decisions fall into this category[1]. Information relating to the practices of physicians and health services is often handled by health information systems. These can be used in conjunction to optimize health care, inform research, and impact policy and decision-making. Security is a significant problem of health information systems when they often view, handle, or retain vast quantities of confidential data[1].

Examples of Health Information Systems (HIS)

All in healthcare, from patients to doctors to public health officials, will benefit from health information systems. They gather information and organize it in a manner that can be used to make medical decisions[1]. Examples of health information systems include:

Practice Management Software: Practice management software supports healthcare professionals with handling day-to-day processes including staffing and billing. Practice management systems are used by healthcare providers of all types, from small practices to hospitals, to simplify certain administrative functions.

Remote Patient Monitoring (RPM): Also called tele-health, is a way of transmitting patient data to healthcare professionals via medical sensors. For those with chronic illnesses, it tracks blood glucose levels and blood pressure on a regular basis.

The information is used to identify medical events that need attention that may eventually be used in a broader population health report.

Electronic Medical Record (EMR) and Electronic Health Record (EHR): **E**lectronic medical record" (EMR) and "electronic health record" (EHR) are nearly synonymous. The printed version of a patient's personal history is replaced with an electronic medical record while patient records, examination reports, and medications are included in the electronic health record. It's also designed to sync data with other electronic health reports, allowing other healthcare facilities to see a patient's medical information.

Master Patient Index (MPI): A master patient index ties together different patient reports from different databases. Each patient enrolled with a healthcare institution has a record in the index, which indexes all other information for that patient. MPIs are used to avoid claim denials by reducing redundant patient data and outdated patient documents.

Patient Portals: Patients can use a patient portal to view personal health information such as appointment dates, prescriptions, and lab reports through the internet. Any patient portals allow patients to connect directly with their doctors, order prescription refills, and arrange appointments.

Clinical Decision Support (CDS): Clinical decision support interpret evidence from a variety of clinical and management systems in order to assist healthcare providers in making clinical decisions. The information may aid in the preparation of diagnoses or the prediction of medical events such as drug interactions. These resources help physicians care for specific patients by filtering data and information. The primary goals of health information systems are efficiency and data management. Health information systems however are mainly driven by the following factors:

Data Analytics: The healthcare sector generates a large amount of data on a regular basis. Health information systems assist with the collection, compilation, and analysis of patient data in order to better monitor population health and lower healthcare costs. The healthcare data analysis will then be used to improve patient care..

Collaborative Care: Patients also need medication from various healthcare providers, which necessitates collaborative care. Health information services, such as health information exchanges (HIEs), allow healthcare providers to access common medical data.

Cost Control: By exchanging healthcare data over wireless networks, efficiencies and cost savings are achieved. Healthcare services save money as geographic markets use health information exchanges to share results. In a smaller basis, hospitals use electronic health reports to achieve the same efficiencies.

Population Health Management: Health information systems can aggregate patient data, analyze it and identify trends in populations. The technology also works in reverse. Clinical decision support systems can use big data to help diagnose individual patients and treat them.The desire to transform and deliver effective health services has resulted in increased use of information and communication technology-based technologies in the healthcare field. It functions as a centralized database that collects and stores all information about patients, doctors, and staff. As a result, healthcare providers can have a rapid evaluation by accessing a patient's health records at any time.It also provides data-handling applications for hospital operational control and healthcare policy assessments. Security is still a top priority for the hospital information system because it manages such a vast amount of confidential data[2].

The roles of a health care provider and the capabilities of information technology are taken into account in an information system that supports the operations of a hospital.

The information management system works in tandem with the other elements of a hospital's highly diverse corporate structure and procedures. By allowing the collection, storing, and exchange of information, it serves as an integrator for all of these components. The Health Information System's (HIS) spectrum, content, and structure support a variety of purposes. It consists of a series of sub-systems and software (often referred to as modules) that make the best use of information-communications technologies and computerization to make hospital facilities more effective[2]. The HIS is mostly concerned with the administration of the hospital's operations. Data from the system, on the other hand, can be gathered, analyzed, and used for strategic management, including analysis. The Managerial Information System houses the information systems that sustain administrative, human resource, facility, and hospitality management operations. The Heath Information System should be able to share patient records with other health-care agencies through the Health Information Exchange, Data Warehouse, or other means in order to ensure quality of care. It is intended to contribute to the national health database by providing evidence for health promotion, disease prevention, and early warning campaigns, as well as preparation, resource utilization, epidemiology, case-mix calculations, and other activities at the district, state, and national levels. A computerized information system expands the range of data storage options. The ability to store data in a database from which pertinent data can be retrieved and manipulated to generate views and reports for particular purposes is a significant benefit[2].

Any hospital, as a complex healthcare unit, necessitates the coordination of many divisions in order to provide high-quality medical services on schedule. As a result, it prevents the use of familia management techniques. A hospital healthcare unit, like any other large company, requires a comprehensive management structure that

is flexible, data-driven, and creative in order to operate properly. The conventional method of keeping paper-based medical records, for example, is not only inconvenient but also time-consuming. Furthermore, it raises the possibility of mistakes and incorrect recording. As a result, nearly all hospital health-care departments are now enthusiastic about introducing innovative management schemes. A hospital management system is an excellent method for resolving any issues related to data recording and access. Regardless of whether it is used in an organization or a healthcare unit, an information management system has evolved in recent years. This is due to the fact that computerized management systems (CMS) are designed to provide an ever-expanding set of capabilities. As a result of these capabilities, hospital management systems are still widely used in all aspects of the healthcare industry around the world. In reality, among healthcare providers, health systems, and hospitals, the use of a common level of information management system has now become increasingly prevalent and imperative. In a healthcare unit, a computerized hospital administration system has not developed dramatically into a more digital healthcare infrastructure. Modern healthcare infrastructures are digitized, and they are in charge of handling, storing, and incorporating massive amounts of revenue, clinical, and organizational data. This data is created on a daily basis in today's healthcare system in order to improve the system's effectiveness, safety, and quality. Electronic health records, or EHRs, for example, are continuously improving healthcare management. This makes it easier for all healthcare practitioners to have access to complete and up-to-date patient information[2].

A Laboratory Information System (LIS)

Laboratory information systems (LIS) have been essential components of clinical laboratory operations since the 1970s[3]. Originally, they were designed to collect, register, present, organize, and archive experimental findings, with an emphasis on producing data for proper laboratory financial management[3]. Although information technology as a whole is progressing at a faster rate, especially in the hardware domain but also in software development, LIS has not remained consistent.Health care systems in general can be characterized as conservative and resistant to change and current health care information systems (HIS) and LIS are a reflection of this conservative approach[3]. Despite the potential cost-savings and patient-care upgrades that a well-designed HIS/LIS can provide, most of these programs fall far behind the capabilities of modern information technology. In reality, some of these programs have flaws that most home and Web-based software has long since addressed, such as efficient navigation, quick response, and spell check. Modern clinical laboratories offer information to health care professionals in the form of laboratory reports, which may be figures, text, graphs, or other images, as well as interpretative data, to help them provide the best possible care to their patients.Clinical laboratories' knowledge has become more complex over time, and with the introduction of large-scale analytic techniques like microarrays and next-generation sequencing, the volume of data generated will quickly increase by many orders of magnitude. For these massive data sets to be clinically useful, advanced advances in data storage and bio informatics would need to be integrated into LIS.

Furthermore, data mining (the ability to query vast cross-sectional laboratory databases) is rapidly being used to increase the consistency and reliability of health-care delivery.These two trends necessitate an ever-increasing need for LIS and

supporting hardware in terms of power and processing. The focus of efforts to enhance laboratory operations is increasingly moving away from the analytic process, which currently poses little challenges, especially for experiments conducted by highly automated instruments, and toward the preanalytic and postanalytic phases of laboratory research. The aim of enhancing the consistency of the extra-analytic dimensions of laboratory research, including the application of paradigm-shifting creative methods, would require advanced LIS and related database and expert systems[4].

A laboratory information system (LIS) is a computer system that aids in the management of many areas of a medical laboratory, such as inputting, processing, and storing data and information. A laboratory information system (LIS) is a computer-based data processing system designed especially for labs. Although supporting the laboratory mission, a LIS is used to facilitate laboratory workflows as well as serve as a repository for laboratory data and they are usually used in standard reports. This information included in typical laboratory include[3]:

i. Visit's start date
ii. Primary care Doctor
iii. Patient demographics and relevant details
iv. The type of sample taken
v. Doctors test orders
vi. Who was charged with his visit?
vii. When his doctor received the examination results,

Hundreds of patients can visit a busy medical lab each week. Keeping all of this information organized can be complicated, but a LIS can help. An LIS aids in keeping all of this data coordinated, which is critical for a medical lab's smooth operation. The

aim is to effectively provide accurate and complete information to laboratory personnel, administrators, and patients by following four key processes: monitor laboratory information during the testing period, compile, store, catalog, and review laboratory data, submit test results for patient treatment, and report data to administration[4].

Types of LIS

There are two common types of LIS:

(1) a section of a hospital's information system (HIS) and

(2) a stand-alone LIS.

Inside HIS, a LIS is primarily used to record outcomes and a few primary data elements. The second machine, a dedicated LIS, has many of the same components as the first and can accommodate any of a laboratory's business processes. An LIS is a method that allows laboratories to collect, interpret, and process data. Laboratories can compile data from the LIS and provide timely reports for surveillance, program administration, and health policy development. As a result, the overall laboratory research process and data processing change, resulting in improved quality control and quality assurance. Areas of focus for the LIS include

i. Changes to the laboratory's workflow
ii. Creating management mechanisms like duty rosters
iii. Measuring and managing laboratory records
iv. Making certain all employees are well trained
v. Procedures for equipment maintenance

Computerized Hospital Laboratory Operations System (CHLOS)

A computerized hospital laboratory operation system is a type of health information that is primarily concerned with laboratory administration. A CHLOS is a

comprehensive information system designed to manage all aspects of laboratory operations, such as blood tests, urine tests, and the corresponding processes of services, in many implementations. The laboratory's management is concerned about the growing effort required to maintain patient laboratory records and diagnoses[7]. The use of a computerized hospital laboratory operation system, which can store patient and employee records as well as medical test results. It can also be capable of effectively managing the patient assessment track and patient reviews[6]. The computerized hospital laboratory operating system is a computer program that stores and manages data generated by health care personnel during their everyday health care routines[8]. It can also be used to monitor and manage services, such as laboratory staff and equipment. Integrating CHLOS is mostly intended to make the handling of a large volume of data in the laboratory easier. Because it uses quality management tools for process monitoring and optimization, this system is very risky for quality control and quality assurance programs. On the basis of research findings, accessibility, reliability and validity of data have a significant effect on the performance of a health information system and contribute to the quality of health care services.

The aim of a health care information system, according to the World Health Organization (WHO), is to establish systems to facilitate the efficient retrieval of patient information for patient care, data, educational, and scientific purposes[9]. Access to uniform data in a structured format is needed for health care providers to deliver proper and prompt patient services. Many research on the use of data in manual or automatic format, focus on the value of sufficient information quality for meeting the health care objectives, on the other hand, the type of information delivered by the system to the patient has a significant impact on the user system engagement and

consequently on the reliability and efficacy of the given service. An effective approach to improve the information quality of health care information system is standardization of the delivered information. The American National Standards Institute (ANSI) has established a systematic collection of laboratory information system standards[10].

1.2 Statement of the Problem

Manual processes involved in laboratory test retrieval, update and storage of information has led to loss of important data and wastage of appreciable time. Manual Laboratories systems are characterized with lack of immediate retrieval of Information which most of the times is very difficult to retrieve and to find a particular information from large junk of files which result in time wastage. Also, information generated by various test results takes time and effort to be stored and sometimes when stored manually, many vital information are lost and even cases of misplacement of results and misallocation of test result may emerge in the process. Prompt and accurate updating of various information like patient test result are difficult to make as paper work is involved. Hence, the development of hospital laboratory operation system support application which is aimed at using information technology to solve the problems associated with manual method of Hospital Laboratory Information System.

1.3 Aim and Objectives of the Study

The aim of this project is to develop a hospital laboratory operations support system

The specific objectives of this research are:

i development of a Hospital Laboratory Operations Support System with a Admin Registration page, Admin Log In, Add Client, Take Test, Send result via real time

email notification having a database for speeding up laboratory data processing, storage, and retrieval.

ii implementation of the developed Support System

iii evaluation of the developed system

1.4 Research Questons

In order to carry out this study, the following research questions were generated;

1. Will there be any difference in the waiting time of results between the developed laboratory Support System and the old Manual Process?

2. Will there be any difference in the way of management of laboratory Operations between the new Laboratory support system and the old Manual process?

3. Will there be any difference in the storage and retrieval of patient data and information?

4. Will there be any difference in the provision of adequate security on patient data and information between the new Laboratory support system and the old Manual process?

1.5 Hypotheses

The following hypotheses were formulated;

i. There is no significant difference in the waiting time of result between the developed laboratory support system and the old manual process.

ii. There is no significant difference in the way of management of laboratory services/operations between the developed laboratory support system and the old manual process.

iii. There is no significant difference in the storage and retrieval of patient data and information between the developed laboratory support system and the old manual process.

iv. There is no significant difference in the provision of adequate security on patient data and information between the developed laboratory support system and the old manual process.

1.6 Significance of the Study

The desire to upgrade and deliver effective patient and laboratory facilities has resulted in a growth in the usage of information and communication technology-based technologies in the healthcare industry, so a computerized hospital laboratory operations system is critical. This is attributed to the growing population and the need for high-quality healthcare. Additionally, instances of repeated opening of folders for the same patient due to failure to track prior details would be eliminated, misallocation of test results would be resolved, and laborious and time-consuming efforts in retrieving patient files depending on registration dates combined with overburdened laboratory workers trying to sort through or scan for patient reports would be significantly reduced. The developed model will increase productivity, effectiveness, appropriateness, efficiency, quality, safety, privacy and confidentiality of laboratory information.

Moreover, the result of this study will serve as an eye opener to both public and private laboratories on the use of Information Technology in optimizing an effective, efficient and seamless laboratory management. Also to the patients, it will reduce their waiting time and the mismatch of results will be eliminated, thereby increasing their confidence in the laboratory analysis.

Academically, the result of these findings will serve as a reference material for projects on open source and less costly App development, computerized health management and other related researches. Findings of this research can also serve as a theory for other related studies.

1.7 Scope of the Study

The scope of this study will be to design a web based computerized hospital laboratory operations' system support application. Also, the design will be experimented in a laboratory for testing and validation.

1.9 Limitation of the Study

The majority of the tools used in this research are open source. Hence, other cost related applications may give a better performance and results. Also the choice of network for internet connectivity can be a limitation, since the design is a web based and solely dependent on the internet speed and choice network.

1.9 Operational Definition of Terms

Software: Application to supports healthcare professionals with handling day-to-day processes including staffing and billing

ElectronicMedical Record: A computer-based electronic (digital) record of a person's medical information.

Information Technology: Involves the use of computer and information system that supports and enhance the operations of a hospital.

Laboratory: A facility that maintains controlled conditions for the conduct of scientific research, experiments, and measurements.

Computerization: The method of transforming manual operations to digital-based operations through the use of computer software

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Chapter Two

Literature Review

2.1. Conceptual Review

Computerization is the method of transforming manual operations to digital-based operations through the use of computer software[1]. Additionally, it can be described as a method of automating manual processes in various sectors to allow them to perform their duties more efficiently and accurately, thereby reducing stress and delays associated with performing their duties efficiently. As viewed through the lens of the modern world, it is critical to have a computer-based system in place to handle manual calculation, which can be considered a human-based capability, and to reduce bulky paper work, time constraints associated with control activities such as processing, increase productivity, avoid data redundancy, and reduce paper work and data processing[1].

However, there are several advantages to computerizing any given system within an organization. The significance of computerization entails the benefit of a computer-based system supplanting the manual process traditionally used[1].

1. Accuracy: the computer's operations are extremely precise. The system-written software verifies and controls data both before and during processing.
2. Speed: Computerization enables the processing of data stored in several data files without wasting time. This is made possible by the computer's high speed
3. Storage capacity: Due to the large storage unit in the computer system, a large amount of data can be easily processed, accessed, and updated.
4. Easy correction of errors: there are some minor errors that occur during data entry and can trigger problems within the establishment. By using a computerization system,

common errors can be easily traced and corrected by utilizing certain system-verified commands to ensure that the data is entered correctly.

5. Easy access: data in a computer-based system can be easily searched and accessed through search engines, which is difficult and frustrating in a manual system. In the late 1970's, managing laboratory samples, related research, and reporting needed a time-consuming manual process prone to human error. It aided organizations in streamlining their data collection and reporting processes. Several independent laboratories developed their own custom solution, while some enterprising companies sought to create a more commercial reporting solution in the meantime, a subset of systems focused on special instructions. Prior to 1980, there was a state of confusion about the compilation and organization of patient records. They were using a manual method, which necessitates additional time and effort and provides less precision. In 1982, a group of laboratories and experts collaborated to develop the first system for facilitating and organizing all patient information in the laboratory, which was a centralized minicomputer[2]. Numerous factory owners in this system welcomed this and aided in the development and production of laboratories during this time period. By 1988, commercial offerings of the second generation were using relational databases to extend LIS into more application-specific territory[3]. In 1982, the first generation of LIMS was launched, providing laboratories with the ability to use automated reporting tools via a centralized minicomputer for the first time. By 1988, the second generation of commercial products had been integrated into a digital database, allowing LIMS to be expanded into a new application. The unique territory and international LIMS conferences were in full swing at the time[3]. By the 1990's, a third wave of LIMS had entered the industry, capitalizing on the emerging client/server architectures[3]. This LIMS enables laboratories to perform data analysis

and exchange more efficiently. Between 1995 and 2002, the system was designed to allow data exchange between processes on a network. In the 1970s, the LIMS entered the market and became widespread as a consequence of U.S. Federal Government Regulations[32]. In the early years, a LIMS was very costly and was altered for every establishment using the in-house personnel or a software vendor. More lately, around 40 vendors offering LIMS software have possessed the capacity to plan the frameworks with enough capabilities to address the issues of most research laboratories[34]. Additionally, the device waswirelessly connected to other networks, allowing for the sharing of files both within and outside the hospital. Finally, the system's most recent version in 2012 was labelled to include some features that will be discussed later[2]. In 1996, a web-enabled LIMS with wireless computing capabilities was launched, and in 1997, in response to USFDA CFR part 11 rules on electronic records and signatures, a new electronic signature feature was added to LIMS. In 1998, LIMS introduced web-enabled Global Positioning Satellite (GPS) technologies for georeferencing sample location during collection, and also XML was recommended by industry as application-specific markup languages, such as chemical markup language (CML) In 1999, the first application service provider (ASP) for LIMS was launched; it could be purchased on a monthly basis and accessed through the internet via a secure line from the LIMS vendor; and in 2000, the first fully XML-based LIMS was introduced on 0icroso's. In 2002, the Internet portal was launched[3]. RDLIMS (relational database laboratory information management system) was created in 2003 to control staff, facilities, equipment, and instruments. Various LIMS were available on the market until 2004, but they were unable to meet all criteria for flexibility and process connectivity.

In 2005, LIMS was created using open-source tools, PHP, and MYSQL. PHP is a hypertext processing language that is well-suited for use on the internet. MYSQL serves as the backend of the LIMS, storing and managing the associated data[3].

In 2006, a LIMS with safe, versatile open database access was needed to develop and maintain a comprehensive protected electronic tracking system. During this time period, LIMS were introduced using a Java program and a Postgres SQL database. In 2007, LIMS embodied the workflow layer of hierarchical operation automation across open system architectures, enabling client/server capabilities and enterprise-wide access to lab data[3]. In 2008, LIMS were implemented in Java, a platform-neutral open-source programming language, and built on the 0icroso Windows platform, which was tested with Windows XP and SUSE Linux. In 2009, the emphasis was on making LIMS more user-friendly, and several other fields began using it as a facilitator for their technology. In 2010, LIMS placed a premium on offering a user-friendly and integrated data management system for efficient laboratory management[3]. As of 2017, LIMS are plentiful in terms of consistency and acceptance but are not the norm due to the costs and challenging existence of vendors converting traditional goods and businesses attempting to incorporate a modern-based LIMS into a complicated setting[3].

A Laboratory Information Management System (LIMS) is a computer or computer network belonging to the class of application software system envisioned for the management and storage of raw data which is required for analytical purposes. In the initial development stages, it tracked the samples and tests performed in the analytical laboratories and enhanced the status of the samples and test results. Moreover, now, in the latest versions, the LIMS system is interfaced with the laboratory instrumentation and the subsequent communication networks that allows the complete automation of

the data compilation, and generation of reports[34]. In a completely mechanized Study & Development of LIMS Web Platform Application laboratory, a sample is logged into a LIMS system, at a point of exchange to the laboratory, where it is arranged for analysis or analyses, and later moved to auto sampler or analyzer. Once it is analyzed, the information is exchanged through a gadget which subsequently translates the raw data into information that a client requires. Furthermore, the interpreted data is reduced, and the LIMS further becomes a repository of information[35].

2.1.1 Laboratory Data Management System

The Laboratory module is a web-based electronic platform with a high degree of usability and ease of use that is used in single clinics and polyclinics[2]. It is a comprehensive management system that manages all aspects of the business, from patient management to results generation and physician decision-making. The framework allows simple data interaction as well as the ability to update data. It is one of the most dependable systems in terms of placing orders and then delivering accurate results stored in databases. Additionally, the device communicates with and shares data between hospitals and clinics about (the status of infection, immunology, and treatment andpatients' medical status) [2].

Figure 2.1: Departments linked with the LIS system

(Source: Speedspath, 2018)

Hematology, chemistry, immunology, blood bank (Donor and Transfusion Management), surgical pathology, anatomic pathology, flow cystometry, and microbiology are among the laboratory science disciplines supported by LIS[2]. Numerous institutions, including nursing homes, surgery centers, home health agencies, clinics, hospitals, and medical laboratories, use the LIS to manage their healthcare files. The system's primary objective is to simplify data management by storing the results of data storage, facilitating access to them, and enabling them to be updated at any time. Additionally, it manages the authority to access patient information in order to protect their privacy[2]. Numerous hospitals and laboratories are burdened by a mountain of patient records and files. Additionally, when renewing transferred papers from one department to another, it is possible to lose a large number of documents or papers, some of which are critical. LIS is a term that refers to the process of creating a paperless environment while maintaining a digital database. A local server or a virtual server may be used to store all files and records. This approach simplifies the process of saving, migrating, and recovering data in the event of a loss[2].

Additionally, it optimizes the medical center's use of medical services. Because the system was designed and developed by laboratory experts, it is linked to a medical central system, allowing data to be exchanged and staff performance improved through more accurate information and fewer errors. The framework provides input to users when they operate on it and notifies them when errors occur. As a result, the efficiency of medical care outcomes is increased. Additionally, the laboratory workflow process can be monitored and controlled using the LIS. Users can perform tests inside the laboratory control samples to provide accurate results on time, such as when entering the sample and transporting it to the laboratory. The LIS will recognize

the patient's data and associate it with the sample. This approach saves workers time and effort in obtaining comparative data and test results for a patient[2].

2.1.1.1 LIS Requirements

When developing processes for labs, hospitals, and private clinics, it is essential to consider what ensures job efficiency and process completion. There are measurements and criteria that assess the whole system, as well as tests that assess individual components. These discrete components are either software or small networks that are integrated into the system. A group of experts may decide to establish clear criteria for evaluating laboratory systems' performance. The primary objective of these standards is to achieve high management performance, protection, and a low rate of errors. There are five primary criteria for evaluating a system, and numerous additional criteria for evaluating specific aspects of the system, such as user satisfaction, consistency, scalability, and usability[2].

2.1.1.2 The LIS Procedures

This is a multi-stage method in which samples and applications are processed. Requests can move through multiple systems during the course of a single operation. Certain systems in hospitals and laboratories are big, broad, and complex and it can take days to determine the results of a sample. The amount of time required to evaluate the sample varies according to the duration and pace of the process.) [2].

Request for Analysis

When a patient is referred to a laboratory by their general practitioner, physician, hospital, or clinic, they present evidentiary material and a specific request for review by approved staff from the responsible jurisdiction. After reviewing all records, the team enters all patient data and samples for analysis into the system[2]. Gathering and

Submitting Evidence

Following the presentation of evidence, all patient data will be manually or electronically entered into the LIS. Additionally, the patient's personal information will be stored in databases and connected to the sample data. Following that, workers can quickly add, erase, and update information about all patients.

Login to Access Evidence

After collecting all of the patient's personal data and associating it with a data sample, the device generates a unique code for the sample patient that is used during the study period. Each sample is assigned a code by the system, which keeps track of the time and date of entry and generates reports during the study. This approach provides greater protection for the patient since the staff handles samples according to their codes and does not know who owns them[2].

Sample Distribution

The system should assist laboratory staff (particularly section directors and analysts) with work lists, routing orders, scheduling review, marking, and chain of custody logging.

Analysis Schedule

The capability of the system to schedule analysis based on workload and resource data. Additionally, the method leverages previous research to aid in the development of highly efficient analytical tables.

Analyze

The system should provide measurement and result in the capture, reporting, and quality control processes for research planning procedures, test measurements, calibrations, and quality control processes.

Prepare a Sample

Certain samples require additional analysis measures to ensure the precision, efficiency, and consistency of the findings. The system keeps track of the preparatory steps required for analysis of the sample. This approach allows for greater versatility in dealing with the analysis and decision measures, depending on the sample size required.

Verification and Adjustment

The majority of analyses need confirmation by another expert. This specialist reads the sample results and modifies them, as well as the work notes, if any numbers are vague or odd. The specialist incorporates both amendments and comments and then re-analyses them. Re-analysis of samples is performed exclusively by experts, who have access rights that laboratory personnel do not.

Reporting

The device generates reports for samples at various levels of study. Each sample report is identical to the others. For instance, the blood test report ID is distinct from that of other reports. The device generates both electronic and paper records.

Contextualization

The final conclusions reached by the analysts based on the test procedures are included in the final report, and the framework should allow analysts to provide their conclusions based on the scientific review[2].

Sample Materials Disposal

After the analysis is complete, the device must dispose of the materials used during the analysis. The device generates information on the location and quantity of materials used. During the study, the device alerts the analyst to the presence of surplus and asks if he or she should dispose of it or return it to the stock.

2.1.2 LIS Characteristics

The system is composed of a core collection of components that contribute to the development of sound environmental management. It includes features that allow the device to incorporate ingredients that are appropriate for the hospital or laboratory's needs. The device incorporates features that are desired by a large number of private and public laboratory owners[2].

Laboratory Inventory and Storage Management; there are several methods for managing patient information and data that differ by device. The system incorporates a bar code reader at the point of sample submission to laboratories. Each sample has a barcode, and when the barcode is read, the system automatically takes all the patient's data into the database, and when the barcode is added, the system automatically changes the patient's data in the database. Additionally, the machine prints reports and maintains records of check samples, as well as provides signals and warnings. When minor issues arise, the device does not wait for the consumer to resolve them but instead proposes acceptable solutions. All of these features provide management with versatility, are quick to understand, and result in less errors.

Security: LIS provides laboratories with a safe platform for collecting, authorizing, archiving, retrieving, reporting, and analyzing their data. With click monitoring, version control, and electronic signatures, the system enables full updating and traceability. It grants unique individuals access to patients' data and information. For instance, laboratory staff handling the samples has no knowledge of the patient's details. They only have access to a sample of data.[2] Workflow Management; prior to implementing a LIS framework in a medical organization, it is essential to consider the processes used for sample processing and patient data management. Following that, LIS will be configured to work with the laboratory's legacy scheme. This

approach improves the staff's experience and requires less time to learn because it is almost identical to the previous process with features. Additionally, users can identify their own meta-data by including images, files, or hyperlinks. The LIS workflow component's queuing functionality also assists in handling review requests from other systems, balancing them, and automatically queuing the associated samples, instruments, and analysts. Users can control workloads according to analyst and instrument, as well as schedule samples for testing in order to maximize workload performance. Additionally, the workflow function collects security details, such as electronic signatures and document changes for version control. It enables the system to be audited and ensures compliance with regulatory requirements[2].

Data analysis: in a laboratory or analysis setting, there are a plethora of digital data, some of which might be identical to other data. This makes it more difficult for the consumer to interpret and locate the necessary numbers and differences. However, the LIS framework includes a set of functions that facilitate data analysis and mapping. Users can display data through the system's data visualization software. This method produces the most precise show, as well as the simplest and fastest results.

Monitoring the laboratory environment: laboratories often contain hazardous materials that are toxic to humans and are used to test samples. It is important to have a safe working environment in order to maximize productivity. The LIS offers environmental monitoring capabilities and can assist in corrective and preventative actions by producing reports on who used products and instrumentation, whether they followed procedures/SOPs or not, and when they did. Additionally, in laboratories that handle environmentally sensitive materials (such as those located in warm environments), the device provides signals and warnings when pressure or an error occurs[4].

Laboratories and hospitals generate a great deal of waste, and these samples are often classified as sensitive material or patient samples. The device generates reports on the quantityof the materials and samples used in the study, as well as the system's emission rates.This approach enables laboratories to more effectively manage their environmental effects. The device is eco-friendly, requiring less samples and materialsthose who generate less ratios and waste reports. The majority of LIMS systems store data in a database management system (DBMS). Commercially accessible database management systems include DB2, DBASE, Informix, INGRES, ORACLE, and RDB. Relational Databases are capable of storing an infinite number of results for each pattern and an infinite number of samples for each order. The advantage of a relational database management system over a more traditional hierarchical device, in which records units may include other data sets, is that thedatabase structure only needs to remember relationships between data elements, not the range of values for any given variable[4]. A database management system (DBMS) implements what is known as transaction control. This method enables many customers to access and store data within the database without affecting the integrity of the data. This capability is critical when data is written to the DBMS, as power outages or hardware failures will result in database transactions being handled incorrectly. Transaction managers adhere to the "all or none" principle; either all statistics are written to the DBMS, or none are written at all. Another critical capability of a LIMS database management system is the ability to conduct ad-hoc database queries. While the LIMS is being developed, it is impossible to anticipate all the ways in which LIMS users may need to present their data. As a consequence, it is much preferable to choose a LIMS that enables users to identify their own reports. The majority of commercial database management systems (DBMS) support a

structured query language (SQL) interface. SQL is a straightforward database query language that is largely based on English language commands[4].

2.1.3. New Technology's Effect on LIMS

Computer hardware costs have decreased dramatically over the years. As a result, electronic systems have become more open to the general public. The improved implementation of innovation allows the provision of more practical capability in smaller, more affordable machines. Advances in network operating systems (NOS) include the database server and concurrent (shared) data processing capabilities needed to support LIMS operations across a network of computers. Previously, this was only possible with an integrated handling model, as seen in conventional minicomputers and centralized servers. The cooperative network model, also known as peer-to-peer processing, distributes data and processing through a network. This enables the construction of expandable systems. Each machine's independence eliminates flaws inherent in the centralized model, such as a single point of failure and high startup and maintenance costs. Peer-to-peer networks were thought to be more manageable and simpler to run. This is not immediately clear, as the appropriation of information needed for autonomy enables systems to store data incidentally and forward it to a central location for access by other device nodes. As a result, not all information is available in the same location at the same time, making successful organization difficult for all but the smallest, most customized systems[5].

Another notable consequence of emerging technologies is the commercialization of the client/server computing paradigm. This model incorporates a more efficient computer for data storage and recovery (the server), which is connected through a network to the client workstations. Client computers are responsible for interacting with the user interface and for authorizing communication and data transfer to and

from the server[4]. The majority of consumers are personal computers or other graphics-capable devices (such as windows terminal). Processing can be dispersed within a highly unified, stable data storage system using this model. Client/server architectures provide a structure that retains the uniqueness of the obliging network (peer-to-peer) computing model while becoming highly open, safe, robust, and manageable. It also benefits LIMS users by providing a graphical user interface (GUI) in which machines, file systems, and programs are classified using simple icons, providing a familiar atmosphere while concealing network and server intricacies[4].

The client/server model often permits informal integration with other network applications (e.g., finance, project management, or human resources) that operate in the environment of the client/server system's server portion. Client/server can be gradually integrated into an established minicomputer environment, often with little negative incremental impact on reskilling and additional expenses[4]. PC workstations have improved in terms of performance and ease of use, and are now ubiquitous in both office and laboratory settings. Utilizing Windows- and Mac-based software that is now commonly available on instrument data stations as the basis for the LIMS reduces training costs and investment requirements when implementing a LIMS[4]. Important networks for peer-to-peer LANs often exist in some form as a result of other office integration efforts. The existence of these networks will frequently reduce the cost of implementing a LIMS by leveraging the reusability of existing laboratory systems and networks[7].

Databases are becoming more consistent, allowing for the addition of more functions to a LIMS and the easy integration of international systems, such as project accounting. As a result, the desktop and client/server models are expected to expand in the future in terms of the percentage of LIMS product contributions and installation

base[8]. The advancement of instrumentation has increased the capability and accuracy of the fundamental analytical techniques used in aggregation with LIMS. These advancements come at a cost in terms of accumulated complexity and volume of data[9]. Despite all of the architectural and technical advancements in computer hardware and software, the demands of information requirements continue to surpass computational capabilities, exerting ongoing pressure on computer manufacturers to further increase storage and processing capabilities. Modern analytical instruments tend to produce results that are not compacted into the single-valued outcomes that are easily entered into LIMSs. Numerous newer instruments produce extremely complex results in the form of tables, spectra, images, or multi-dimensional associations that are difficult to represent in databases using the relational model used by the majority of current LIMS[8]. There are several options available, ranging from using a non-numeric completion characteristic that may refer to a secondary computer file containing the multifaceted results (this file may or may not exist on the same computer as the LIMS) to treating the multifaceted results as single objects and progressing to the use of object-oriented database tools to accomplish the anticipated information within the LIMS itself[6]. In the short term, integration with existing file and record management systems can be used to simulate the experience of an object-oriented database (OODB).

Though data acquisition has improved, standards remain deficient. As a result, data collection becomes the most time-consuming and challenging aspect of the global LIMS implementation. The time savings associated with automated data capture are typically considered to be important, despite the difficulties. Except in chromatography laboratories and other environments with more uniform instrumentation, the data acquisition portion of a LIMS implementation is more likely

to be a custom integration creation project. This results in a relatively stable structure that can be adversely affected by deviations from fundamental analytical subsystems (upgrades)[4]. Although efforts are being made to develop uniform standards for information exchange between analytical instruments and external (host) computers, the instrumentation market's diversity and competitive nature tend to stymie these efforts, resulting in an environment of constant change and a critical need for new and unwritten programs to link LIMS and automated instruments[10].

Clinical laboratories in the modern era are information suppliers, providing laboratory findings in the form of numbers, text, graphs, or other images, as well as interpretive data to assist health care providers in providing optimal patient care[11]. The complexity of the data generated by clinical laboratories has increased over time, and with the advent of large-scale analytical techniques such as microarrays and next-generation sequencing, the amount of data generated would rapidly increase by many orders of magnitude. For these large data sets to be clinically useful, advanced developments in data management and bio informatics must be integrated into LIS. Furthermore, the capability to query large cross-sectional laboratory databases (data mining) is increasingly being used to enhance the quality and efficiency of health care delivery. These two trends necessitate an ever-increasing demand for LIS and supporting hardware capacity and processing power[11].

The emphasis of efforts to improve laboratory operations is increasingly shifting away from the analytic phase, which currently presents few problems, particularly for tests performed on highly automated instruments, and toward the preanalytic and postanalytic phases of laboratory testing. Advanced LIS, as well as associated database and expert systems, will be critical to achieving the goal of improving the

quality of non-analytical aspects of laboratory testing, including the implementation of paradigm-shifting innovative approaches.

2.1.3.1 Information Security

Health care information systems must be protected from unauthorized internal and external access and must maintain the confidentiality of health records in accordance with applicable law and regulation without impairing legitimate users' functionality. For example, health care providers should have access to all pertinent information about their patients but not to that of other patients unless they are consulted. Individuals who are responsible for evaluating the quality of care should have access to certain patient data. Different levels of security should be available, and the system should enable users to form work groups with user-defined sets of functions and data access[11].

Secure interfaces to the LIS should include advanced login capabilities, such as biometric recognition or radio frequency identification devices (RFIDs), which minimize keystrokes and log-in time while automating log-out upon workstation exit. In certain secure locations, the system should be capable of continuously displaying live laboratory test results (e.g. pending"STATs" in the laboratory or patient results in the operating room) without requiring multiple log-ins. The system should support remote login and access to ordering and reporting systems, for example, via a secure Web browser, enabling providers and laborators to access the LIS from any location and via mobile and tablet devices.

The system should support a variety of flexible, reliable, and informative electronic signatures for data and document authentication.

2.1.3.2 Test Ordering

The ordering of tests is the most amenable to intervention in order to optimize laboratory resource utilization (laboratory utilization). Test-ordering systems in conjunction with intelligent decision-support systems have the potential to reduce turnaround times and length of stay, as well as guide providers toward optimal test utilization,[11] and can be a function of either LIS or HIS, or sit on the LIS/HIS border. Appropriate specimen collection and processing are critical to the quality of laboratory results, which adhere to the well-known adage of "garbage in, garbage out." An ideal LIS should include the following functionalities to optimize specimen collection and processing:

1. Lists of specimens collected in accordance with institutional requirements. For instance, the system generates the appropriate list of patients to be collected for each phlebotomy round to a set of locations, along with preprinted accession labels. The list should indicate the most efficient path to each patient, taking the desired testing priority into account.

2. The system assists the specimen collector by displaying proper specimen collection instructions online or in print, in an easy-to-follow format with hyperlinks to a thorough examination.

3. The system can display a list of pending laboratory orders to the collector and generate unique bar-coded or RFID labels at the bedside upon scanning the patient identification wristband or other unique physical patient identifiers. At the time of collection, labels should include a minimum of two patient identifiers, the date and time of collection, the collector's identity, the urgency of the order, and, to the extent possible, abbreviated names for tests requested. Utilizing two-dimensional bar codes or RFID labels enables the specimen to be labeled with a greater amount of

information. When the specimen is received in the laboratory, the system should be able to identify it by scanning the labels attached to the specimen container and initiate testing without further human intervention, if applicable, such as in a robotic specimen-processing automation line.

4. In addition to automatically recording patient information, the location, the date and time of collection, and the collector's identity, the system should allow the collector to enter pertinent information in either codified or free-text format that may be necessary for the proper performance and interpretation of certain laboratory tests.

5. The system should be capable of bidirectional communication with portable devices for patient identification, specimen acquisition, and point-of-care testing, including the ability to transmit data via wireless connections. Results from point-of-care testing should be combined with those from primary analyzers to determine their source.

6. A point-of-care test management system should be available to track instruments, reagents, quality control, as well as user identification, training, and competency records.

7. Separate records should be maintained for specimen accessioning (ie, matching an order to a physical specimen), specimen receipt in the laboratory, and specimen activation for analysis. For instance, a phlebotomist scans the patient's bar-coded wristband and selects an appropriate pending order; the system logs the collection time and accessiones the specimen; and the phlebotomist prints an accession label using the portable device carried by the phlebotomist. In the presence of the patient, the specimen is collected and labels are attached to the specimen container. When specimen accession labels are received at the laboratory reception desk, they are scanned to confirm receipt and then transported to the laboratory's analytic section.

When the specimen is placed on an automated robotic specimen processing line, the labels are scanned once more and the accession is activated for analysis. Alternatively, the final two steps may be combined and specimens scanned and activated prior to being placed on a robotic track. Thus, laboratory turnaround time can be segmented into time spent from order to collection to accession to receipt to activation to reporting. The final component (activation to report) represents the analytic time period, whereas the preceding components represent the preanalytic period. It is critical to distinguish between the various components of turnaround time, as the laboratory frequently has complete control over only the receipt-to-report processes. Using these time points, "incomplete lists" can be focused on pending orders, on specimens received in the laboratory, or on accessions ready for analysis exclusively.

8. The system should accommodate deviations from the above-described sequence of specimen processing in accordance with institutional policy, such as: (a). Without an order or accession, but with the appropriate patient identifiers, specimens are received in the laboratory. The system should acknowledge receipt of these specimens in the laboratory, pending the arrival of a matching order. The laboratory staff should be able to enter a paper or verbal order into the system in specified circumstances. (b). Identified specimens received in the laboratory pursuant to a written or electronic order but without accession labels. The laboratory acknowledges and verifies the order and specimen's appropriateness, and then accessions and labels or RFID tags the specimen appropriately. (c). The system should be capable of accessioning and processing non-patient specimens, such as animal, research, or environmental specimens that are unrelated to a patient, as well as performing quality control and validation supplies, and most importantly, proficiency-testing supplies. The system should enable authorized personnel to assign proficiency-testing materials to one of

numerous unique virtual patient identities, concealing the specimens' status as proficiency-testing materials from the analyst performing the test[11].

9. The system should be capable of de-identifying and codifying specimens for research purposes, as well as managing biobanks and tissue repositories' databases.

10. The LIS should communicate with laboratory automation management software to ensure that all preanalytic requirements specified during the ordering process are communicated to the specimen processing system (e.g., centrifugation speed, time, number of aliquots, reflexive testing).

11. The system should be able to track the specimen's location throughout the preanalytic, analytic, and postanalytic phases, including transportation to various sections of the laboratory or external sites, and specimen storage management[18]. The latter includes functionality for quickly retrieving the precise specimen storage location and periodic reports to facilitate batch specimen disposal.

12. The system should be capable of creating multiple specimen aliquot labels that can be scanned in order to conduct the appropriate testing on each aliquot. This capability should include tracking and archiving multiple aliquots and slides derived from a single specimen.

2.1.3.3 Phase of Analysis

The analytic phase has been the focus of the majority of technological advances in clinical laboratory science and is typically associated with the lowest rate of laboratory error. Additionally, it interfaces with specimen handling and analytic instrumentation software (often referred to as middleware) to streamline the processing of analytic requests—including the ability to route testing to the appropriate instrument based on workload, recall specimens for repeated testing,

direct specimen dilutions, perform reflexive testing, process add-on requests for additional tests, and reprocess specimens

1. Keep track of and associate all components necessary for testing with individual testing records, particularly for manual assays and methods involving laboratory-developed reagents. The details should contain information about reagents and other test components.

2. The analyst can easily view or print the appropriate standardized operating procedure for each test (particularly for manual assays), which is managed by a document control system.

3. Each patient evaluation is recorded using the testing instrument, which has the capability of alerting the scheduled maintenance and support to the customer. If the laboratory so specifies, the instrument manufacturer should also be notified automatically.

4. The system should generate laboratory-specific workload lists ("worklists") to facilitate batch processing and analysis of manual and automated tests, as well as to track uncompleted orders. If additional specimens are received after the creation of the worklist, the worklist should be expandable via bar code or RFID scanning.

5. "Incomplete lists" of tests that have been accessed but not completed, highlighting those that have exceeded the specified time for the requested category, should be displayed on demand, as well as on continuous report screens, if desired. Similarly, lists of incomplete or unfilled orders should be available on demand or according to a schedule, with the ability to pinpoint the point at which the failure occurred. Tests sent to reference laboratories should be included in incomplete lists. A continuous display of emergency room orders that have not been completed within a predefined time frame, possible with color coding and/or sorting by age of request, to alert staff

to investigate and process orders or specimens that are at risk of exceeding acceptable turnaround time thresholds, is an example of an incomplete test display with significant clinical impact.

2.1.3.4 Entry and Validation of Results

The LIS should not only store laboratory results generated during the analytic process, but should also guide analysts toward producing high-quality results that are accurate, reproducible, and appropriate for the clinical situation. The following are desirable functionalities for result entry and validation:

1. Capability to store results in a variety of data formats, including numbers, text with extended characters, and images, using a data storage strategy that avoids restricting the size of data.

2. Automated and manual results entry and correction for tests conducted in interfaced or non-interfaced analyzers, as well as manual tests, with acceptable security levels applied. Person result entry should be supported, as well as batch result entry, batch entry by exception, amended results, and appended results. Final and intermediate results. Individual tests or panels with user-defined panel configurations may be used to enter results.

3. The system should support several levels of outcome certification and the right to withhold results before they have been accepted by a higher-level consumer, such as a supervisor.

4. The system should be able to obtain results from other laboratories, including external reference laboratories, in a variety of formats, such as tables and graphs, through electronic interfaces, allowing for seamless incorporation of all laboratory results into the electronic record. A situation in which such a combination of data is highly appropriate is in the diagnosis of leukemia, where clinical data in conjunction

with hematology, hematopathology, molecular, and flow data are often required to make an accurate diagnosis.

5. The framework should be capable of performing auto validation of outcomes using advanced expert decision support. Auto validation eliminates the need for human interference in the certification of laboratory results and is a significant driver of laboratory performance improvements[12]. The more advanced the device used to conduct auto validation, the lower the likelihood of reporting an incorrect result and the more time available for a human expert to test exceptional results. The following inputs are used to arrive at an auto validation decision:

a. Contrast with the outcomes of previous tests reported in the patient's medical record (temporal delta checks).

b. Comparison to the findings of other closely related experiments performed on the same or similar specimens (cross-sectional check). Consider creatinine versus urea.

c. Examining the specimen for hemolysis, lipemia, or icterus under predefined limits.

d. Clinical data, such as demographics, facility type (inpatient versus outpatient), conditions, prescriptions, and procedures.

e. External and internal quality management performance.

f. Statistical evidence on the distribution of outcomes

6. The ability to conduct temporal delta checks should include the review of temporal data and the estimation of rates of change as well as absolute adjustments in comparison to predefined limits that may differ according to patient clinical details such as demographics, diagnoses, and treatments[11].

7. The expert system should be able to order reflexive testing based on outcomes interpretation and clinical data, as defined by institutional or laboratory policy and

customized by the ordering provider, communicate with specimen processing and analytic systems, and append appropriate codes or comments to the results[24].

The analytic process has been the subject of the majority of technological advances in clinical laboratory science and is usually correlated with the lowest rate of laboratory error. Additionally, it interfaces with specimen handling and analytic instrumentation software to streamline the processing of analytic requests, including the ability to route testing to the appropriate instrument based on workload, recall specimens for repeated testing, direct specimen dilutions, perform reflexive testing, process add-on requests for additional tests, and reprocess specimens.

1. Keep track of and associate all components required for testing with individual testing records, especially for manual assays and methods involving laboratory-developed reagents. The details should contain information about reagents and other test components.

2. The analyst can easily view or print the required standardized operating procedure for each test (particularly for manual assays), which is handled by a document control system (see below).

3. Each patient evaluation is recorded using the testing instrument, which has the capability of alerting the scheduled maintenance and support to the customer. If the laboratory so specifies, the instrument manufacturer should also be notified automatically.

4. The system should generate laboratory-specific workload lists ("worklists") to promote batch processing and analysis of manual and automated samples, as well as to monitor uncompleted orders. If additional specimens are obtained after the development of the worklist, the worklist should be expandable through bar code or RFID scanning, additional specimens' tags.

5. "Incomplete lists" of tests that have been accessed but not completed, highlighting those that have surpassed the specified period for the requested category, should be shown on demand, as well as on continuous report screens, if desired. Similarly, lists of incomplete or unfilled orders should be available on demand or according to a timetable, with the ability to identify the point at which the failure occurred. Tests submitted to reference laboratories should be included in incomplete lists. A continuous display of emergency room orders that have not been completed within a predefined time period, possible with color coding and/or sorting by age of request, to warn personnel to examine and process orders or specimens that are at risk of reaching appropriate turnaround time thresholds, is an example of an incomplete test display with significant clinical effects.

2.1.3.5. Result Distribution

The system should be capable of generating a variety of reports for use in patient care, including standard and user-defined reports that are organized by test, test party, date, and date, span, ordering provider or provider party, clinic or specialty, cumulative worksheets in sequential or tabulated format, and the following additional capabilities

In addition to the actual value calculated, numeric test results should contain the following information (which may be optional or obligatory, depending on the situation):

1. Measurement units
2. Interval of the relevant reference population's reference population (user-configurable by a variety of clinical inputs, including ambulatory versus recumbent, sex, age, race, body mass, gestational age, menstrual cycle phase).
3. An indicator of uniqueness should be shown to assist in interpreting the reference set[25]. For measures with a high degree of individuality, where within-subject

variability is significantly less than between-subject variability, a note should be included indicating that individual-based reference changes are preferable to population-based reference intervals. For tests with a high degree of individuality and patients with sufficient recorded data, the method should be capable of calculating and displaying an individual-specific reference set, such as the central 90% of previous outcomes, with the consumer or expert system having the ability to remove from the calculation results clearly associated with disease.

4. Confidence interval for the results, based on observed analytic variability at a given stage alternatively change values, that is, the interval around the result caused by analytic imprecision, within-subject biologic variability, and the number of repeated tests performed[25,27]. The user should be able to customize the reference change value interval by selecting a confidence level (e.g., 95 percent) and the appropriate Z-value for decisions involving. Flags associated with results are usable, and users may define their own thresholds. e.g. Analysts' pertinent remarks.

Flexible And User-Configurable Report Production For Both Producers (Laboratorians) And Recipients (Providers, Patients) Of Test Information.

Reports should be accessible through a number of methods, including user-configurable automatic secure faxing, emailing, and other electronic text transmission mechanisms.

1. Advanced graphing of test outcomes, preferably in conjunction with other relevant clinical data such as vital signs, biometrics, and drug dose/timing. Graphing capabilities should be comparable to those of leading graphing systems, including dynamic axis and scale shifts, histograms, conditional formatting, color

coding, user-defined formulas for measured performance, and the display of multidimensional data. It is preferable to have colored screens.

2. The ability to provide hyperlinks in result comments to pages containing additional test details, such as analytic parameters, the half-life of toxins, medications, and certain chemicals.
3. Additional analytes, calculators, clinical protocols, recommended follow-up, literature references, and other pertinent data to assist clinicians in interpreting and using the findings of clinical treatment.
4. The system should link pre- and post-test diagnostic information by showing positive and negative probability ratios for selected diagnoses, either from the HIS or from user feedback. When a specific clinical condition is selected, the device should show sufficient Bayesian statistics, such as sensitivity, precision, accuracy, positive and negative predictive values, and receiver operator curves, along with hyperlinks to relevant references.
5. Show of all potentially relevant interferences and causes of irregular test results. This information should be flagged if derived from HIS data, and full lists should be displayed upon connection selection by the user.
6. Intelligent cumulative reports are generated in response to patient-related incidents, such as discharge or outpatient visit, to expedite clinical care. For instance, a decision support system has been defined for avoiding inappropriate discharges due to unexplained or unaddressed clinically relevant laboratory results[13].
7. An expert system should be capable of appending relevant interpretative comments to test results, taking into account not only the test outcome itself, but also other pertinent test and clinical information available in the HIS, as well as a

knowledge database that can be updated with local data, such as disease prevalence. Chronological

8. Consider trends, especially when tracking therapeutic drugs and calculating clinically useful pharmacokinetic parameters such as the region under the concentration curve and approximate elimination half-life.

2.1.3.6 Management of Notifications

Distribution of results to end users should be specified by a combination of institutional policy for certain types of results (such as "sensitive results") and user-selected notification mechanisms for routine reports (e.g., printout, fax, e-mail, HIS alert). To determine the appropriate process and timing for user notification, a rule-based structure should be used. The notification management system should be capable of the following[13]:

1. The LIS should have a sophisticated mechanism for notifying users of "positive results". The framework should have several levels of urgency for notifying users of important results. Due to example, the Massachusetts Coalition for the Prevention of Medical Errors established 3 levels of notification: red, orange, and yellow[11]. ‘‘Red’’ results are those implying immediate danger of mortality or morbidity if not rapidly acted upon. The "orange" results are extremely significant and should be acknowledged but are not[13]. Notification is not immediately threatening to the patient and can occur several hours later (target, 6–8 hours). ‘‘Orange’’ results include, for example, highly elevated creatinine, amylase, lipase, and aminotransferase levels. Notification of the provider should be made by a high priority process, for example, by a high-priority HIS alert requiring acknowledgment by the recipient, with a cascading process of surrogate notification if the appropriate provider is unavailable. Finally, ‘‘yellow’’ level results may be associated with significant morbidity or

mortality if diagnosis and treatment are not initiated in a timely manner, but are not immediately threatening. Yellow results require notification within 3 days and may include passive methods, such as an HIS alert or chart note, with mandatory acknowledgment and tracking[13]. Examples include a high thyroid stimulating hormone (TSH) or lead level, or a new diagnosis of cancer or human immunodeficiency virus infection[13].

2. Significant result notification should use artificial intelligence and expert decision-support systems for more relevant identification of true-positive (e.g. life-threatening) results, while minimizing false-positive signals (e.g. expected results) (e.g. expected results). The expert system should use the various inputs previously described for order entry and auto validation systems. Even without expert system intervention, dynamic rules should be used to determine whether a result is critical. For example, a single threshold for low hemoglobin level is inappropriate, as chronic anemia is much better tolerated than acute anemia. A dynamic threshold to detect a rapid rate of hemoglobin decline will be more clinically relevant and will identify patients at risk whose condition may not be considered critical when using a fixed threshold[11].

3. Along with the providers and surrogates specified during the order entry process, the system notifies relevant third parties, such as infection control or public health departments, based on the laboratory result.

4. Any changes or corrections to laboratory findings should be communicated to providers promptly, and reports generated by interfaced HIS systems should be accurate and complete.

5. The system should allow end users to inquire about laboratory testing, specimen receipt, and results availability, as well as provide links to pertinent online resources, information and messaging between laboratory personnel if additional information is

required. Search engines can use cutting-edge technology to accommodate synonyms, misspellings, and complex Boolean combinations of search words. Laboratory administrators should have access to reports on user behavior for the purpose of process improvement.

2.1.3.7. Analysis of Data and Cross-Sectional Reports

The ability to conduct queries against laboratory and clinical databases is critical for optimizing laboratory performance and quality, detecting clinical problems affecting a specific population, conducting epidemiologic and public health studies, and conducting case finding for clinical or academic purposes. An advanced LIS should provide advanced data warehouse and mining capabilities. The following are some examples of useful queries and reports:

Through the use of Boolean logic, search functions for combinations of laboratory results and clinical details, such as diagnoses, medications, and treating specialty, are produced, reports that show queried and non-queried fields such as patient demographics, specimen accession data, and location in a user-customizable manner. However, these reports should be concise.

The data can be exported to spreadsheet programs for further analysis. In an ideal world, aggregate data should be accessible through popular statistical functions.

Laboratory research turnaround time reports with the option to combine or separate the different components, such as order to collection, collection to laboratory, laboratory to testing, and testing to study, as well as grouping by accession areas, individual tests or test groups, hours or shifts, employee, patient location, clinics, or providers.

Online reporting of surveillance data to public health authorities in the proper format and according to the relevant standards.

Nosocomial infection surveillance and antibiograms that summarize the frequency distribution of antimicrobial resistance in bacteria. Interfacing with pharmacy records to keep track of antimicrobial use and susceptibility.

Laboratory usage reports are available by physician, provider category, specialty, hospitals, wards, patient types, diagnoses which diagnostic groups, and ICD-9/10 codes, and provide test form, volume, and cost per case. The system should provide clinicians with timely input on usage results, for example, at the time of patient discharge.

Analyses of patient outcomes using laboratory data mining and clinical data derived from the HIS. Correlations with laboratory tests can be useful for determining mortality, morbidity, hospital duration of stay, and cost of treatment, all of which are classified according to diagnostic categories.

2.1.4 LIS Constraints

Each framework presents unique challenges that can be investigated, created, and suitable solutions discovered. To begin, since the system is highly powerful, complex, and interconnected with other systems, it is extremely difficult to correct errors. When a system malfunction prevents workers from understanding and repairing it, they must connect with the company to request a team to resolve the issue. Certain issues take a long time to resolve, especially if the system is interconnected with other systems, resulting in crashes and overstock in patient outcomes[2].

Second, the device will provide the consumer with the final results and explain the reasoning behind them. When numbers are implausible, the employee must look behind them in order to comprehend. Additionally, some analyst reports prohibit data sharing, forcing other agencies to print a hardcopy report. This approach is in direct

conflict with one of the system's primary objectives, which is the establishment of paperless laboratories.

Third, as the framework and software resources evolve, a plethora of new programs and training are needed. Among these programs is Data Visualization, in which users often struggle to comprehend numbers and pictures.

Finally, existing monitoring systems have a small range of available data sources. Typically, the systems are linked directly to the LIS and do not have the capability to integrate data from other systems such as Pathology, Payroll, Materials Management, and Billing. Today's laboratory leaders want a holistic view of the laboratory but are limited to handling data from individual systems in a piecemeal fashion[2].

2.1.5 The Design and Implementation of a Computer- or Laboratory-based Information System

Developing and implementing information systems (LIS) in a healthcare facility is a complex and time-consuming process[14]. The availability of various software and hardware modules in the open market make it difficult for providers or organizations to identify and implement the most appropriate LIS. Apart from the efficiency, budget, and long-term effects of LIS, the staff members should be aware if creating a custom LIS would be more cost-effective and efficient than a stand-alone open-maker framework. In a recent study, a team of experts suggested that designing and implementing a customized in-house LIS is far more effective and successful. The developmental team might also include a single programmer who could manage and implement unique solutions for the laboratory. Many of the risks associated with LIS could be easily mitigated by the use of open-source software and well-structured development process. The experts suggested that in-house solutions had a comparatively better prospect and benefit as it was easily adjusted based on

departmental needs which in turn led to better, higher, and effective quality patient care. The implementation of a laboratory information and management system (LIMS) is an effective way to process lab data in an efficient and faster manner. Because most processes such as data collection, storage, and retrieval will be automated, there would be considerable time and effort savings[14]. The inclusion of a LIMS in hospital-care settings is bound to save time and improve overall efficiency. In a recent study, a team of healthcare professionals suggested that LIMS not only saved time but also resulted in productive resource usage. It enhanced overall patient engagement and satisfaction which in turn translated to improved quality care outcomes. LIMS or LIS has aided many healthcare facilities in coping with heavy patient influx effectively and reliably. The use of LIMS/LIS technology as shown in figure 2.2 eliminates the need for traditional paper-based processing, storage, and handling of patient reports or details. The data is collected and archived in a digital/electronic format, which carries a lower risk of loss or theft than paper processing and storage. The majority of LIS/LIMS systems are capable of developing and delivering reports to patients in real time, which improves the laboratory's overall reputation and reliability. According to a study of the literature, some of the primary advantages or benefits of LIMS include the following: (a) real-time sample monitoring (b) time savings (c) increased logistics performance (d) reduced

(e) increased savings (f) decreased risk of death (g) decreased investment, and (h) increased market opportunities and/or escalation[14]. When LIS is used, the technician can monitor samples in real time since the whole process is automated and each sample is bar-coded individually. The selection, registration, and re-registration of samples is the most difficult, time-consuming, and time-consuming task in laboratories. However, by using a LIMS as shown in figure 2.2, lab technicians can

create a batch-based system for tracking all samples collected and evaluated. Batch-based assessment saves time and effectively processes a large number of samples without the possibility of human error[14].

Sensitive report evaluation by individual physicians and pathologists is a time-consuming procedure. However, with the assistance of a LIMS, a specific authorization code may automate the process of approving samples that fall within normal ranges. Automated authorization saves time and improves overall operating performance. Doctors and pathologists will be required to authorize only reports with abnormal values, reducing their workload, effort, and time[15]. Sample collection from centers is a time-consuming operation. However, lab technicians and managers can track and control samples in real time using a batch-based bar coding system. This would allow them ample time to procure necessary resources such as running head, reagents, chemicals, and other testing materials. Effective resource control prior to the delivery of samples enables technicians to screen and analyze a large volume of samples in a short period of time[14].

Human error is a significant risk in pathology laboratories, whether it occurs through data entry, analysis, or assessment. Advanced computer-based systems, on the other hand, remove the need for manual effort. These systems are focused on the integration of laboratory equipment and devices into a stable platform, from which data is transferred to the LIMS automatically. Thus, not only is the time required to process samples decreased, but it also removes the need for tedious manual effort and human error. The pathology and laboratory departments place a premium on patient safety. In life-threatening or medical-emergency situations, the findings of lab tests draw a line between a patient's life and death. An integrated and detailed LIMS includes a pre-programmed warning mode (program) that notifies or communicates to prescribing

physicians any anomalies in the reports. This allows the practitioner to make immediate, educated decisions, which can be life-saving[14].

2.2. Empirical Review of Study

Apart from patient protection, healthcare facilities may realize considerable cost savings, if not eliminate them entirely, increase total sales. Effective LIMS dashboards will allow technicians to evaluate financial, inventory, operational, and laboratory-related reports in a customized format. Numerous empirical data sets can be mined and crunched in order to generate trends, patterns, and predictions. This will assist the lab head in increasing sales and overall profitability[16]. Automated systems would notify the lab head/technician when materials, chemicals, or reagents were expired. The LIMS may process predictive pre-ordering of samples or items using artificial intelligence. The whole process would remove unnecessary costs, waste, and theft. The use of cloud-based technologies enables more transparent sample selection and analysis in remote locations. Lab owners and staff will expand their company by using cloud-based computer servers[17].

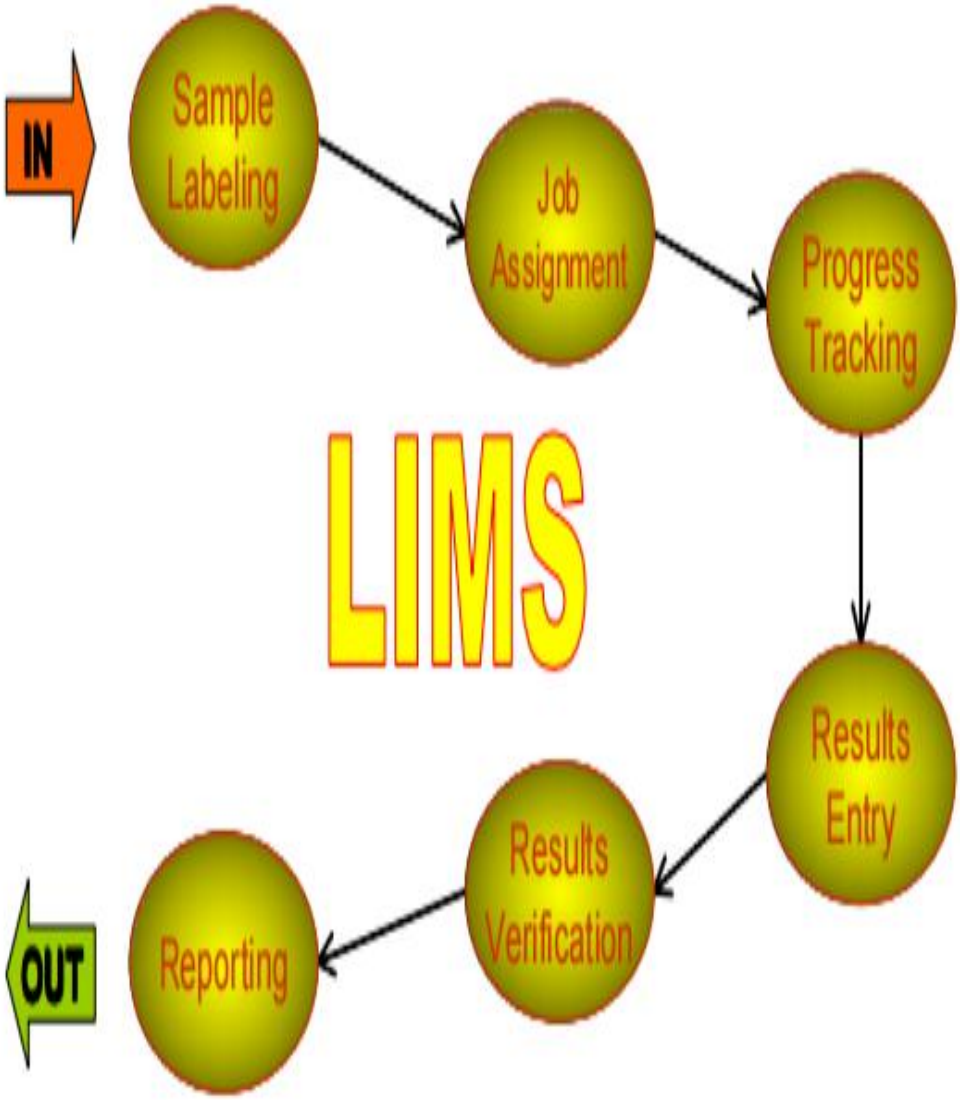

Figure 2.2: LIMS procedures

(Source: Speedspath, 2018)

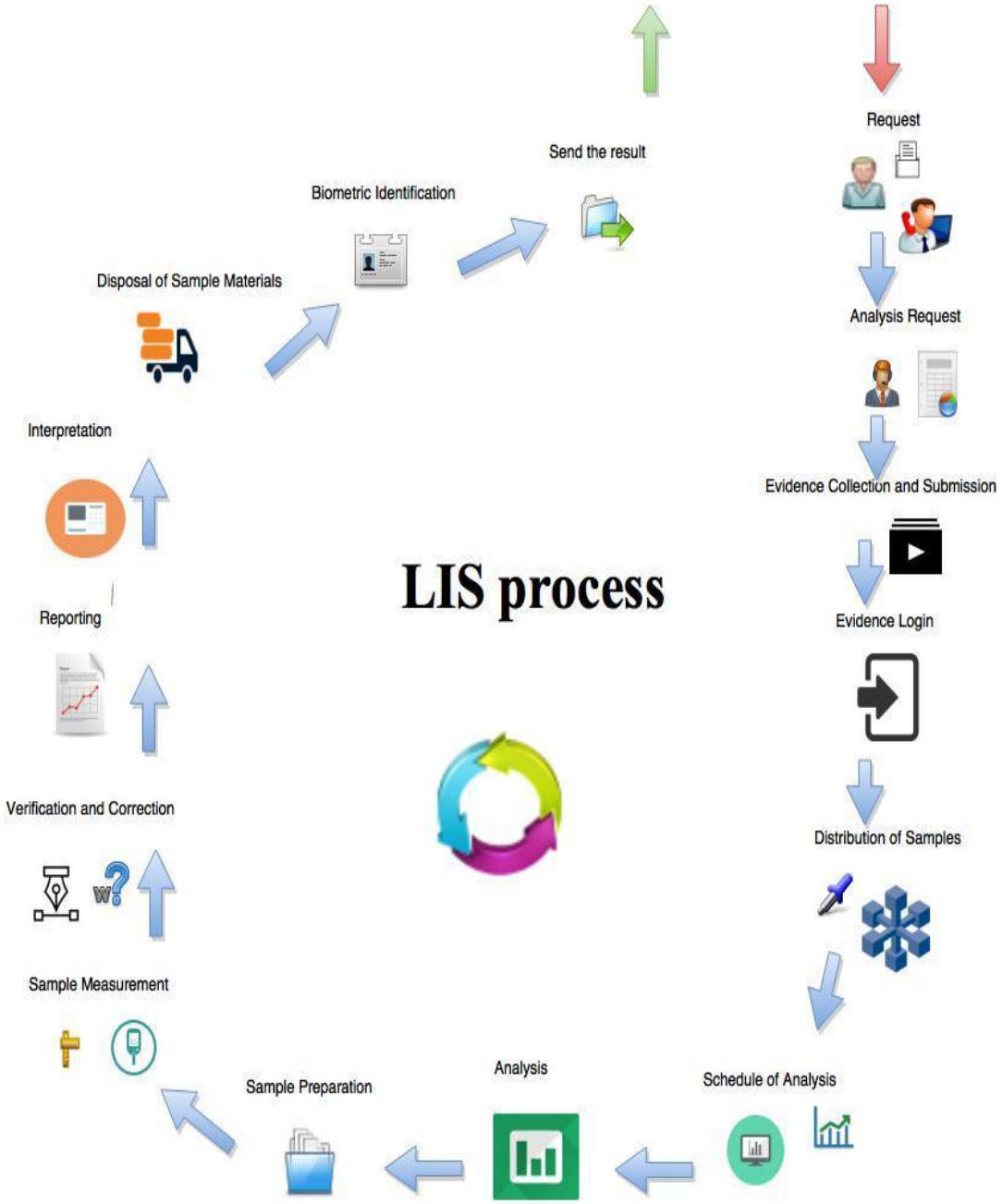

Figure 2.3: Process of LIS system

(Source: Speedspath, 2018)

A clinical decision support system (CDSS) aims to enhance healthcare delivery by augmenting medical decisions with tailored clinical expertise, patient information, and other health data[18]. A typical CDSS consists of software designed to assist clinicians in making clinical decisions. The characteristics of a particular patient are compared to a computerized clinical knowledge base, and patient-specific tests or recommendations are then provided to the clinician for decision-making. Today, CDSSs are mainly used at the point of treatment, allowing clinicians to combine their expertise with the CDSS's information or recommendations. However, CDSS are increasingly being built with the capability to leverage data and insights that are otherwise unavailable or unintelligible to humans. The origins of computer-based CDSSs date all the way back to the 1970s. They lacked device integration at the time, were time-consuming, and often restricted to academic pursuits[18]. Additionally, ethical and legal concerns were raised about the use of computers in medicine, physician autonomy, and who will be held accountable for following the advice of a device of imprecise 'explainability[19]. At the moment, CDSS often use web-based software or integration with electronic health records (EHR) and computerized provider order entry (CPOE) systems. They can be administered via desktop, notebook, or smartphone, as well as via biometric tracking and wearable health technology. These devices may or may not generate outputs or be connected to EHR databases. CDSSs have been categorized and subdivided into a variety of categories and styles based on their intervention timing and mode of delivery. CDSS are frequently divided into knowledge-based and non-knowledge-based categories. Rules (IF-THEN statements) are generated in knowledge-based systems, with the system retrieving data to test the rule and generating an action or output. Rules may be developed based on evidence from the literature, experience, or patient-directed

research. CDSS that are not based on expert medical knowledge also need a data source, but the decision is made using artificial intelligence (AI), machine learning (ML), or statistical pattern recognition, rather than being designed to follow expert medical knowledge[18]. While non-knowledge-based CDSS are a rapidly increasing application of AI in medicine, they are fraught with difficulties, including difficulties in comprehending the reasoning used by AI to generate recommendations (black boxes) and issues with data availability[21]. However, they have not yet been widely implemented.

Another diagnostic subset for which CDSS can be beneficial is laboratory testing and interpretation. Alerts and reminders for irregular laboratory findings are a common feature of EHR systems. CDSS may also be used to expand the utility of laboratory-based experiments in order to prevent riskier or more invasive diagnostic procedures. When it comes to Hepatitis B and C testing, liver biopsies are considered the gold standard, as non-invasive laboratory tests are not considered accurate enough. However, AI models that combine multiple tests (serum markers, imaging, and gene tests) are being developed to achieve significantly higher accuracy. CDSS can also be used as an interpretation tool when the reference ranges for a test are highly personalized, such as age, sex, or disease subtypes[22]. Pathology reports are critical decision-making tools in a wide variety of other medical specialties.

2.1.6 Computerized Hospital Laboratory Operation System (CHLOS)

This is a collection of computerized methods for the acquisition, analysis, storage, and reporting of laboratory data.

Figure 2.4: Manual laboratory system

(Source: Limswiki : Laboratory information management system)

Types of Data Used in CHLOS

• Alphanumeric

• Descriptive

• Limits

In hospitals and labs, it takes a long time for doctors, nurses, laboratory technicians, and other laboratory personnel to coordinate and organize patient records. Every day, hospital systems accumulate an increasing amount of data about patients, and this data must be reliable. Additionally, after entering basic patient information into the system, staff must enter additional information such as appointment booking, medication, and diagnosis, all of which must be correct. There are many systems in hospitals today that are costly and complex, requiring specialists to train users and posing difficulties with maintenance and development in the event of a problem, such as cancer treatment systems.

On the other hand, there are systems that are straightforward, quick to operate, and affordable, and that can be managed by physicians, nurses, lab technicians, interns, and employees. These systems are typically simple to maintain, and in the absence of superior systems, they are indispensable. Both complex and simple systems must exercise caution when dealing with patient data. It is important to minimize errors because even minor errors may cause problems for the patient. For instance, if a lab attendant incorrectly added a diagnosis to a patient's file, the doctors or pharmacist could administer the incorrect medication to the patient, resulting in a serious problem. Numerous companies have begun designing and producing systems and applications that aid hospital and laboratory personnel in organizing patient records. As discussed previously, some of the systems are expensive to implement and require a significant amount of capital, and in this situation, hospital administrators abandon older systems

that cannot be developed. The purpose of this paper is to discuss one of the most critical systems used by many hospitals worldwide to coordinate and arrange patient information while also allowing for knowledge sharing among employees.

2.1.6.1 The Primary Advantages of Implementing a Computerized Hospital Laboratory Operations System (Chlos)

A CHLOS enables a laboratory to serve a broader range of users. The following is a summary of some significant benefits[27,28].

Productivity

The user enters data about the product, the client, and the sample, and the test can be used to generate reports and export data. It is not necessary to re-insert to produce reports.

Quickly Data Recovery: The method of retrieving information from a collection of data is made clear and straightforward by the use of various queries, which increases the application's reliability and flexibility.

Create and Distribute Reports: The process of quickly and dynamically producing reports has become easy, and they can also be sent directly to the client. The dynamic report generation ensures the laboratory data is more accurate.

Increased Throughput: It is possible to examine samples and monitor laboratory data records. Additionally, the laboratory does not need any additional personnel to handle this type of material. Additionally, the machine generates a more precise report than manual calculation.

Monitor Productivity: In general, all laboratory information management systems collect data about the customer, the product, the sample, and the test. Additionally, we will keep track of the sample tests are coming up, which are about to expire, and which have already expired.

Time Management: This application is a time-saving tool that enables users to function without performing paper-handling tasks and dynamically produce reports. Previously, and even now, some laboratories used spreadsheets to handle their results. Managing laboratory data via spreadsheet and reporting on papers is difficult. Although the spreadsheet allows for filtering, it is still difficult to manage data and produce reports. To manipulate data, the user must locate or collect it from various locations so that CHLOS software can handle it automatically. By using CHLOS, software users can quickly resolve this problem, as it is a time-consuming device.

There is no need to exert additional effort to complete tasks. Without requiring additional effort, LIMS software improves an organization's productivity and documentation level.

Precision

Reduce Error: The CHLOS program greatly reduces error, owing to the application's restriction on manual data entry and the user's requirement to pick primary items from drop-down and menu lists. The CHLOS software system is capable of quickly and easily collecting data. Additionally, by using this program, the user can build their own workflow, thereby reducing lengthy and repetitive manual processing and increasing performance.

Verify Data at Input: Today's systems are more intelligent, and the user may enter data and the system will validate some of the fields and enable it to be inserted into the database.

Avoid Missing Deadlines: By comparing dates, the CHLOS program shows upcoming samples on the dashboard and also highlights samples that have already missed deadlines.

Avoid Embarrassment Due to False Results: The LIMS method produces automatic results by extracting data from the database associated with the study, which may help avoid the embarrassment associated with getting false results.

Secured Access

CHLOS can safeguard data by establishing distinct user levels. The framework utilizes this function to segment features and provide access according to the user level. The framework offers user-level permissions for security purposes.

Watch Database Revisions: Current CHLOS software is capable of automatically tracking sample and test data and managing laboratory information with ease. The device will provide laboratory information for an acceptable period of time by using the tracking function. The system will provide information about upcoming samples and tests through the following features.

Customer Satisfaction: The CHLOS customizes reports to satisfy specific customer requirements. Automated Invoice Customer Reports are generated by the system. Daily reports are produced by the CHLOS program. Additionally, since the system is hierarchical, it automatically retrieves data from the database and generates reports without errors. In this way, we can assert that current LIMSs are capable of producing error-free reports on a regular basis.

2.3. Theoretical Framework

The theoretical framework for this study is TTF theory. According to TTF theory, a better fit between technology and task results in improved performance. As a result, an improved laboratory information system will result in increased accuracy and response time. In Task-technology fit (TTF) theory, information technology is more likely to improve individual performance and be used if its capabilities match the tasks that the user must perform[23]. Goodhue and Thompson developed a task-

technology fit metric that includes eight factors: quality, localability, authorization, compatibility, ease of use/training, production timeliness, and systems. Each factor is assessed using between two and ten questions, with responses ranging from strongly disagree to strongly agree on a seven-point scale.

Goodhue and Thompson discovered that the TTF measure, when combined with utilization, was a significant predictor of user reports of increased job performance and effectiveness as a result of their use of the investigated system.

While the Goodhue and Thompson model analyzes individuals, Zigurs and Buckland present an analogous model at the group level. Since its inception, TTF has been applied to a wide variety of information systems, including electronic commerce systems, and has been combined with or used in conjunction with other models of information system outcomes, such as the technology acceptance model (TAM). The TTF measure presented by Goodhue and Thompson has been modified numerous times to accommodate the study's objectives.

The Task-Technology Fit (TTF) theory enables quantification of technology's effectiveness in a system by examining the relationship between the technology and the tasks it is intended to support[23]. While the theory is widely recognized and has been applied in a variety of ways, little work has been done to summarize and synthesize TTF's application in the literature. By conducting a scoping review, the purpose of this study is to identify and summarize the focus areas of studies that used TTF, the environment in which it was used, and the technologies that were considered. It was discovered that applied studies were primarily concerned with developing theory or assessing specific real-world phenomena; they were conducted in a variety of settings, the majority of which were in healthcare; and they considered a variety of technologies, with an increasing number of studies focusing on mobile technology.

is defined as the degree to which a technology assists an individual in performing his or her tasks and is influenced by the interaction of the task's characteristics and the technology's functionalities[23]. Typical dimensions considered when measuring fit, as defined by Goodhue and Thompson, are data quality, data locatability, and authorization to access data[23]. The purpose of Goodhue and Thompson's study was to demonstrate that for technology to have a positive impact, it must have a strong TTF. Thus, as technology is matched to the mission characteristics it is intended to help, performance should increase. The increased performance is usually the result of the task being executed smoothly, the expense of executing the task being reduced, or the task being made easier to accomplish[23].

The laboratory information system (LIS) supports laboratory requirements and incorporates several laboratories[27]. However, the laboratory information system's role in avoiding repeated errors in the laboratory testing process is still a work in progress. Platform heterogeneity in lab-clinical settings contributes to error incidents through device creation, software usage, and discrepancies in technology management and information systems used in both settings. To determine the root cause of an error, laboratory research procedures must be rigorously tested. In general, laboratory testing consists of nine steps: (1) test request; (2) sample collection; (3) sample labeling; (4) transportation of labeled sample to the lab; (5) preparation of raw specimen; (6) analysis of specimen testing; (7) interpretation of test results; (8) reporting of test interpretation; and (9) archiving of test results[27].

System for the Total Testing Process (TTP)

TTP serves as a fundamental guideline for medical laboratories' research procedures. It is a one-of-a-kind method for analyzing and mitigating error risk not only in laboratory test centers, but also in other clinical units[27]. TTP covers internal and

external laboratory operations that include one or more procedures and include coordination between internal and external laboratory personnel. Failure in any TTP operation may have a negative impact on patient care, as doctors make clinical decisions based on laboratory findings. Medical professionals have used the term to perform lab research procedures ranging from a stimulated idea to testing patient samples to treating patients. The proof of each step's efficacy suggests a decrease in errors in patient care and treatment. In medical laboratories, TTP workflow focuses on process smoothness as well, as smooth and systematic processes result in successful quality control. Process rigor founded on a productive and ethical work culture is vital for sustaining and enhancing workflow efficiency, as it leads to error minimization and, ultimately, patient safety[28].

The majority of studies on TTP found error events in all phases; however, the first and final phases have the highest error percentages due to the lack of external laboratory process monitoring. If it occurs beyond the laboratory supervision, a TTP error is considered a laboratory error. Bad communication, actions taken by individuals involved in the laboratory testing phase (doctor, nurse, and phlebotomists), such as position misunderstanding, and inefficient process flow, such as incomplete and redundant process steps, all led to those errors.

Framework for HOT-fit

The HOT-fit system for evaluating HIS included detailed dimensions and metrics of technology, individual, and organizational factors[29]. It also included an adaptation of two IS models, namely the IS Success Model and IT-Organization[27].

By incorporating the Fit Model, HOT-fit will evolve into a thorough assessment method for a variety of HIS, including LIS. The framework is composed of nine interrelated dimensions, including system quality (information processing quality), information quality (IS output), service quality (technical and support services), system development, system use, and user satisfaction, organizational structure (related to management, strategy, and organizational plan), organizational environment (related to politics, finance, and interorganizational relations), and organizational structure (related to management, strategy, and organizational plan) (overall IS impact). The HOT-fit framework's fit definition between technology, person, and organization is dynamic, subjective, and abstract[29]. Due to its broad scope, HOT-fit is not only used to measure HIS results, effectiveness, and effect. Additionally, it could guide systematic error evaluation based on the process step and level of the three variables.

2.4. Summary of Gaps in Literature Reviewed

The authors of an article titled an overview of clinical decision support systems: advantages, drawbacks, and strategies for success provide a state-of-the-art overview of the use of clinical decision support systems in medicine, including the various forms, existing use cases with demonstrated effectiveness, common disadvantages, and potential harms[18]. They concluded by making evidence-based guidelines for risk minimization in the design, implementation, assessment, and maintenance of CDSS. Additionally, they stated that computerized clinical decision support systems, or CDSS, reflect a paradigm shift in contemporary healthcare. CDSS assist clinicians in their dynamic decision-making processes. CDSS have evolved at a breakneck rate. They are increasingly administered through electronic medical records and other computerized clinical workflows, which has been encouraged by the global adoption

of advanced electronic medical records. Despite these advancements, there are still many unknowns about the impact of CDSS on providers, patient outcomes, and costs. There have been numerous published examples of CDSS success stories over the last decade(s), but significant losses have also shown that CDSS are not without danger.

Another related research, The Ideal Laboratory Information System, aims to compile ideas for developing or improving a state-of-the-art LIS from the perspective of practicing laboratory professionals, with an emphasis on maximizing clinical laboratory operations and improving clinical care through intelligent information management[11]. They describe LIS broadly in their work, and some of the basic functionalities described may be given by software modules that are not strictly classified as LIS. This will include clinical ordering and reporting systems integrated into the HIS, analyzer-integrated software, specimen processing and management software (often referred to as "middleware"), as well as accounting, inventory, and personnel management packages. The authors are interested in defining the desired functionalities regardless of which software package can provide them.

In a study titled evaluating the Usability of the Laboratory Information System Evaluating the Usability of the Laboratory Information System (LIS) in Coombe Hospital and Hail Hospital, the author assessed the usability of the Laboratory Information System (LIS) in two separate countries: Coombe Hospital in Dublin, Ireland, and Hail Hospital in Hail, Saudi Arabia[2]. This research utilized two widely known usability models – SUS and QUIS. The results of the comparison of the two hospitals revealed shared weaknesses/strengths as well as distinctions between two health facilities located in countries with distinct languages and cultures. Questionnaires were sent to both hospitals, and interviews with staff at each hospital were performed to discuss various aspects of the system. Following the review of

questionnaires and interviews, the search results established that both hospitals faced similar systemic issues. As a result, systemic issues stemming from every hospital was given access to the analysis of both surveys in order to improve the system's performance.

Hospital Information Systems Implementation Framework: Critical Success Factors for Malaysian Public Hospitals[23]. The author established an implementation framework for HIS implementation in this report. The framework included critical elements to direct HIS implementation. To capture the multifaceted essence of performance, the DeLone and McLean IS success measures were adapted and presented as a reflective second order element in the system. The author reports that 500 questionnaires were distributed to six public hospitals in Malaysia, and 213 were analyzed. This is a product of a strong response rate of 42.6%. To determine the degree of performance, a structural equation modeling (SEM) method based on partial least squares (PLS) was used. The study's results indicated that CSFs in Malaysia are distinct from those in developing countries. Three out of seven success factors were found to be important, namely device selection, enterprise-wide coordination, and team composition. Significant implementation factors such as top management support, business planning, project management, and change management were identified.

The analysis empirically evaluated a system for implementation in Malaysian settings; as such, it greatly contributes to the theoretical, methodological, and functional aspects of science. In theory, it developed a new classification of CSFs that could have an effect on how HIS is implemented. This new classification represents an important step toward providing a practical list of CSFs that enables practitioners to concentrate on critical areas during framework implementation. In terms of a realistic

contribution, the study offers guidance for managers in making future HIS implementation decisions and preparing. His study developed a model that practitioners and researchers can use to better understand the HIS implementation process, especially in Malaysian public hospitals. Additionally, its contribution is applicable to comparable contexts such as information management (IS), enterprise resource planning (ERP), and enterprise systems (ES).

Similarly, in a similar study on Laboratory Information Management Systems, the authors documented the current state of LIMS software and proposed a count of the technology's shortcomings[3]. They examined the implementation, cost, and efficiency challenges confronting pharmaceutical companies. These range from an in-house development environment to an intuitive user interface. Additionally, their study discussed the strengths, advantages, drawbacks, and benefits of LIMS in pharmaceutical companies, as well as the standards that affect LIMS.

Additionally, in Laboratory Information Management System Study & Development of LIMS Web Platform Application for CTCV - Coimbra, the author developed software that utilizes an industry-standard relational database management system (RDBMS) for data entry and retrieval, in conjunction with a platform-independent web browser interface for data entry and retrieval[4]. (This is a three-tiered technology). The laboratory workflow steps simplify the monitoring and recording of all tests and test results, ensuring that the appropriate information is accessible to the appropriate individual at the appropriate time. This method would result in an effective laboratory process, which will result in quicker work, less errors, and a more streamlined workflow for an organization. According to the authors, the waterfall methodology was used to design and create a web-based customized LIMS program for managing small laboratory data such as sample, test, and dynamic report generation.

Additionally, the program was designed using the Microsoft.NET platform, which offers a virtual machine in which our LIMS application can be run, tested, and executed.

In a paper titled Towards an Assessment Process for Laboratory Information Systems they explore a new LIS evaluation framework that takes into account both the laboratory research period and the socio-technical aspects of LIS[27]. They conducted a study of the literature on laboratory research and LIS discourses, dimensions, and assessment methods. Additionally, they conducted a critical appraisal of the Total Testing Process (TTP) and the individual, organization, and technology-fit factors (HOT-fit) assessment systems in order to classify error incidents, their contributing factors, and preventive action applicable to laboratory testing processes and LIS. As a result of their work, they outline a new assessment system for LIS that takes a systematic and socio-technical approach. Positive relationships between laboratory and clinical workers resulted in a more efficient laboratory testing process, with fewer mistakes and improved process reliability, while successful use of LIS simplified the testing processes. According to the authors, the TTP-LIS framework developed could be used as an evaluation and problem-solving method for the laboratory testing process and system.

In the Design and Implementation of a Chemical Analysis Laboratory Information Management System. The author designed the software using the B/S (Browser/Server, browser / server) software architecture and the three-layer device structure. The system is built on the Zend framework's multi-layer software architecture, which includes a presentation layer, a business logic layer, and a data access layer. This type of multi-layer architecture enables dynamic and sustainable

software design, thereby simplifying subsequent program modification and extension, and it is commonly used in three-tier architectures.

Similarly, in a study titled How Laboratory Informatics Has Affected Healthcare in General, a systematic analysis of the literature was conducted, in which related articles about laboratory information systems were identified[30]. Their research used a qualitative design in which they qualitatively defined main concepts or trends from papers and studies. Laboratory information systems' benefits can be seen as a forum for enhancing patient satisfaction, quality care, and patient safety. The aim of their research is to conduct a review of the available literature and to gain an understanding of the advantages and disadvantages of laboratory information systems used in a variety of healthcare settings. Their research used a random sample of papers from a single source. The sample size (number of articles) was insufficient to generalize the findings of the analysis. Other academic databases that may have improved the general ability of the study findings were not consulted.

In a related article, the authors present the results of conceptual and, at times, philosophical work on this subject[31]. Apart from a realistic and logical approach, the writers attempted to explain the theoretical underpinnings of such a method.

Endnotes

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Chapter Three

Methodology

3.1 Introduction

The system is a web based model built on laravel 7.29 and a WAMP (Windows, Apache, MySQL, PHP) server. All the code structure follows an MVC (model-view-controller) coding standard so every action has a model, a view and a controller; the view is the HTML and JavaScript codes. MVC is a software architecture that separates domain/application/business logic from the rest of the user interface. It does this by separating the system into three parts: the model, the view, and the controller[1]. Also, Laravel is a PHP-based web framework that is largely based on the MVC architecture[1].

The developed system processes are

1. Admin Registration
2. Log In
3. Add Client
4. Take Test
5. Send result via real time email notification

3.1.1. Admin Registration

This is where the admin registers to have access to the design. The page has provision of the name, email address, password, confirm password and the register tab. This authenticates the Administrators. If the user of the system is valid, it allows the user to enter into the system and use the system. Alerts when unauthorized users try to access or manipulate the system as shown in figure 3.1. The Register page was designed using the following code. The full code is available on Appendix I

section('content')

```
<div class="container">
   <div class="row justify-content-center">
      <div class="col-md-8">
         <div class="card">
            <div class="card-header">{{ __('Register') }}</div>
```

3.1.2 Login Page

Here the admin login in with his/her login parameters. Once the admin is logged in, a dashboard page pops up as shown in figure 3.2 and 3.3. The dashboard consists of the client, test and result. Also, the client name, phone number, action, take test, view profile and add client tab. Here the admin will be able to either perform vital actions based on the preference of the client or patient. The Register page was designed using the snippet code below. The full code is available on Appendix II

```
@extends('layouts.app')

@section('content')
<div class="container">
   <div class="row justify-content-center">
      <div class="col-md-8">
         <div class="card">
            <div class="card-header">{{ __('Login') }}</div>
```

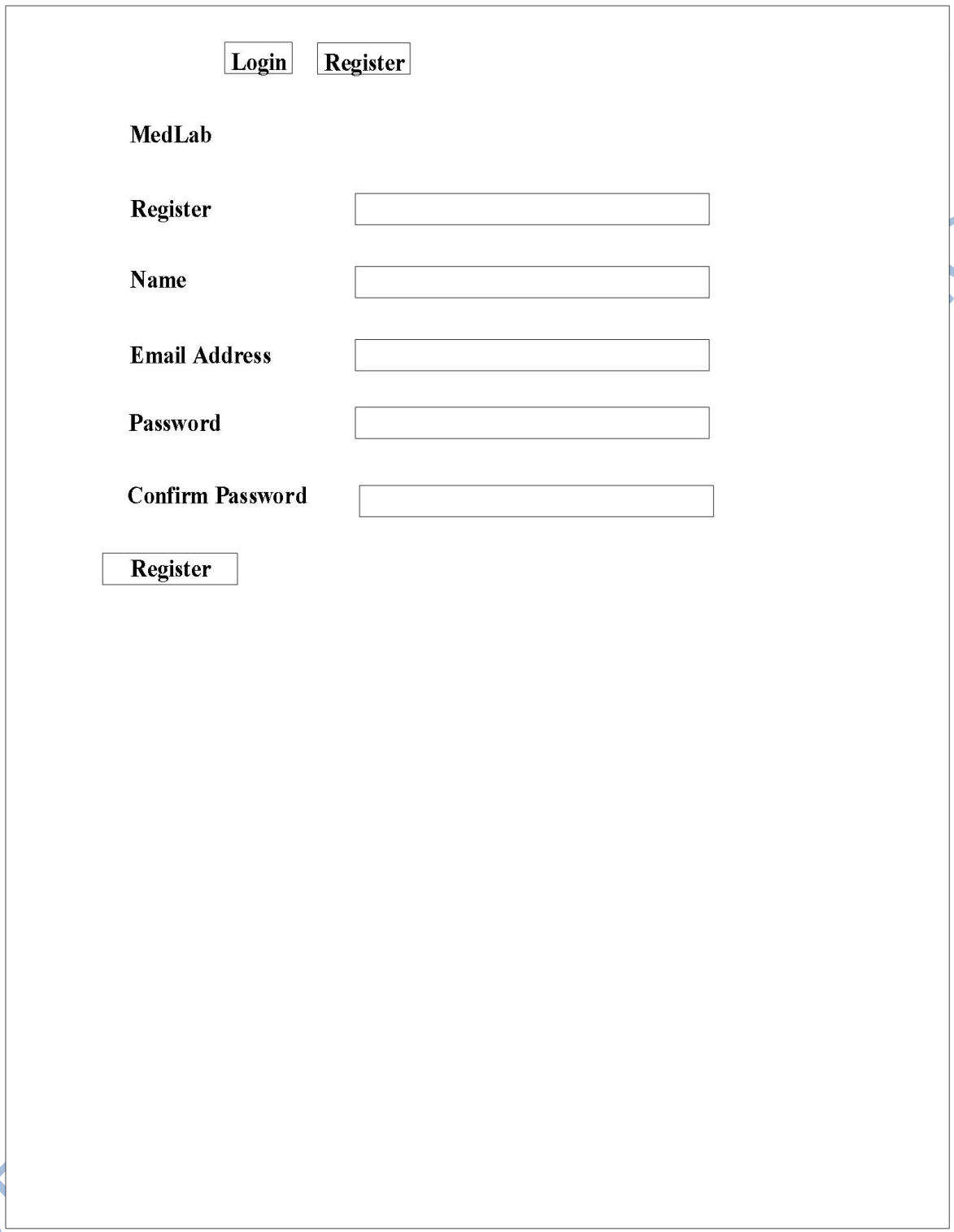


Figure 3.1: Design of registration page of laboratory support system

(Source: Research Design, 2022)

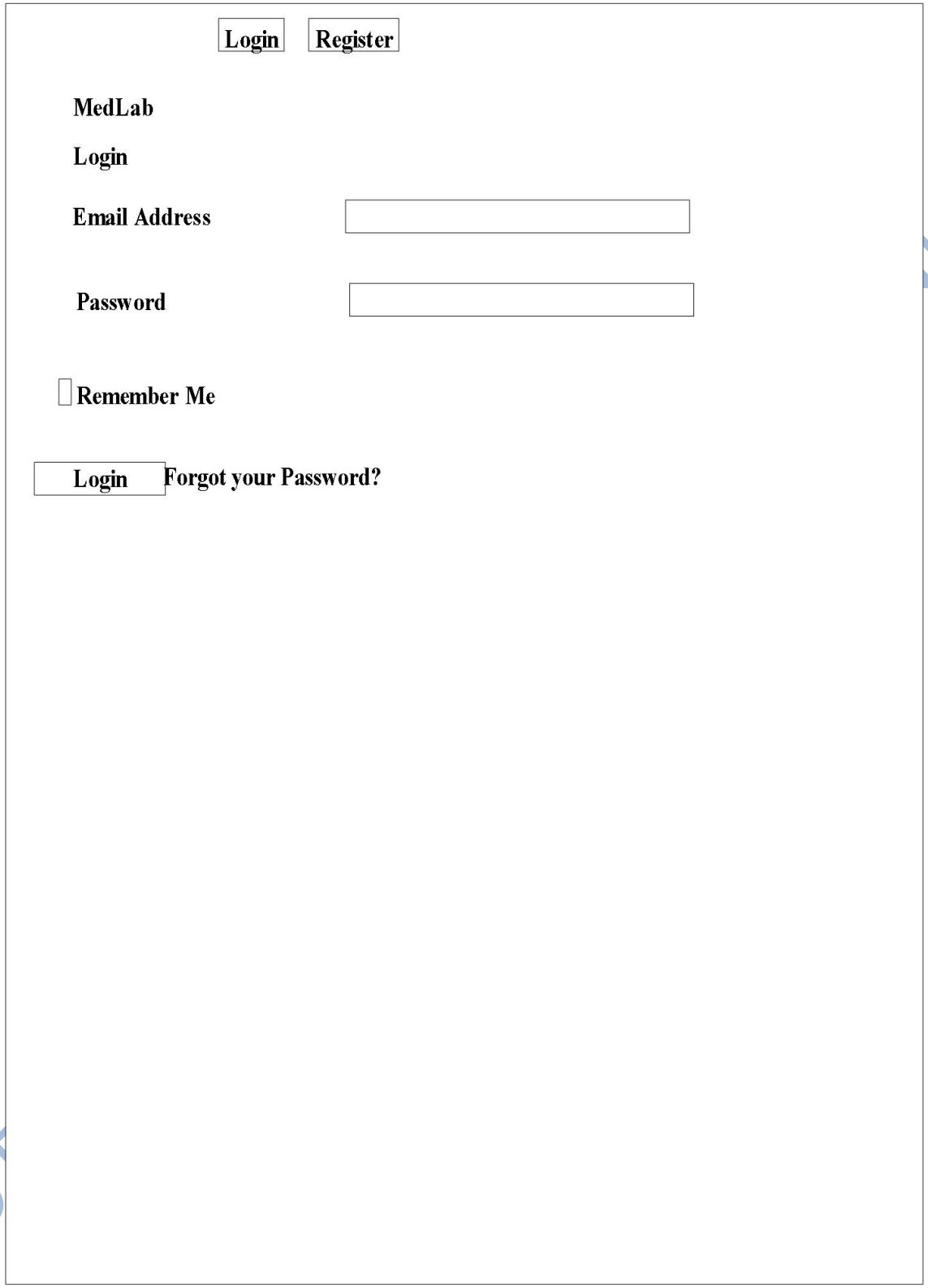


Figure 3.2: Design of login page of computerized laboratory support application

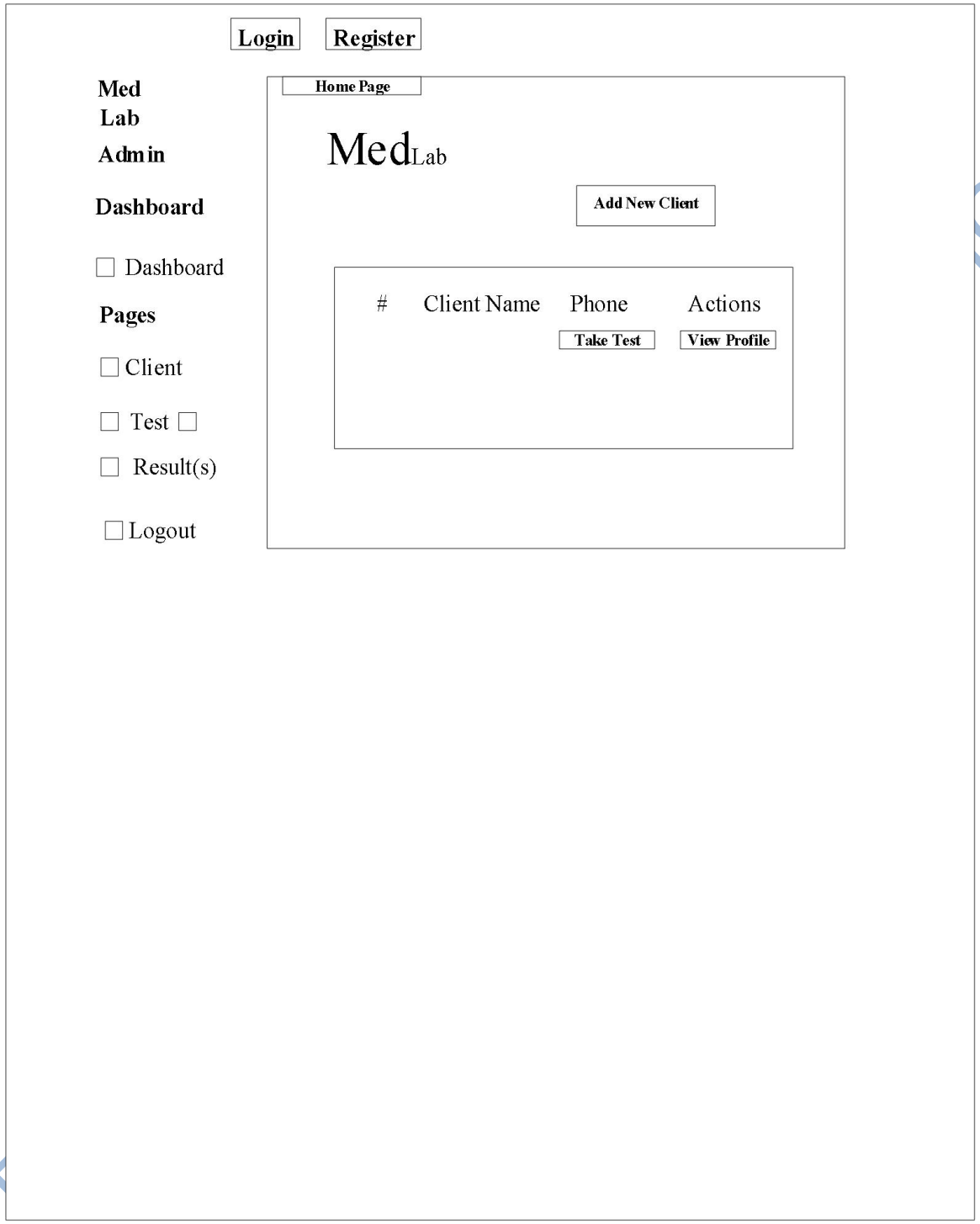


Figure 3.3: Design of dashboard page of computerized laboratory support application (Source: Research Design, 2022)

3.1.3 Add New Client

New clients are added via the add new client tab to fill up the information of the new client which include the name, email, phone number, sex and date of birth as shown in figure 3.4. The record was stored in the database and can be recalled anytime it's needed. The add client page was designed using the snippet code below. The full code is available on Appendix III.

```
@extends('layouts.admin')
@section('title')
  MedLab
@endsection
```

3.1.4 Add Test

This is where the test to be taken is added. Once the admin clicked add new test, a new window showing add new test page pops up. The add new test consist of the test name (For example , HIV test), the test type (blood or urine or oral fluid), the number of parameters to be checked depending on the type of test. For HIV 3-4 parameters are checked (**NATs** which look for the actual virus in the blood, Antigen/antibody tests look for both HIV antibodies and antigens, Antibody tests look for antibodies to HIV in your blood or oral fluid) [2]. Then the add test tab was clicked to give the details of all the parameters. The take test was designed using the snippet code below. The full code is available on Appendix IV.

```
extends('layouts.admin')
@section('title')
  MedLab
@endsection
@section('styles')
<!-- <script src="https://cloud.tinymce.com/stable/tinymce.min.js"></script>
 <script>tinymce.init({ selector:'textarea' });</script> -->
@endsection
@section('page')
<a href="{{url('/addclient')}}">Add New Test </a>
```

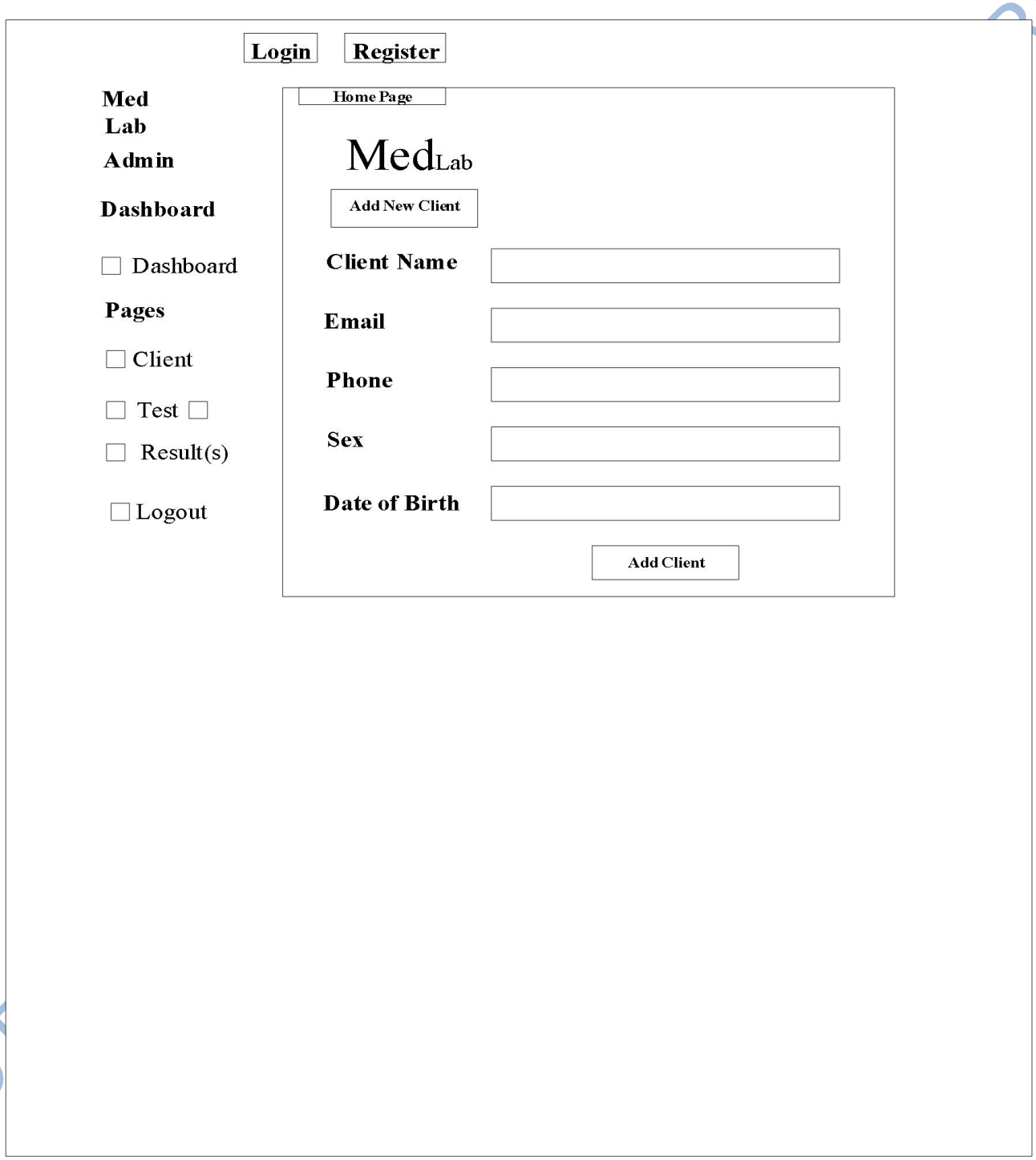


Figure 3.4: Design of add client page of laboratory support application

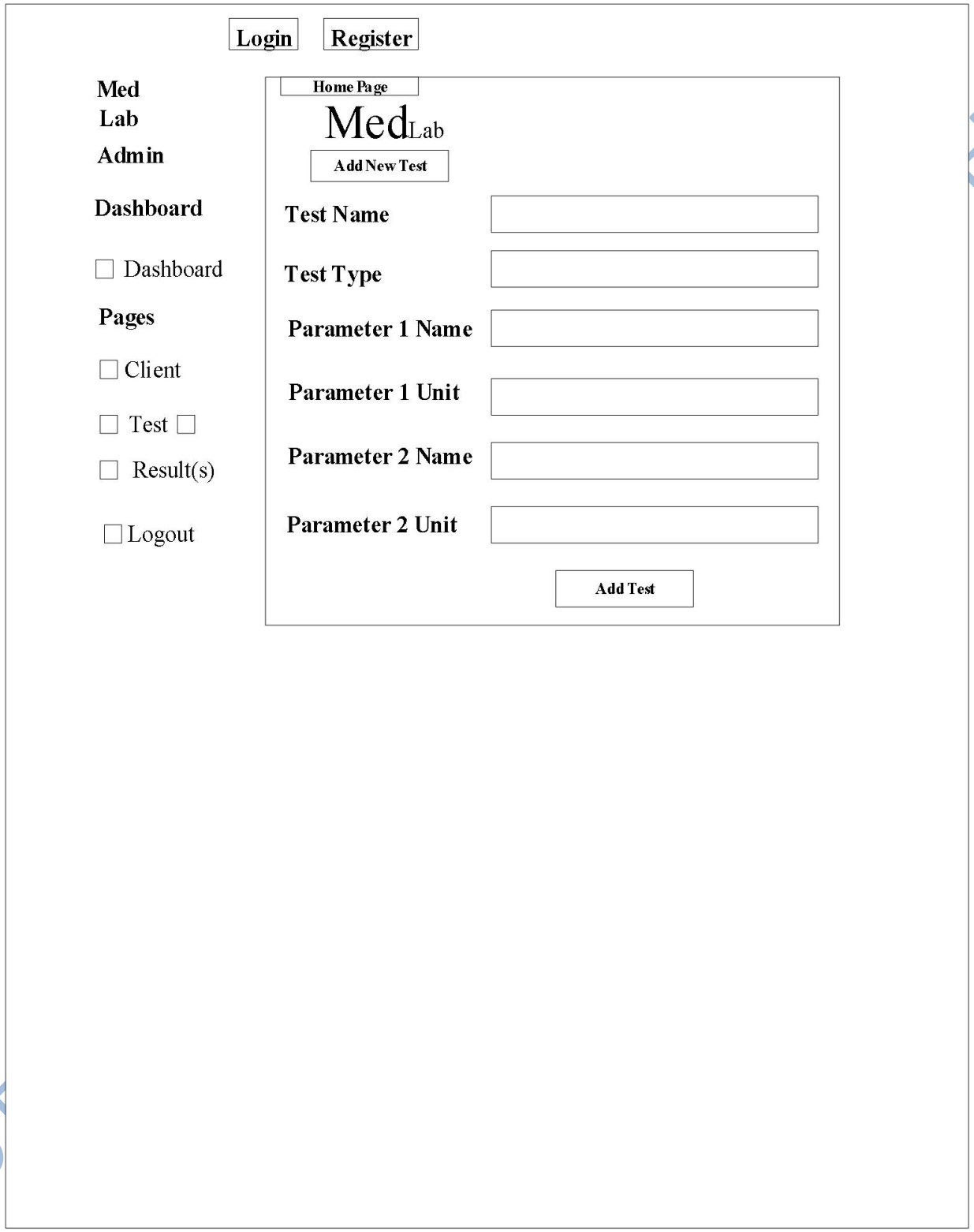


Figure 3.5: Design of add client page of laboratory support system

(Source: Research Design, 2022)

Hence once the result is ready, the test name and the corresponding result will be imputed and submitted. Once it is submitted using the submit result tab as shown in figure 3.6, it can now be viewed on the dashboard in figure 3.3 using the view profile tab.

The client information can also be viewed on the user information page as shown in figure 3.7. This can enable the admin confirm the identity of the client before sending a real time email to the mail address. It can be useful for editing and updating of client information.

3.2 Real Time Email Notification of Test Result

After the result of the test had been generated, an email notification will be sent to the client email by clicking the send mail tab as shown in figure 3.8. Hence, a client or patient may not need to wait after the test, once the result is sent to the mail, the client can print directly from the mail and present to where ever it may be needed. This will greatly reduce the client waiting time. The snippet code to generate email notification is shown below. The full programming code is on Appendix V

```
public function senattach(Request $request){
   header('Content-type:application/json;charset=utf-8');  //email rid
      $email = $request->email;
      $rid = strip_tags($request->rid);
     // File::move($image, public_path("pipeline/"));
     // $this->mailmag("pipeline/", 'test.png');
     //$pdf = base64_decode($image );
```

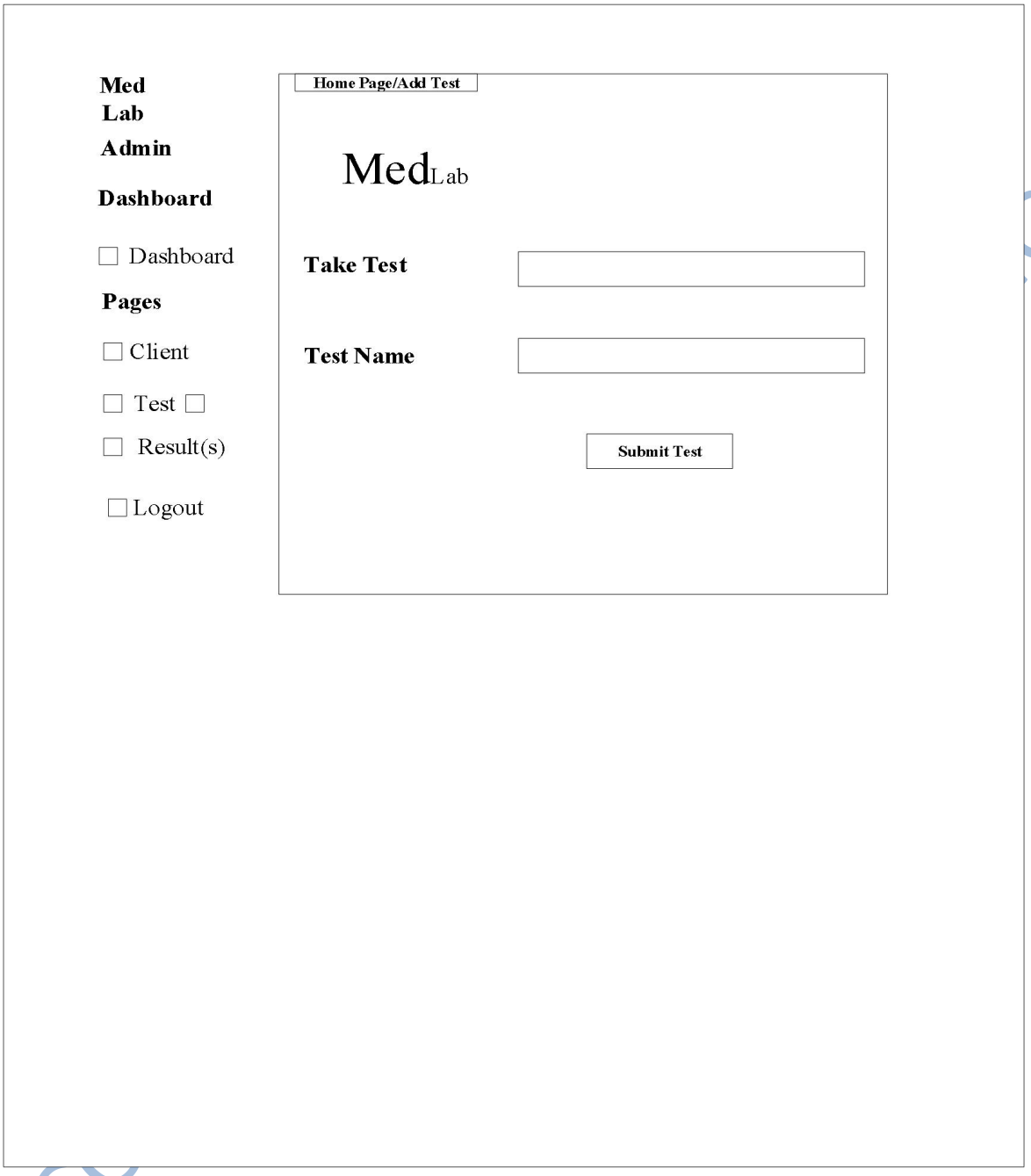


Figure 3.6: Design of submit test page of laboratory support system

(Source: Research Design, 2022)

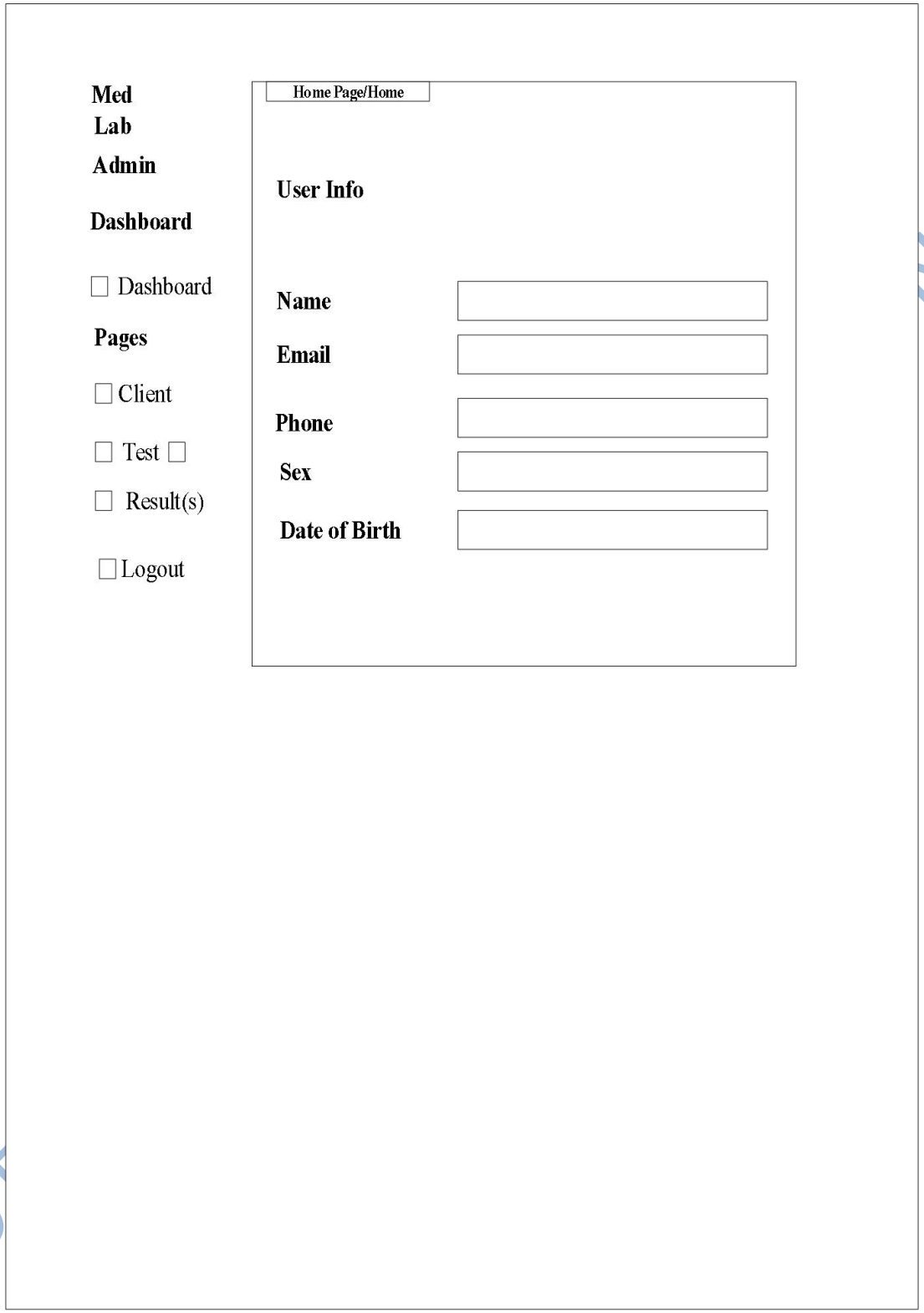


Figure 3.7: Design of user information page of laboratory support system

(Source: Research Design, 2022)

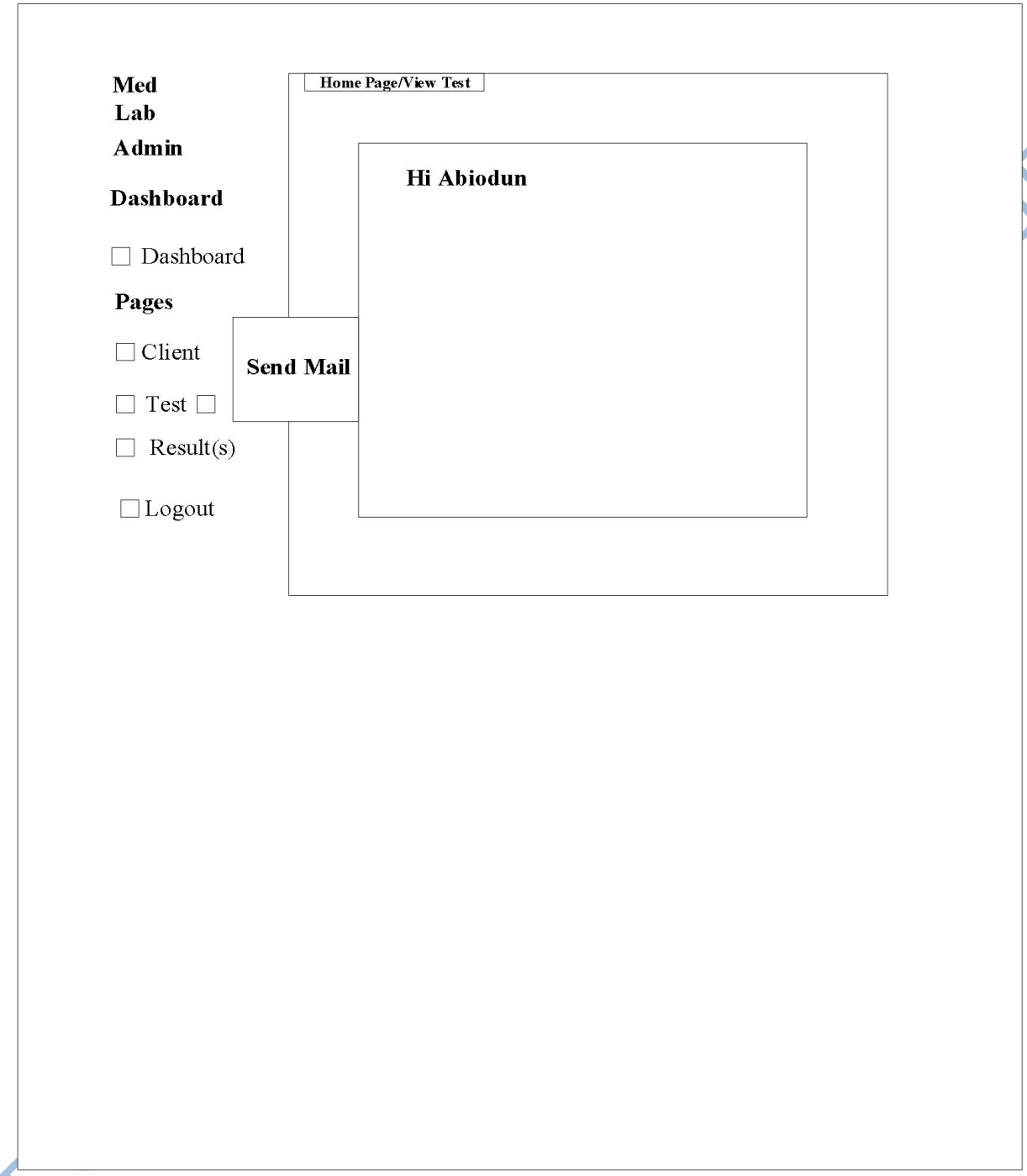


Figure 3.8: Design of send test result page of laboratory support system

(Source: Research Design, 2022)

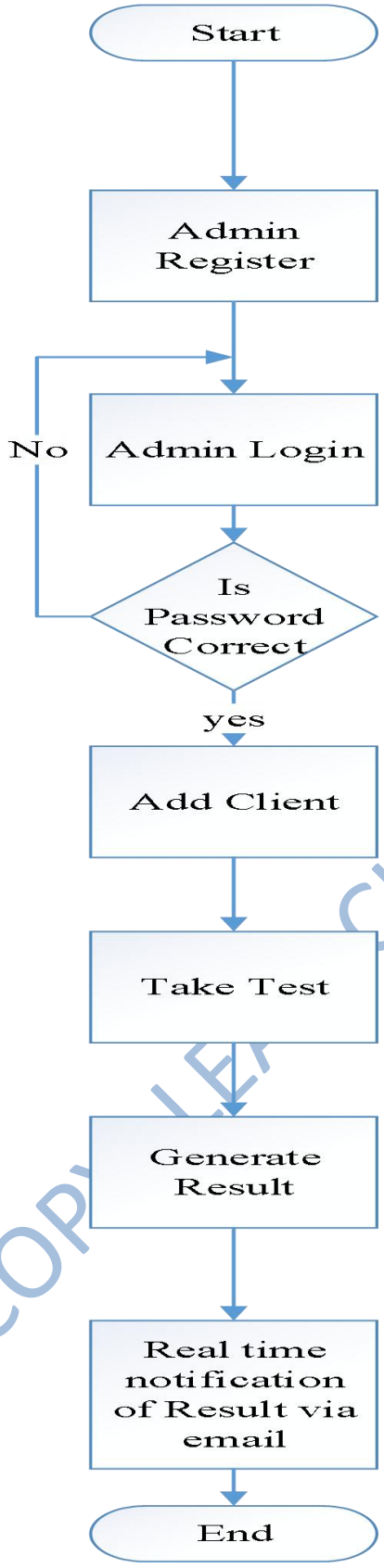


Figure 3.9: Flowchart of the design of computerized laboratory support system

(Source: Research Design, 2022)

3.3 Evaluation of the Developed Application

The application was evaluated at a chosen manual driven laboratory in Ibadan and Oyo and it was tested by a web based applications test engineer based on performance (Response Time, Stability and Load), compatibility and reliability and usability (easy to understand, easy to access, effective navigation). Also**,** the application was used to generate real time notification results of test conducted.

Endnotes

[1]https://blog.pusher.com/laravel-mvc-use/

[2] *Division of HIV/AIDS Prevention, National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention*. Available at https://www.cdc.gov/hiv/testing/index.html

Chapter Four

Result and Discussion of Findings

4.1 Results on the Development of a Computerized Laboratory Support System

For the design, a command “PHP artisan serve” was written on the command prompt to start the local host as shown in figure 4.1. Also, the server (WAMP) must be running on background and connected to the internet. Once this is done, the local host address was typed on the address bar of the browser so as to open the designed software showing the registration and login module as shown in figure 4.2

4.1.1 Result of Admin Registration Page

This is the area where the administrator registers for access to the design. The page contains fields for entering the user's name, email address, password, and confirm password, as well as a register tab (see figure 4.3). This verifies the Administrators' identities. If the user of the system is valid, the user is granted access to and use of the system. It also sends notification when unauthorized users attempt to gain access to system.

4.1.2 Result of Login Page

The dashboard is divided into three sections: client, test, and result(s). Additionally, there are tabs for the client's name, phone number, action, take test, view profile, and add client as illustrated in figure 4.4. The administrator will be able to execute critical activities based on the client's or patient's preference.

4.1.3 Result of Add New Client Page

New clients were added using the add new client tab, which allows to populate the new client's information, which includes their name, email address, phone number,

sex, and date of birth, as illustrated in figure 4.5 a&b. The entry was saved to the database and can be retrieved at any time.

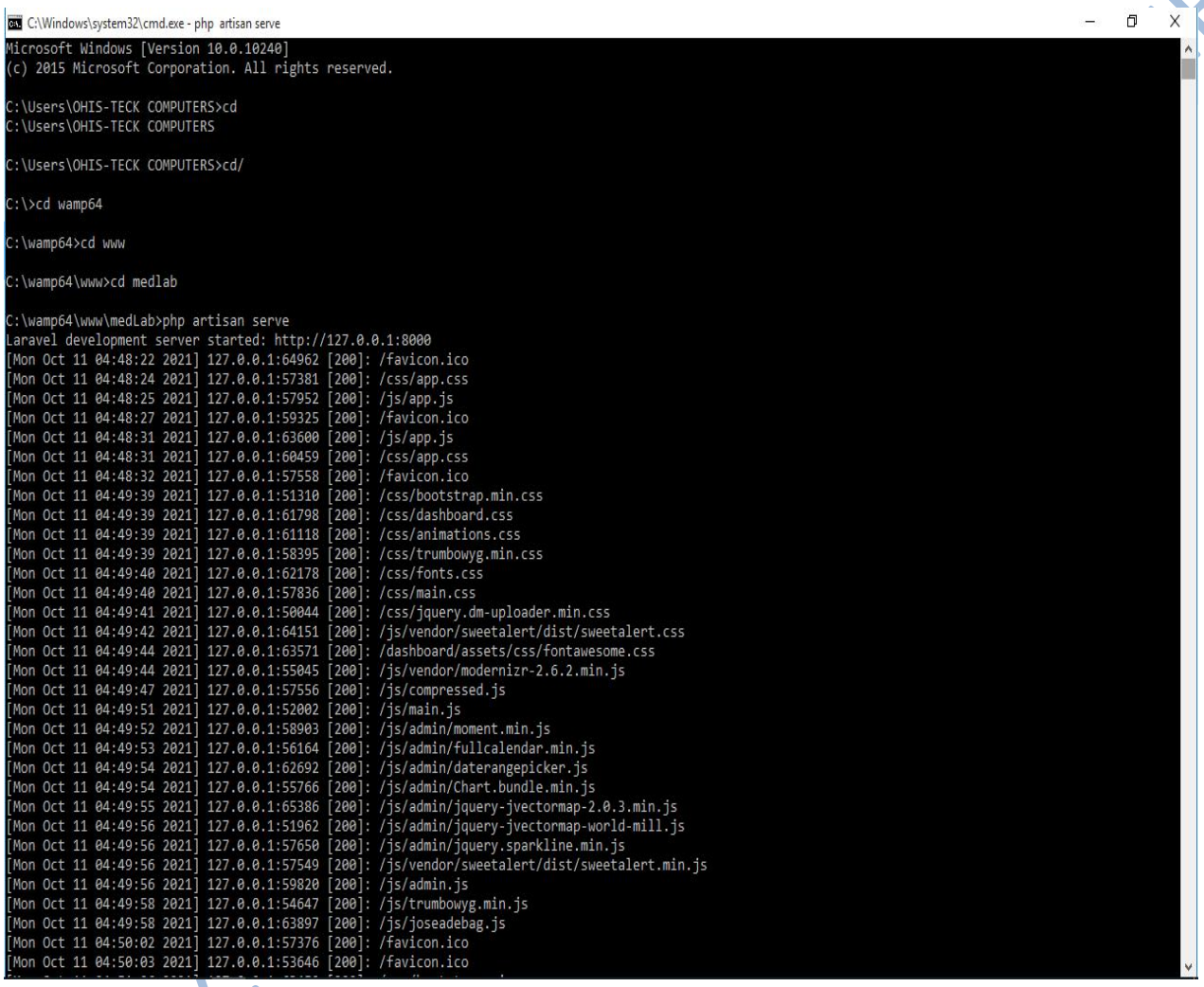


Figure 4.1: Snapshot of "php artisan serve" command written to start the local host (Source: Research Design, 2022)

.

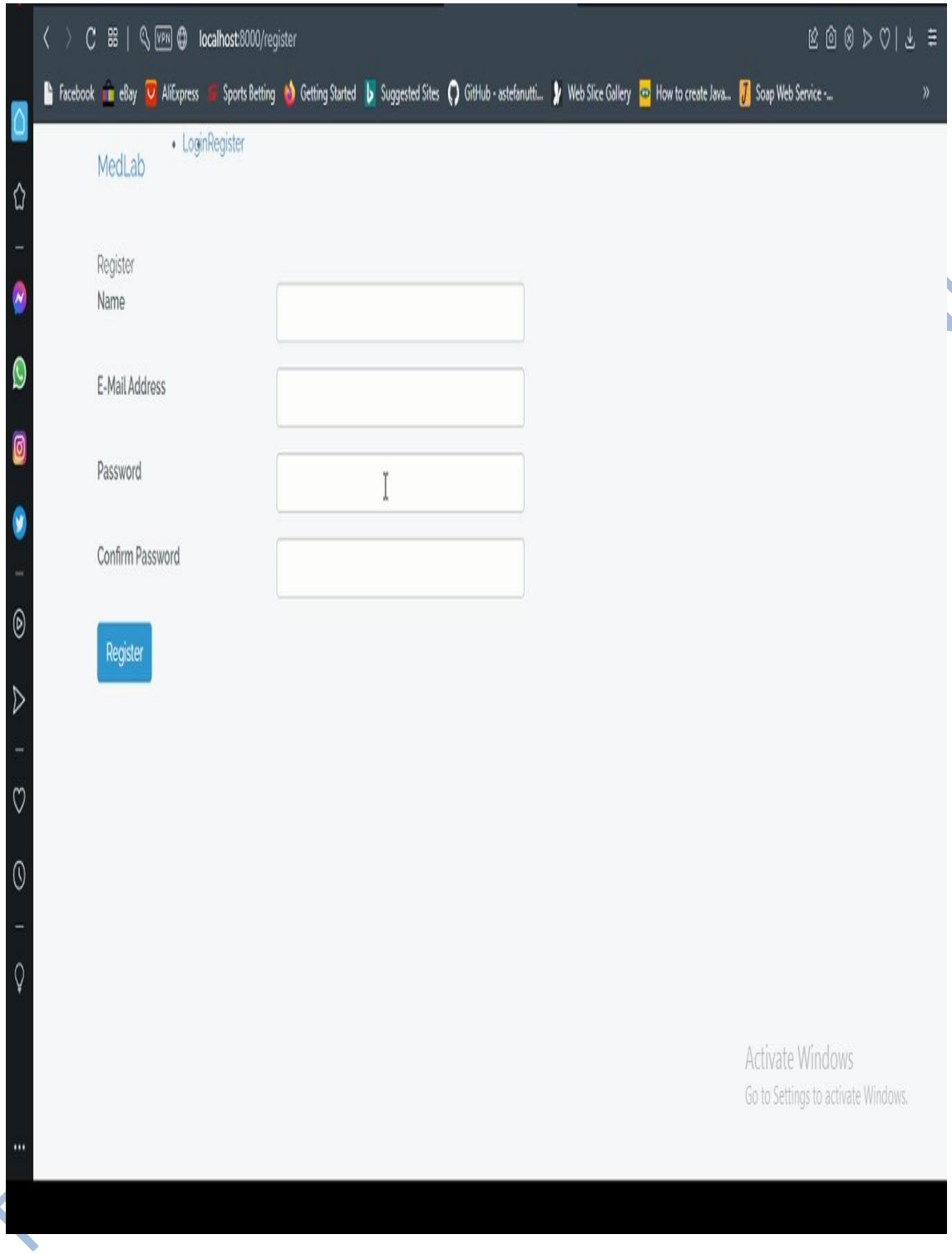


Figure 4.2: Snapshot of the admin registration page computerized laboratory support system

(Source: Research Design, 2022)

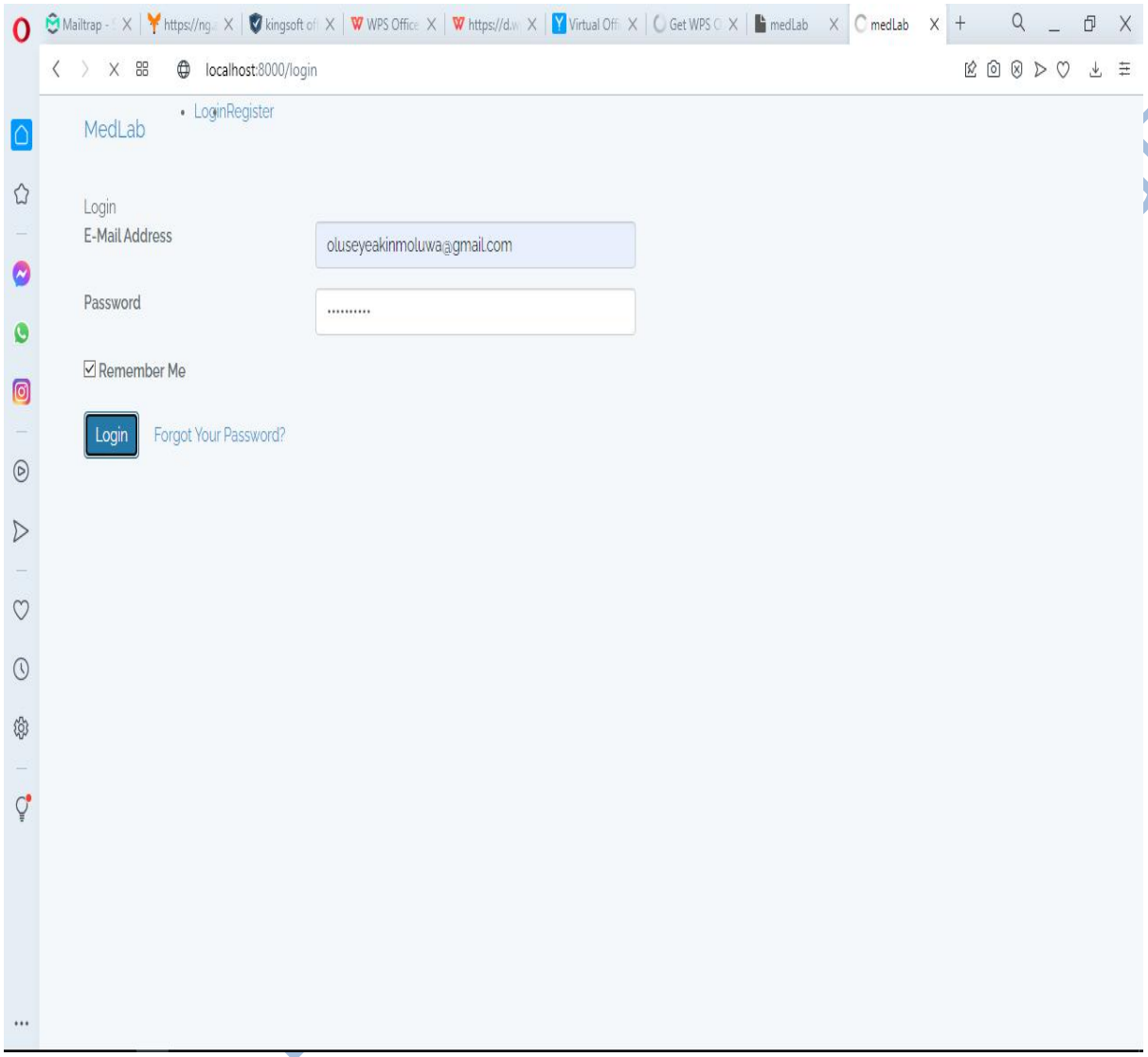


Figure 4.3: Snapshot of login page computerized laboratory support system (Source: Research Design, 2022)

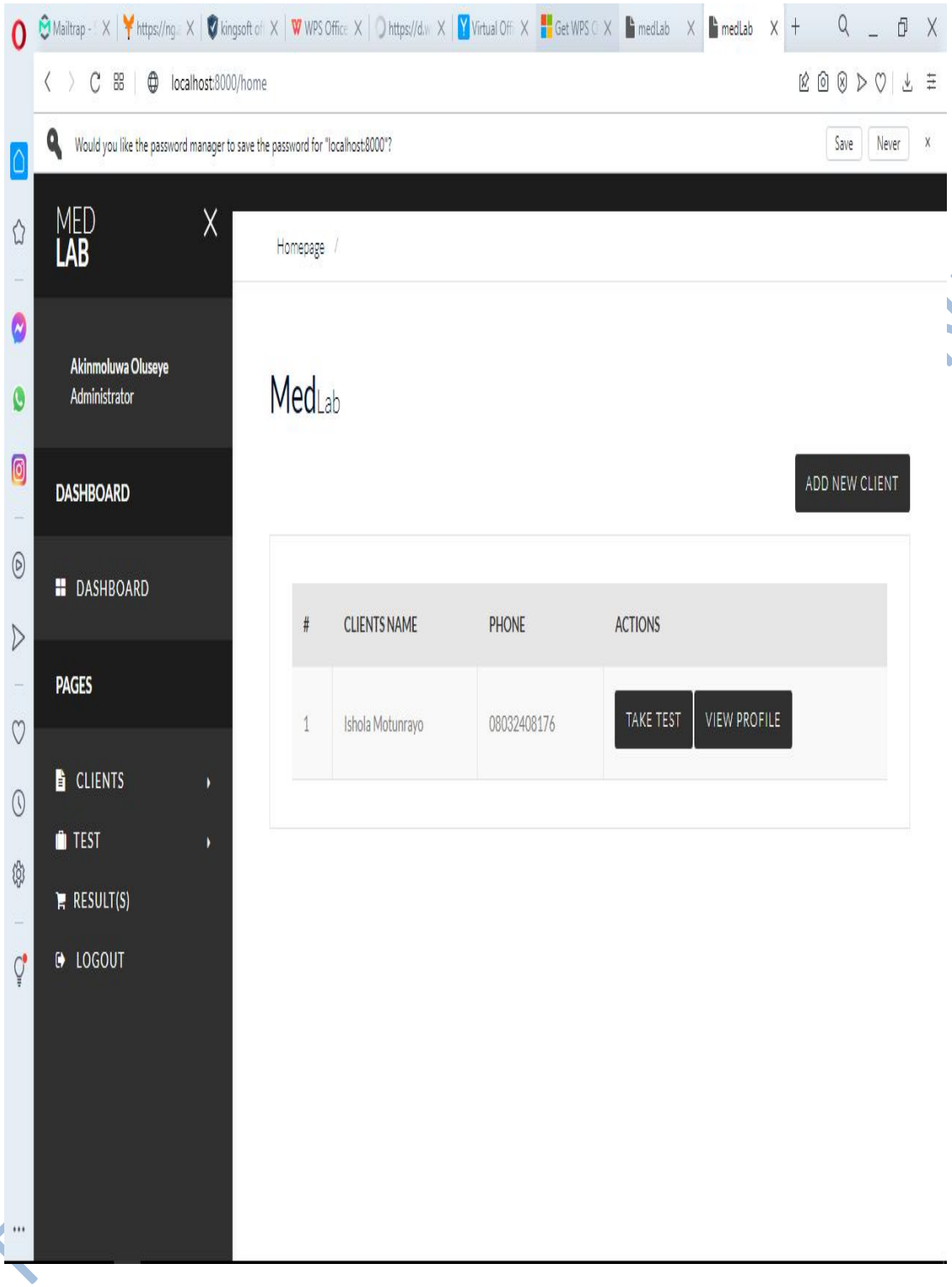


Figure 4.4 (a): Snapshot of the add new client/dashboard page computerized laboratory support system

(Source: Research Design, 2022)

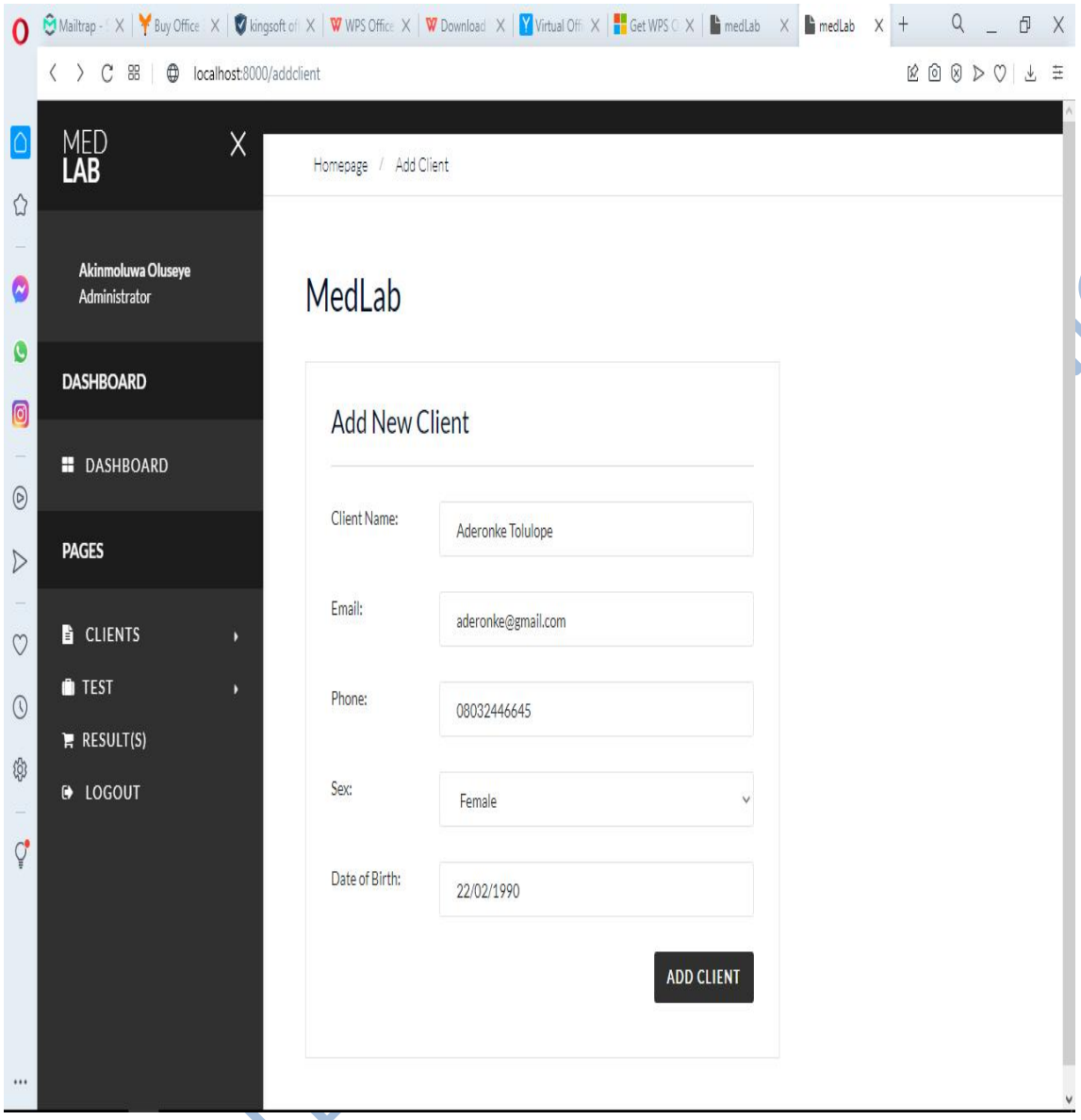


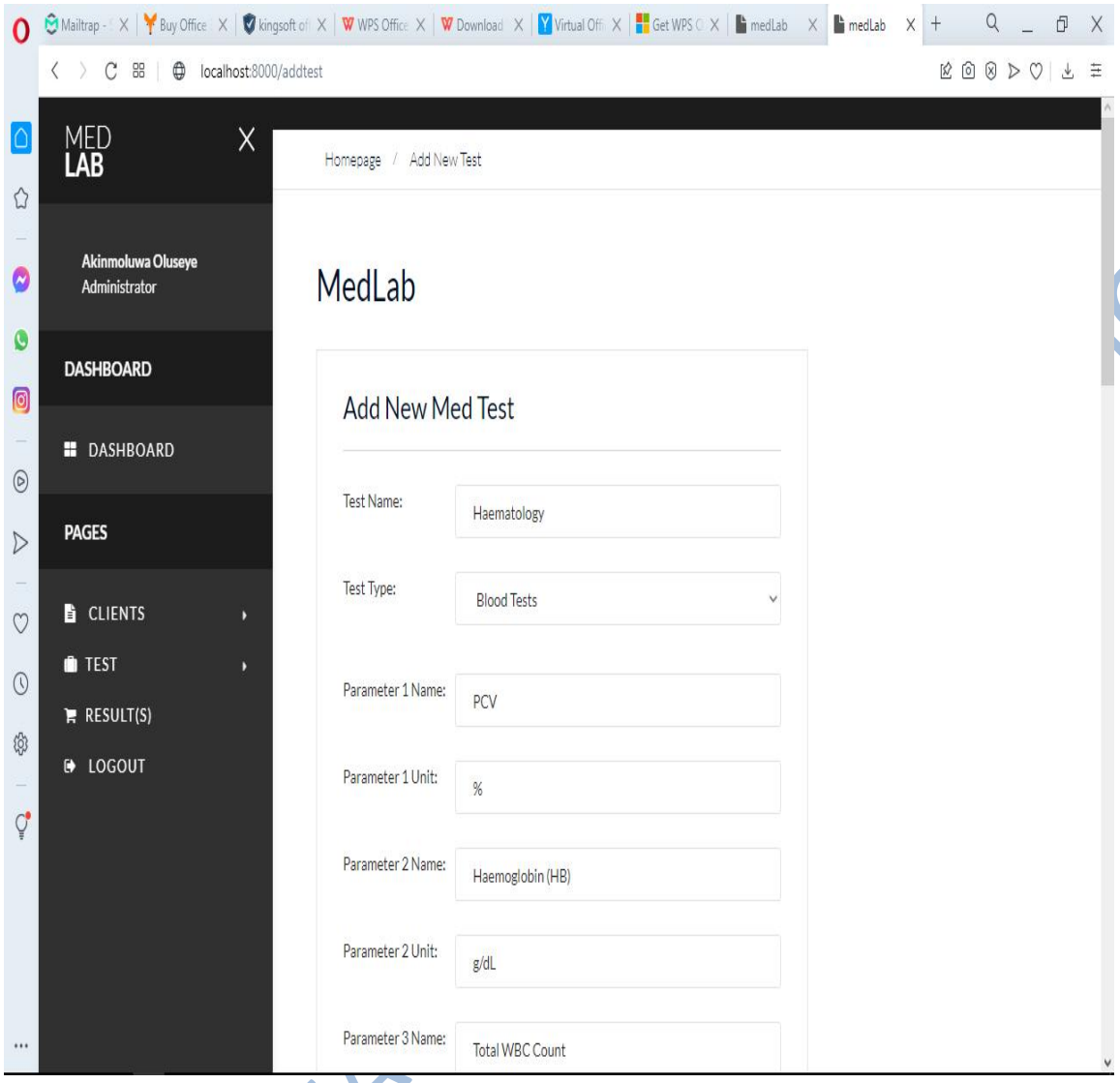
Figure 4.4 (b): Snapshot of the add new client page of computerized laboratory support system

(Source: Research Design, 2022)

4.1.4 Add Test Page

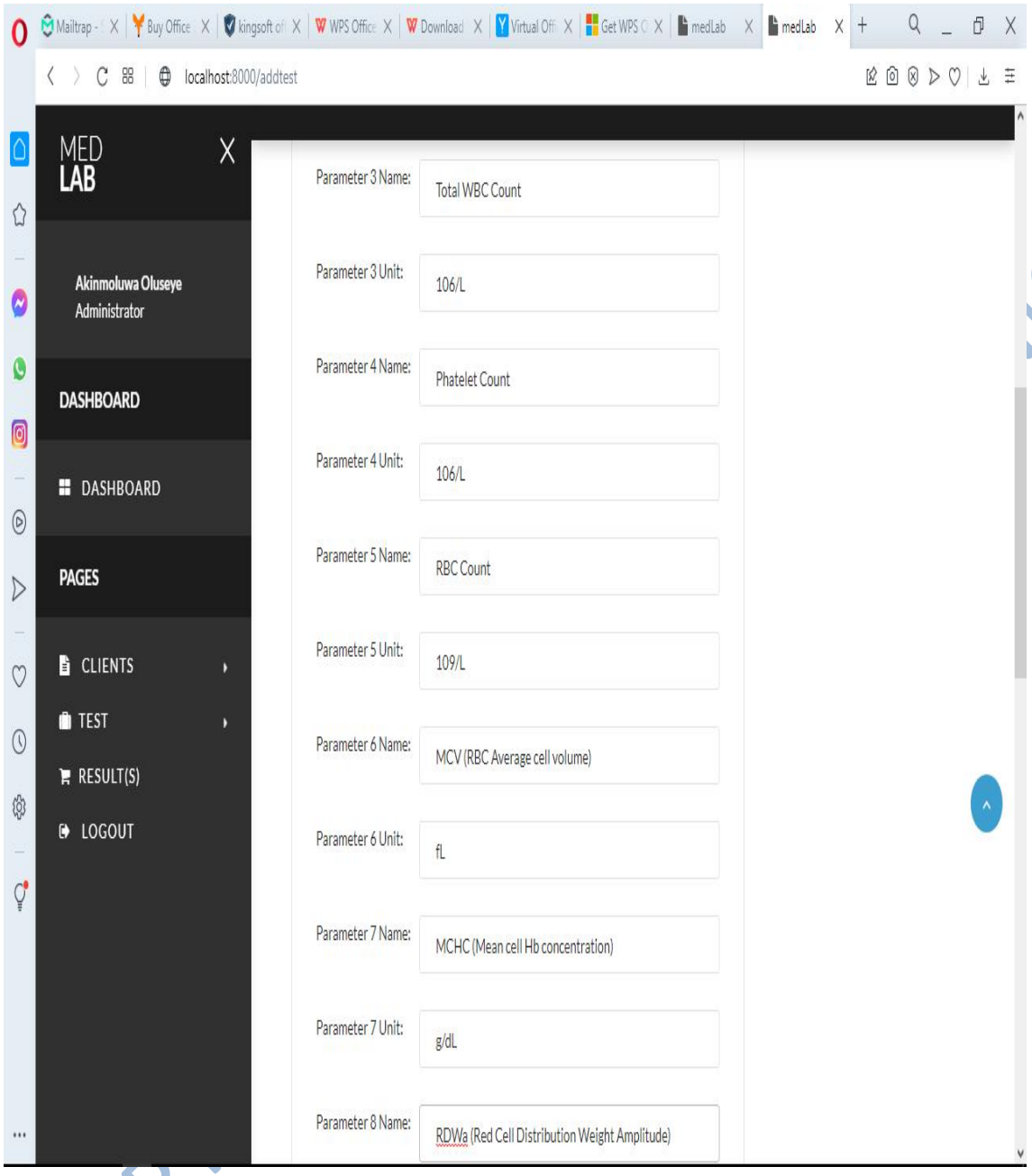
This is the section where the test to be administered is added as illustrated in figure 4.6. After the administrator clicks add new test, a new window displaying the add new test page appears. The add new test command specifies the test's name and the number of parameters to be verified, which varies according to the test's type. For the implementation, the test type is Malaria, where haematology is the test name which have 15 parameters. Then, the add test tab was clicked and a page showing success of the test added popped up as shown in figure 4.6 (d).

Immediately the test is conducted, the values for each parameter will be inputed. For example, if the body temperature of the client or any other results, is 36.7^{o}C, it will be detailed in the result module of the take test page as illustrated in figures 4.7 (a-d) after which a page pops up showing the success of the new test result submission. This can now be accessed via the view test tab on the test taken page of the dashboard as shown in figure 4.8 which will have the test id, test name and date. Additionally, the client information can be read on the user information page which enables the administrator to verify the client's identity before to sending a real-time email as illustrated in figure 4.9. It might be advantageous for changing and updating customer data.



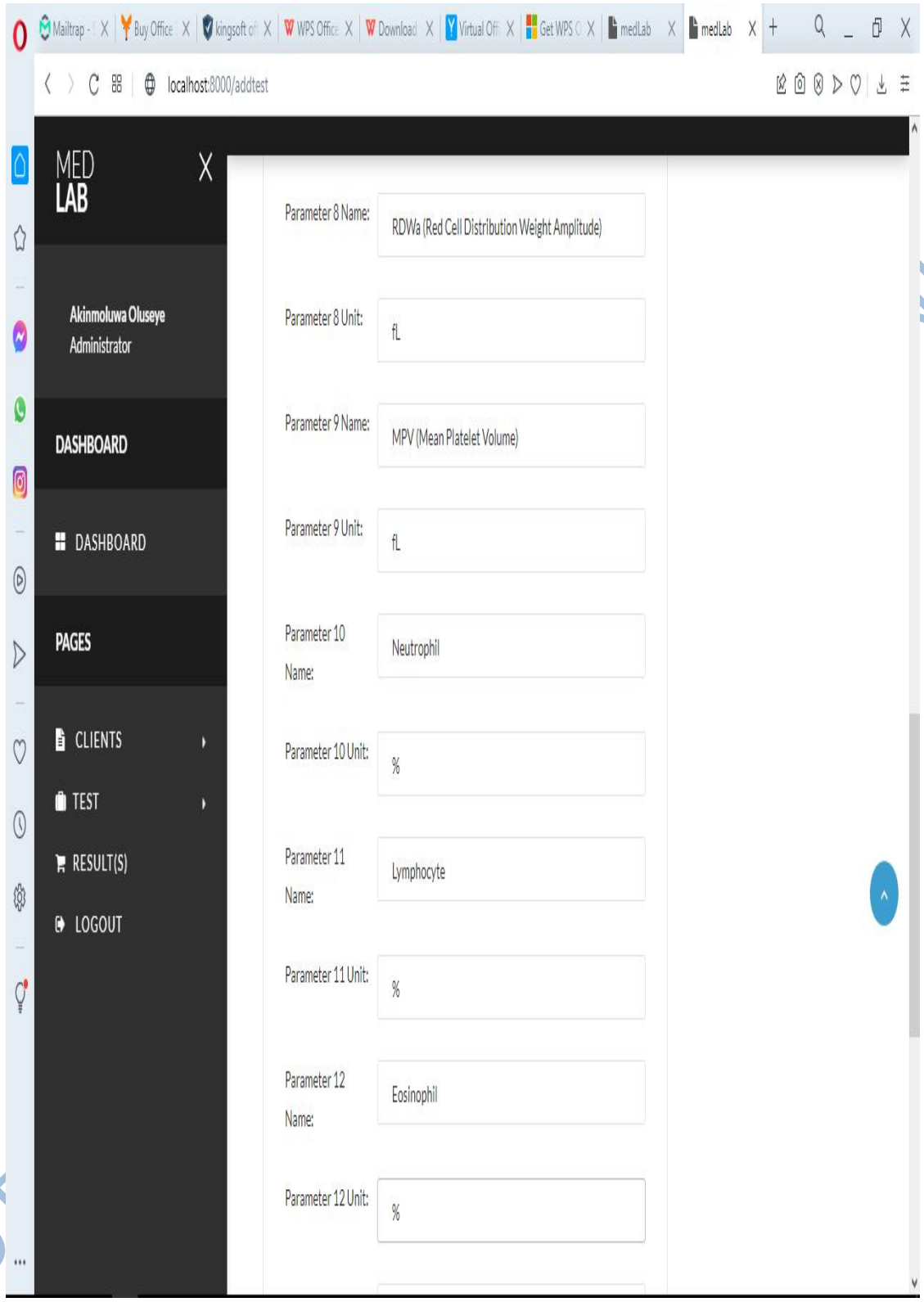
(a)

(Source: Research Design, 2022)



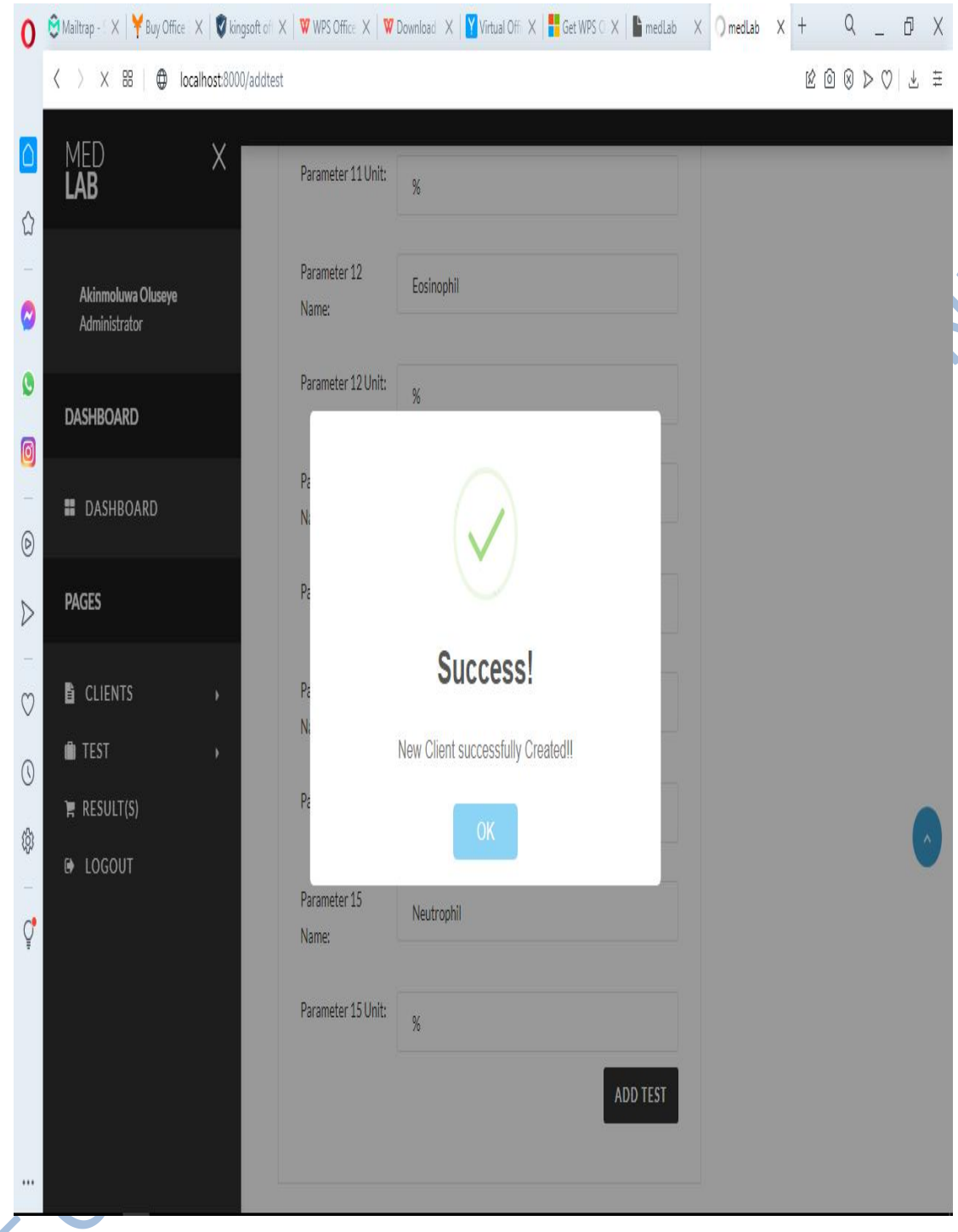
(b)

(Source: Research Design, 2022)



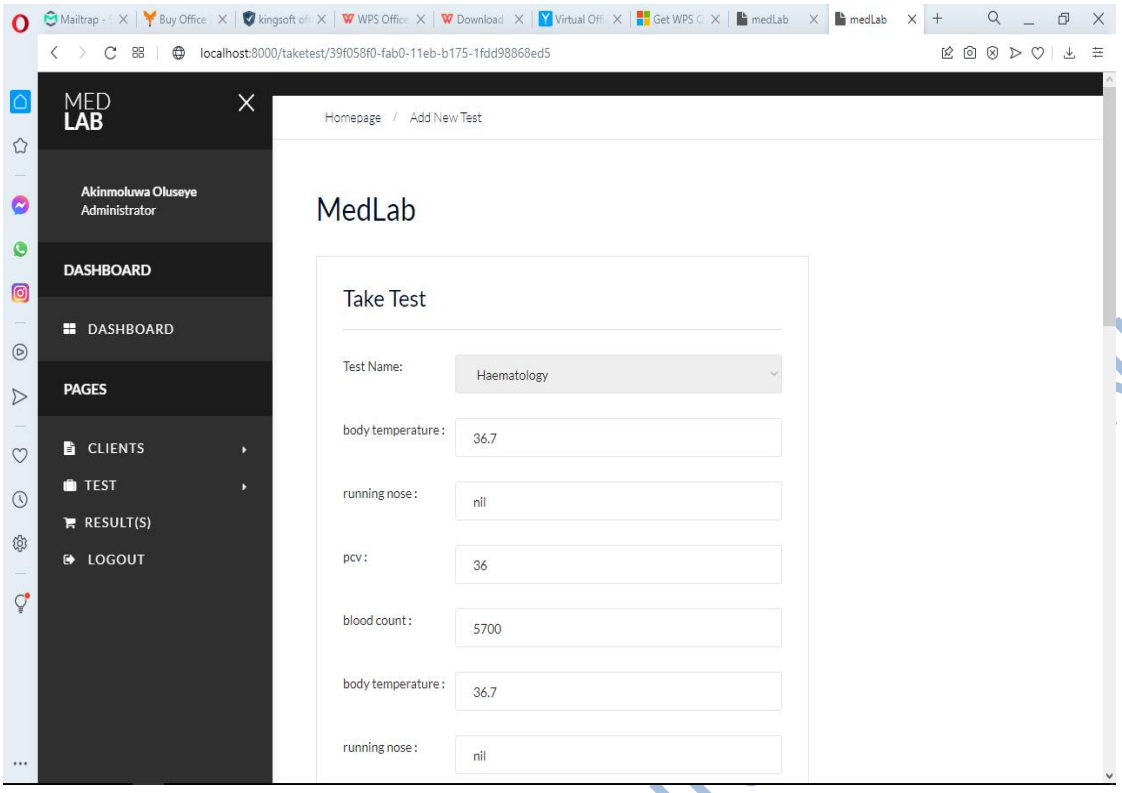
(c)

(Source: Research Design, 2022)

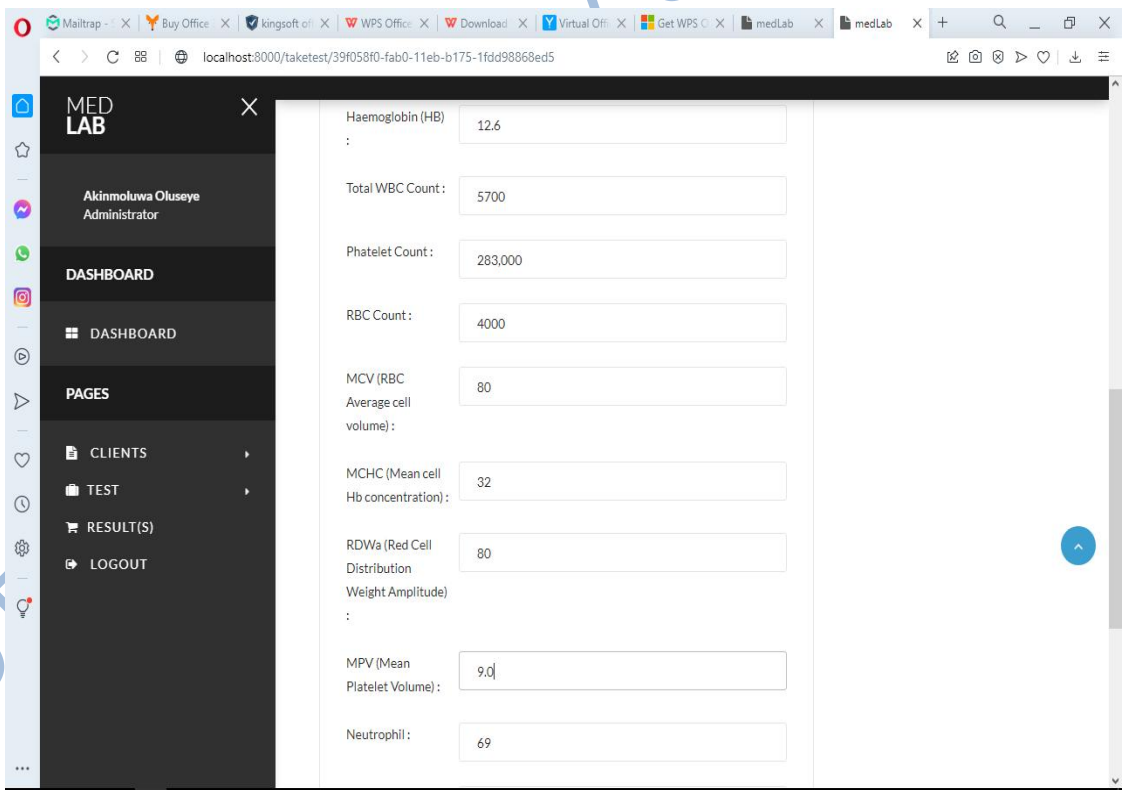


(d)

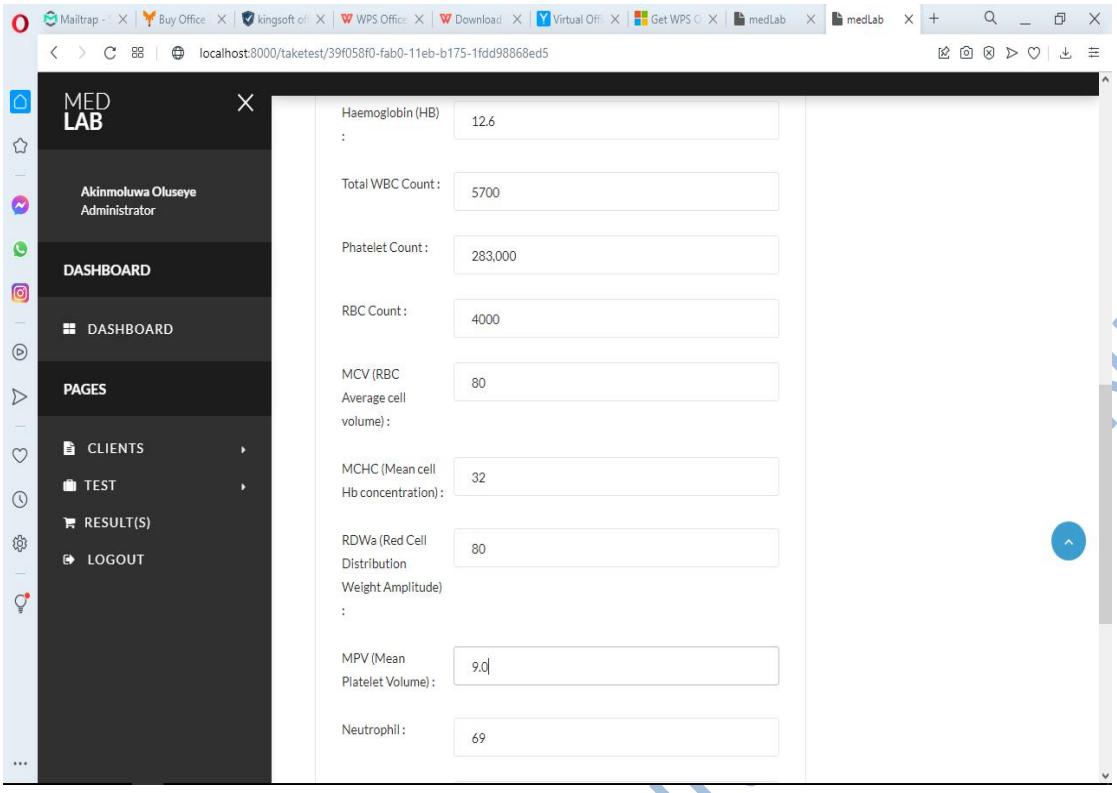
Figure 4.5 (a-d): Snapshot of add test page of computerized laboratory support system (Source: Research Design, 2022)


localhost:8000/taketest/39f058f0-fab0-11eb-b175-1fdd98868ed5
MED LAB
Akinmoluwa Oluseye
Administrator
DASHBOARD
DASHBOARD
PAGES
CLIENTS
TEST
RESULT(S)
LOGOUT
Homepage / Add New Test
MedLab
Take Test
Test Name: Haematology
body temperature : 36.7
running nose : nil
pcv : 36
blood count : 5700
body temperature : 36.7
running nose : nil

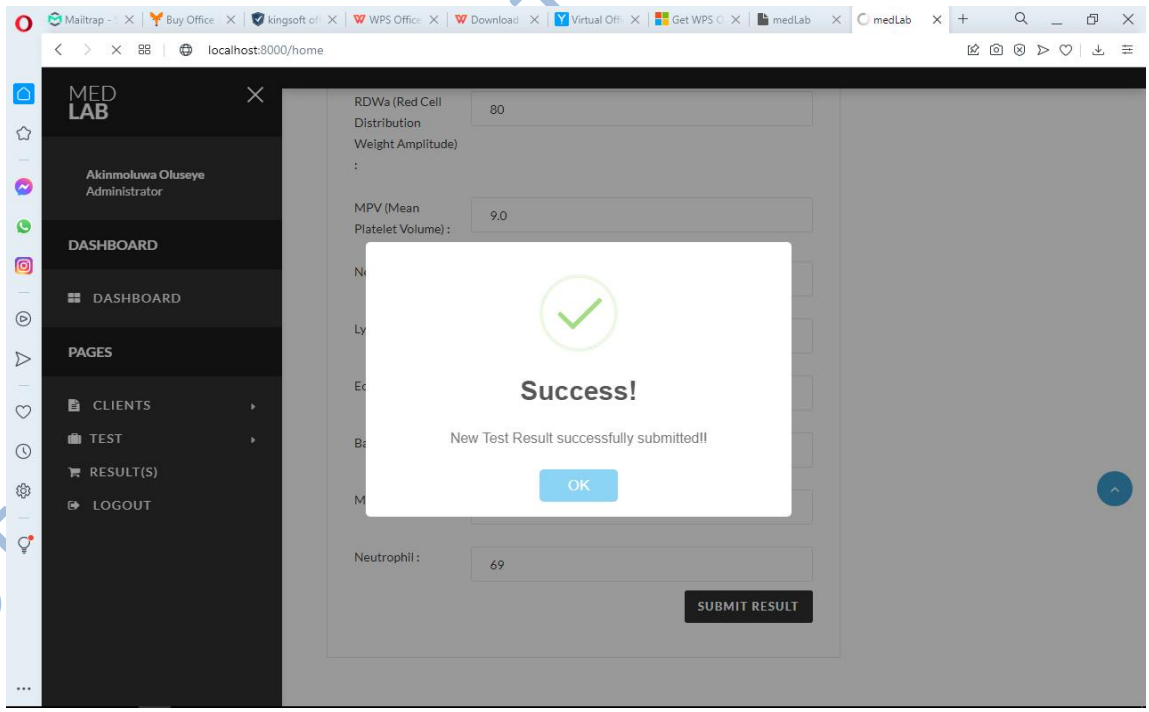
(a)


localhost:8000/taketest/39f058f0-fab0-11eb-b175-1fdd98868ed5
MED LAB
Akinmoluwa Oluseye
Administrator
DASHBOARD
DASHBOARD
PAGES
CLIENTS
TEST
RESULT(S)
LOGOUT
Haemoglobin (HB) : 12.6
Total WBC Count : 5700
Phatelet Count : 283,000
RBC Count : 4000
MCV (RBC Average cell volume) : 80
MCHC (Mean cell Hb concentration) : 32
RDWa (Red Cell Distribution Weight Amplitude) : 80
MPV (Mean Platelet Volume) : 9.0
Neutrophil : 69

(b)



(c)



(d)

Figure 4.6 (a-d): Snapshot of submit test page of computerized laboratory support system

(Source: Research Design, 2022)

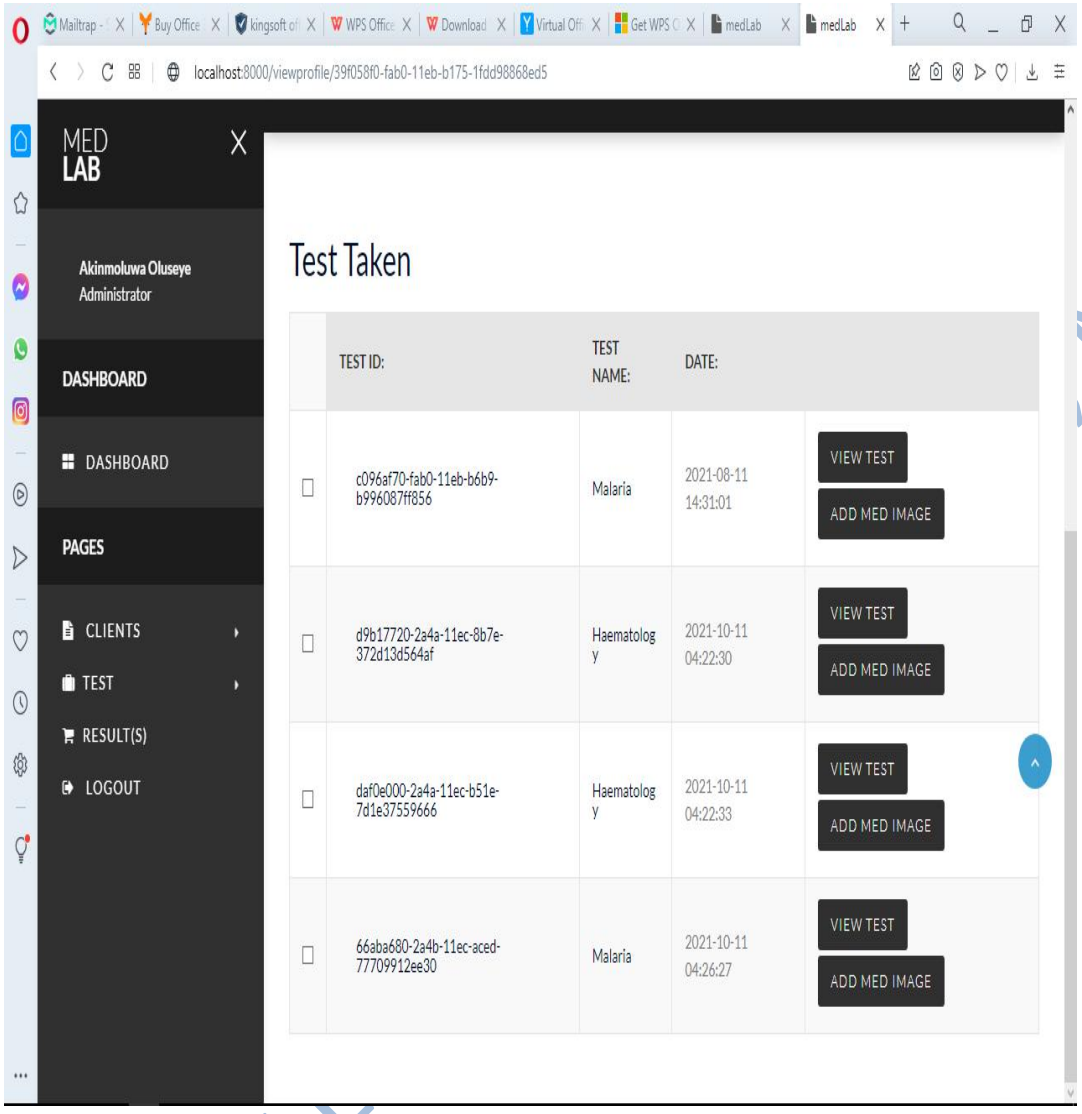


Figure 4.7: Snapshot of view test page of computerized laboratory support system {Source: Research design, 2021)

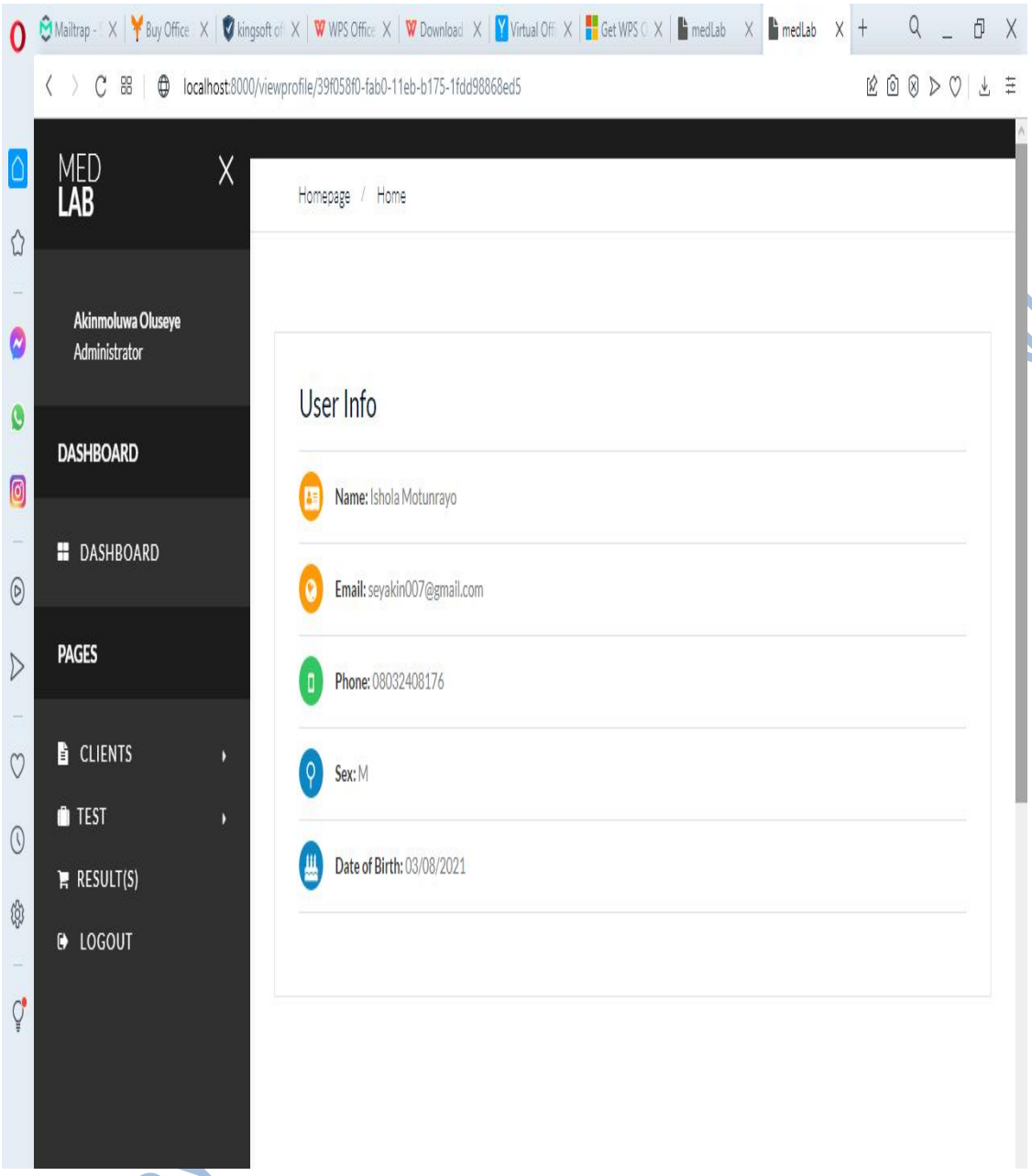


Figure 4.8: Snapshot of user information of computerized laboratory support system (Source: Research Design, 2022)

4.2 Result on Real Time Notification of Test Result

After the test was conducted, completed and saved on the database, an email notification of the result showing the test type, date, time and all parameters with units was sent to the client's email address via the send mail tab as illustrated in figure 4.9 and 4.10 respectively.

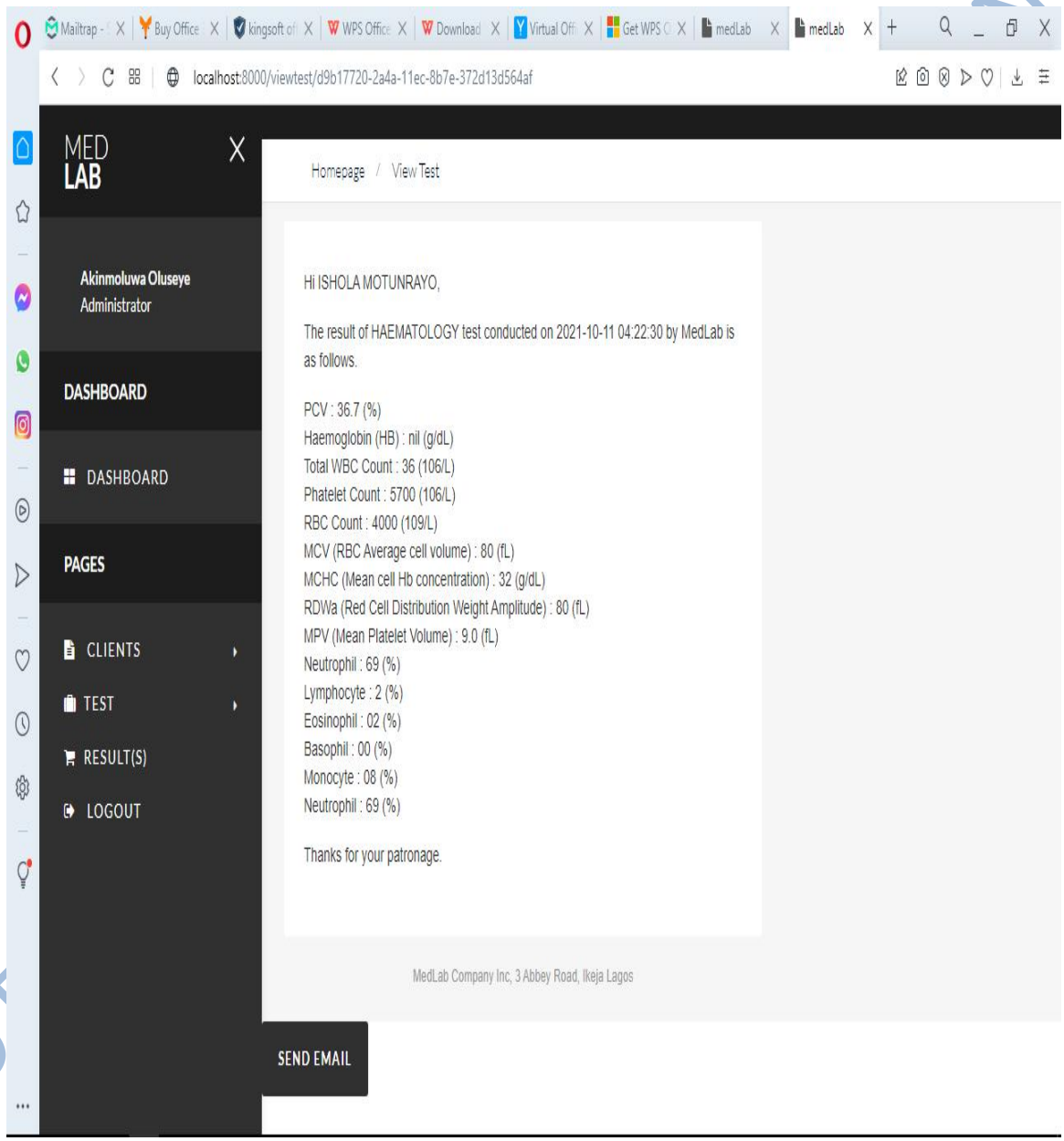


Figure 4.9: Snapshot of test result of computerized laboratory support system (Source: Research Design, 2022)

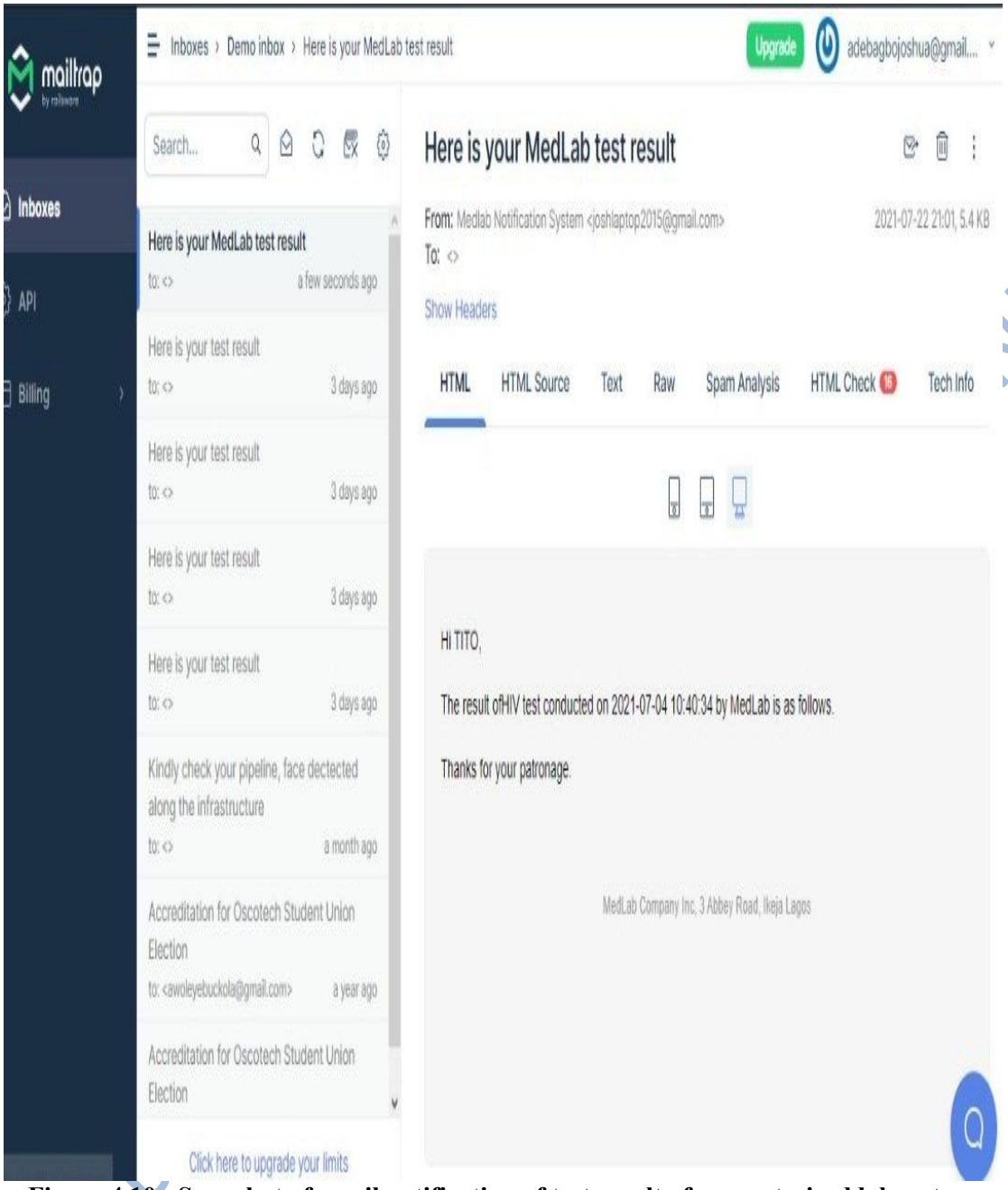


Figure 4.10: Snapshot of email notification of test result of computerized laboratory support system

(Source: Research Design, 2022)

4.3 Result on Evaluation of the Developed Application

Table 4.1: Evaluation Table of the Developed Application

S/N	Test Type			Score (%)
1	Performance	i.	Response Time	95
		ii.	Reliability	93
2	Usability	i.	Easy to Understand	95
		ii.	Easy to Access	93
		iii.	Effective Navigation	95
3	Compatibility	i.	Software	95
		ii.	Hardware	90
		iii.	Network	90
4	Scalability	i.	Throughput	90

(Source: Research Design, 2022)

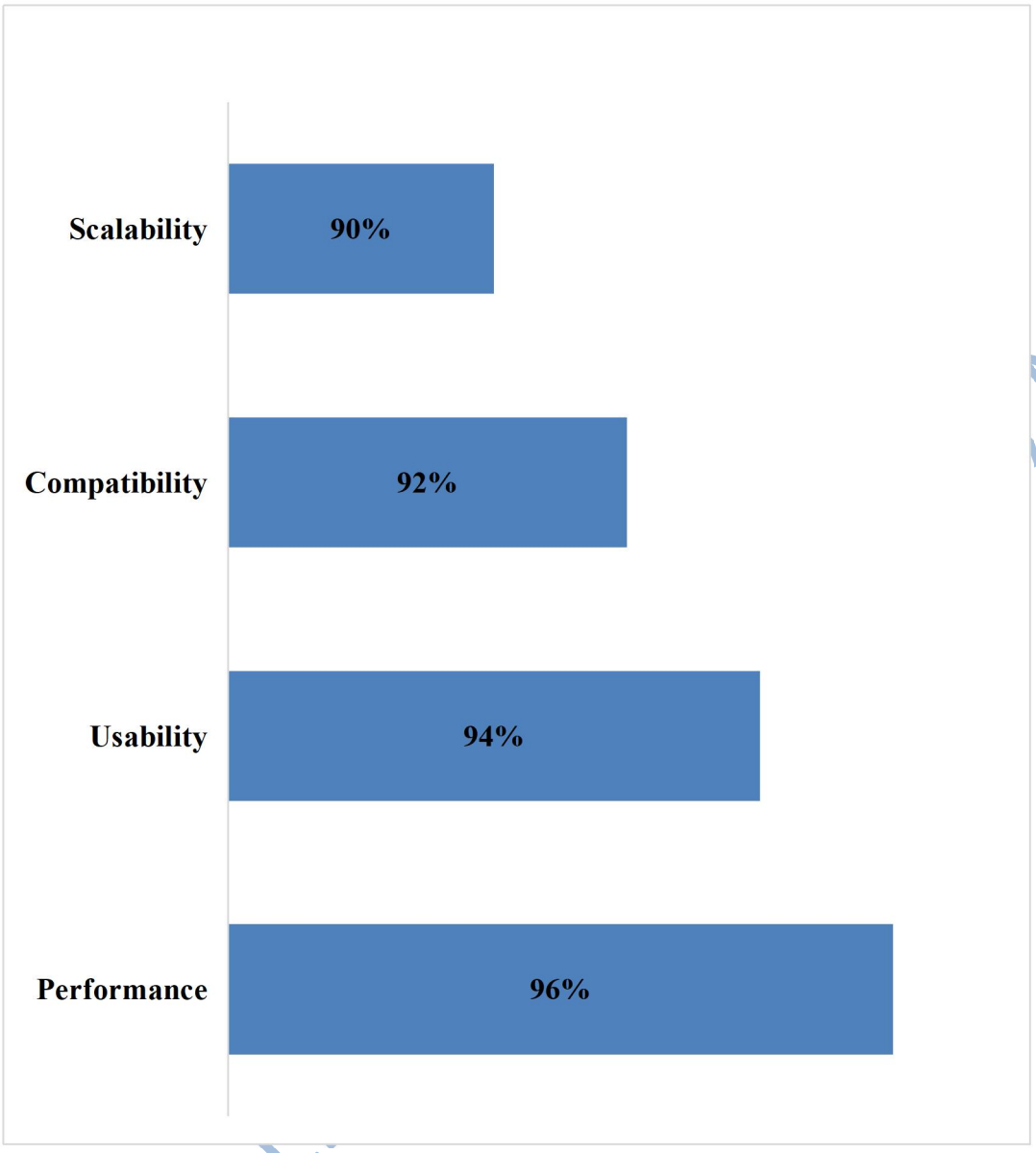


Figure 4.11: Evaluation chart of the designed system

4.4 Discussion of Findings

The developed computerized laboratory support application is a web based model built on laravel 7.29 and a WAMP (Windows, Apache, MySQL, PHP) server running on the background. The developed system comes with the ability to add clients details, take test, and send test results via to the clients email as shown in figure 4.1, the "php artisan serve" command was written there by starting the developed server. Once the developed server starts, the web based application begins typing "local host 8000" on the internet address bar which in turn leads to the login in page of the application.

Figures 4.2-4.8 show snapshot of the implementation of the developed system where the admin registers and log in, add client after which the client can go ahead to take test and the test parameters are saved on the database for retrieval.

Evaluating the design as shown in figure 4.9 at a chosen manual driven laboratory, the design was tested by a software test engineer and a web developer. The test is based on performance (Response Time, Reliability), compatibility (software, hardware), usability (easy to understand, easy to access, effective navigation) and scalability. The design was used to generate real time notification results of test conducted.

4.4.1 Performance Testing

Response time: It is the time taken by the server to respond to the request. Mails are sent to the client email at about 2-3 seconds which showed a good response time of 95%. However, the response time is dependent of the network used for internet.

Reliability: The design was reliable at a good network speed.Hence a score of 90%

4.4.2 Usability Testing

User-friendliness, efficiency, and accuracy of the design were tested. The design is easy to understand,easy navigation, simple process with efficient HCI. Easy to access since the component required are open source, faster to access i.e, the design is faster while accessing,good internal linking and informative header and footer. Hence having a score of easy to understand, easy to access, effective navigation 95%, 93% and 95% having an average score of 94% respectively

4.4.3 Compatibility Testing

Software: The design is compatible with different operating systems, both for forward compatibility and backward compatibility having a score of 95%. Also with different browsers like **Google Chrome, Firefox,** and **Internet Explorer.**

Hardware: The design is compatible with hardware of different sizes such as RAM, hard disk, processor, and the graphic card with a score of 90%

Network: Compatibility with different network parameters such as operating speed, bandwidth, and capacity with a score of 90%

4.4.4 Scalability Testing

The design has a Throughput of 90%,

Chapter Five

Conclusion

5.1 Summary of Findings

This research developed a web based computerized laboratory support system built on laravel and a wamp server. The developed system comes with the ability to add new clients and their details, take test, and send test results via the web server to the clients email. All client details and test taken was also automatically stored on the web for retrieval and future references. The developed web based computerized laboratory support application was evaluated and worked as expected, having a response time of 95%, 94%usability and 90% reliability. The system is significant in reducing customer waiting time at the laboratory, eliminating bulky manual files causing hectic information retrieval, reducing drastically loss of data due to the manual processes, sends real time test results via emails. The developed model will be able to perform its required functions for a long time without change of features.

5.2 Conclusion

Different tests were conducted and the result of the tests was sent real time to clients email addresses. Also, the speed of transmission to the email depends on the strength of the network. The system had a good response time, scalability, and reliability. However, response time is dependent of the network used for internet.

For this research, the test results were sent immediately and received in the email. Hence, the system provided a simple, cheaper and durable computerized hospital laboratory operations system. The major limitations of this research were the internet network connection and internet speed. The developed applicationis based solely on good and efficient network for prompt and effortless transmission and connectivity. Another limitation is that the test conducted was in one laboratory based on relationship, other government laboratories and some private ones visited were not accessible due to ethical reasons. Also, email result was simulated using a paid email

address (Mail Trap) as gmail flags a security breach alert on every mail sent, blocking the receipt of mail in the gmail address.

5.3 Recommendation

It is recommended that the developed web based computerized laboratory support application is embraced and implemented in hospitals (both private and government), laboratories and all health related facilities as it will go a long way to solve customer waiting time at the laboratories, eliminate bulky manual files leading to delayed information retrieval, reducing drastically loss of data due to the manual processes

5.4 Contribution to Knowledge

The result will serve as an eye opener to both public and private laboratories on the use of Information Technology in optimizing an effective, efficient and seamless laboratory management, also to the patients, it will reduce the patients waiting time, and the mismatch of results will be eliminated, there by increasing their confidence in the country's laboratory analysis.

Academically, the result of this findings will serve as a reference material for projects on open source and less costly App development, computerized health management and other related researches

5.5 Suggestions for Further Research

The following are the suggestions for further research:

i. More research should be done on computerized laboratory support system by integrating and miniaturizing the web app into a mobile app which will be available on mobile phones and accessible on the go

ii. Moreover, further work can be done by adding a capturing module, where client photograph can be captured during registration and the result will be sent with the image of the client attached for proper identification.

iii. Finally, the developed system can be improved upon to send not only email, but also, messages on clients social media platforms like WhatsApp, facebook messanger, and even text messages as some client may not be online to check their mail on social media handles

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Appendix I

Register Code

```
@extends('layouts.app')

@section('content')
<div class="container">
   <div class="row justify-content-center">
      <div class="col-md-8">
         <div class="card">
            <div class="card-header">{{ __('Register') }}</div>

            <div class="card-body">
               <form method="POST" action="{{ route('register') }}">
                  @csrf

                  <div class="form-group row">
                     <label for="name" class="col-md-4 col-form-label text-md-
right">{{ __('Name') }}</label>

                     <div class="col-md-6">
                        <input id="name" type="text" class="form-
control @error('name') is-
invalid @enderror" name="name" value="{{ old('name') }}" required autocomplete="
name" autofocus>

                        @error('name')
                           <span class="invalid-feedback" role="alert">
                              <strong>{{ $message }}</strong>
                           </span>
                        @enderror
                     </div>
                  </div>

                  <div class="form-group row">
                     <label for="email" class="col-md-4 col-form-label text-md-
right">{{ __('E-Mail Address') }}</label>

                     <div class="col-md-6">
                        <input id="email" type="email" class="form-
control @error('email') is-
invalid @enderror" name="email" value="{{ old('email') }}" required autocomplete=
"email">

                        @error('email')
                           <span class="invalid-feedback" role="alert">
                              <strong>{{ $message }}</strong>
                           </span>
                        @enderror
```

```
                    </div>
                </div>

                <div class="form-group row">
                    <label for="password" class="col-md-4 col-form-label text-md-
right">{{ __('Password') }}</label>

                    <div class="col-md-6">+
                        <input id="password" type="password" class="form-
control @error('password') is-
invalid @enderror" name="password" required autocomplete="new-password">

                        @error('password')
                            <span class="invalid-feedback" role="alert">
                                <strong>{{ $message }}</strong>
                            </span>
                        @enderror
                    </div>
                </div>

                <div class="form-group row">
                    <label for="password-confirm" class="col-md-4 col-form-label text-
md-right">{{ __('Confirm Password') }}</label>

                    <div class="col-md-6">
                        <input id="password-confirm" type="password" class="form-
control" name="password_confirmation" required autocomplete="new-password">
                    </div>
                </div>

                <div class="form-group row mb-0">
                    <div class="col-md-6 offset-md-4">
                        <button type="submit" class="btn btn-primary">
                            {{ __('Register') }}
                        </button>
                    </div>
                </div>
            </form>
        </div>
    </div>
</div>
</div>
@endsection
```

Appendix II:
Login Code

```
@extends('layouts.app')

@section('content')
<div class="container">
    <div class="row justify-content-center">
        <div class="col-md-8">
            <div class="card">
                <div class="card-header">{{ __('Login') }}</div>

                <div class="card-body">
                    <form method="POST" action="{{ route('login') }}">
                        @csrf

                        <div class="form-group row">
                            <label for="email" class="col-md-4 col-form-label text-md-
right">{{ __('E-Mail Address') }}</label>

                            <div class="col-md-6">
                                <input id="email" type="email" class="form-
control @error('email') is-
invalid @enderror" name="email" value="{{ old('email') }}" required autocomplete=
"email" autofocus>

                                @error('email')
                                    <span class="invalid-feedback" role="alert">
                                        <strong>{{ $message }}</strong>
                                    </span>
                                @enderror
                            </div>
                        </div>

                        <div class="form-group row">
                            <label for="password" class="col-md-4 col-form-label text-md-
right">{{ __('Password') }}</label>

                            <div class="col-md-6">
                                <input id="password" type="password" class="form-
control @error('password') is-
invalid @enderror" name="password" required autocomplete="current-password">

                                @error('password')
                                    <span class="invalid-feedback" role="alert">
                                        <strong>{{ $message }}</strong>
                                    </span>
                                @enderror
                            </div>
                        </div>
```

```
                    <div class="form-group row">
                        <div class="col-md-6 offset-md-4">
                            <div class="form-check">
                                <input class="form-check-
input" type="checkbox" name="remember" id="remember" {{ old('remember') ? 'che
cked' : '' }}>

                                <label class="form-check-label" for="remember">
                                    {{ __('Remember Me') }}
                                </label>
                            </div>
                        </div>
                    </div>

                    <div class="form-group row mb-0">
                        <div class="col-md-8 offset-md-4">
                            <button type="submit" class="btn btn-primary">
                                {{ __('Login') }}
                            </button>

                            @if (Route::has('password.request'))
                                <a class="btn btn-link" href="{{ route('password.request') }}">
                                    {{ __('Forgot Your Password?') }}
                                </a>
                            @endif
                        </div>
                    </div>
                </form>
            </div>
        </div>
    </div>
</div>
@endsection


<?php

namespace App\Http\Controllers\Auth;

use App\Http\Controllers\Controller;
use App\Providers\RouteServiceProvider;
use Illuminate\Foundation\Auth\AuthenticatesUsers;

class LoginController extends Controller
{
    /*
    |--------------------------------------------------------------------------
    | Login Controller
    |--------------------------------------------------------------------------
```

```
    |
    | This controller handles authenticating users for the application and
    | redirecting them to your home screen. The controller uses a trait
    | to conveniently provide its functionality to your applications.
    |
    */

    use AuthenticatesUsers;

    /**
     * Where to redirect users after login.
     *
     * @var string
     */
    protected $redirectTo = RouteServiceProvider::HOME;

    /**
     * Create a new controller instance.
     *
     * @return void
     */
    public function __construct()
    {
        $this->middleware('guest')->except('logout');
    }
}
```

```
<?php

namespace App;

use Illuminate\Contracts\Auth\MustVerifyEmail;
use Illuminate\Foundation\Auth\User as Authenticatable;
use Illuminate\Notifications\Notifiable;

class User extends Authenticatable
{
    use Notifiable;

    /**
     * The attributes that are mass assignable.
     *
     * @var array
     */
    protected $fillable = [
        'name', 'email', 'password',
    ];
```

```
    /**
     * The attributes that should be hidden for arrays.
     *
     * @var array
     */
    protected $hidden = [
        'password', 'remember_token',
    ];

    /**
     * The attributes that should be cast to native types.
     *
     * @var array
     */
    protected $casts = [
        'email_verified_at' => 'datetime',
    ];
}
```

Addclients

```
@extends('layouts.admin')
@section('title')
  MedLab
@endsection

@section('styles')
<!-- <script src="https://cloud.tinymce.com/stable/tinymce.min.js"></script>
  <script>tinymce.init({ selector:'textarea' });</script> -->
@endsection

@section('page')
<a href="{{url('/addclient')}}">Add Client</a>
@endsection

@section('content')

        <section class="ls section_padding_top_50 section_padding_bottom_50 colu
mns_padding_5">
            <div class="container-fluid">

                <div class="row">
                    <div class="col-sm-12">
                        <h3>MedLab

                        </h3>
                    </div>
                </div>
                <!-- .row -->
```

```
<div class="row">
<div class="col-md-8">
        <div class="with_border with_padding">

            <h4>
               Add New Client

            </h4>

            <hr>

            <div class="row form-group">
               <label class="col-lg-3 control-label">Client Name: </label>
               <div class="col-lg-9">
                  <input type="text" id="tname" class="form-control">
               </div>
            </div>


            <div class="row form-group">
               <label class="col-lg-3 control-label">Email: </label>
               <div class="col-lg-9">
                  <input type="email" id="temail" class="form-control">
               </div>
            </div>

            <div class="row form-group">
               <label class="col-lg-3 control-label">Phone: </label>
               <div class="col-lg-9">
                  <input type="text" id="tphone" class="form-control">
               </div>
            </div>

            <div class="row form-group">
               <label class="col-lg-3 control-label">Sex: </label>
               <div class="col-lg-9">
                  <select class="form-control with-selected" name="with-
selected" id="tsex">

                        <option value="M">Male</option>
                        <option value="F">Female</option>

                  </select>
               </div>
            </div>
            <div class="row form-group ">
            <label class="col-lg-3 control-label">Date of Birth: </label>

            <div class="col-lg-9">
```

```
                        <input type="text" class="form-control" id="tdate" data-
provide="datepicker" data-date-format="dd/mm/yyyy">

                    </div>
                    </div>

                    <div class="row">
                        <div class="col-sm-12 text-right">
                            <button type="submit" id="addteacher" class="theme_butt
on wide_button">Add Client</button>

                        </div>
                    </div>
                    <!-- .row  -->

                </div>
                <!-- .with_border -->

            </div>
        <!-- .col-* -->
    </div>
    <!-- .row -->

    <!-- .row -->

</div>
<!-- .container -->
</section>

@endsection


@section('script')
<script src="../js/joseadebag.js"></script>
<script src="../js/bootstrap-datepicker.min.js"></script>
<script src="https://cdnjs.cloudflare.com/ajax/libs/bootstrap-
datepicker/1.9.0/js/bootstrap-datepicker.min.js" integrity="sha512-
T/tUfKSV1bihCnd+MxKD0Hm1uBBroVYBOYSk1knyvQ9VyZJpc/ALb4P0r6ubw
VPSGB2GvjeoMAJJImBG12TiaQ==" crossorigin="anonymous"></script>
<script type="text/javascript">
$.fn.datepicker.defaults.format = "dd/mm/yyyy";
    $('.datepicker').datepicker({
        format: 'dd/mm/yyyy',
        startDate: '-3d'
    });


    $("#addteacher").off('click').on('click', function() {

        //tdate tsex tphone temail tname
```

```
var name = $.trim($('#tname').val());
var email = $.trim($('#temail').val());
var tdate = $.trim($('#tdate').val());
var tsex = $.trim($('#tsex').val());
var phone = $.trim($('#tphone').val());


 crosssite();
 if($('#tname').val() == ''){
    swal("Error!", "Please supply Client's name!", "error", {
      button: "OK",
      });
     return;
 }
 if($('#temail').val() == ''){
      swal("Error!", "Please Client's supply email!", "error", {
       button: "OK",
      });
     return;
 }
 if($('#tdate').val() == ''){
     swal("Error!", "Please supply Client's date of birth!", "error", {
       button: "OK",
      });
     return;
 }
  if($('#tsex').val() == ''){
     swal("Error!", "Please supply Client's sex!", "error", {
       button: "OK",
      });
     return;
 }
  if($('#tphone').val() == ''){
     swal("Error!", "Please supply Client's phone!", "error", {
       button: "OK",
      });
     return;
 }

       $.ajax({
         type: 'POST',
         url: '/addclient',
         data:{_token : $('meta[name="csrf-
token"]').attr('content'), name:name, email:email, sex:tsex, phone:phone,dob:tdate },
         success: function (data) {
              console.log(data);
              if(data.msg==1){
               swal("Success!", "New Client successfully Created!!", "success", {
                          button: "Success!",
                        });
```

```
                window.location.href = '/home';


              }else{

                swal("Error!",data.msg, "warning", {
                            button: "Okay!",
                          });

              }

          }
        });

    });
    $.ajaxSetup({
  headers: {
    'X-CSRF-TOKEN': $('meta[name="csrf-token"]').attr('content')
  }
});

</script>
@endsection



Add test
@extends('layouts.admin')
@section('title')
   MedLab
@endsection

@section('styles')
<!-- <script src="https://cloud.tinymce.com/stable/tinymce.min.js"></script>
  <script>tinymce.init({ selector:'textarea' });</script> -->
@endsection

@section('page')
<a href="{{url('/addclient')}}">Add New Test </a>
@endsection

@section('content')

        <section class="ls section_padding_top_50 section_padding_bottom_50 colu
mns_padding_5">
            <div class="container-fluid">

              <div class="row">
```

```
                    <div class="col-sm-12">
                        <h3>MedLab

                        </h3>
                    </div>
                </div>
                <!-- .row -->

                <div class="row">
                <div class="col-md-8">
                        <div class="with_border with_padding">

                            <h4>
                                Add New Med Test

                            </h4>

                            <hr>

                            <div class="row form-group">
                                <label class="col-lg-3 control-label">Test Name: </label>
                                <div class="col-lg-9">
                                    <input type="text" id="tname" class="form-control">
                                </div>
                            </div>

                            <div class="row form-group">
                                <label class="col-lg-3 control-label">Test Type: </label>
                                <div class="col-lg-9">
                                    <select class="form-control with-selected" name="with-
selected" id="ttype">
                                            <option value="Nill"> </option>
                                            <option value="Urine test">Urine test</option>
                                            <option value="Blood Tests">Blood Tests</option
>
                                            <option value="Tumor Markers">Tumor Markers
</option>
                                            <option value="others">Others</option>
                                    </select>
                                </div>
                            </div>
                            <div class="row form-group" id="parad">
                                <label class="col-lg-3 control-
label">No of Parameters: </label>
                                <div class="col-lg-9">
                                    <select class="form-control with-selected" name="with-
selected" id="pno">
                                            <option value="1">1 </option>
                                            <option value="2">2</option>
                                            <option value="3">3</option>
```

```
                                    <option value="4">4</option>
                                    <option value="5">5</option>
                                    <option value="6">6</option>
                                    <option value="7">7</option>
                                    <option value="8">8</option>
                                    <option value="9">9</option>
                                    <option value="10">10</option>
                                    <option value="11">11</option>
                                    <option value="12">12</option>
                                    <option value="13">13</option>
                                    <option value="14">14</option>
                                    <option value="15">15</option>
                                </select>
                            </div>
                        </div>


                        <div class="row">
                            <div class="col-sm-12 text-right">
                                <button type="submit" id="addparameter" class="theme_
button wide_button">Add Test</button>

                            </div>
                        </div>

                        <div id="pcontainer">

                        </div>



                        <div class="row">
                            <div class="col-sm-12 text-right">
                                <button type="submit" id="addtest" class="theme_button
wide_button">Add Test</button>

                            </div>
                        </div>
                        <!-- .row  -->

                    </div>
                    <!-- .with_border -->

                </div>
            <!-- .col-* -->
        </div>
        <!-- .row -->
```

```
                <!-- .row -->

            </div>
            <!-- .container -->
        </section>

@endsection


@section('script')
<script src="../js/joseadebag.js"></script>
<script src="../js/bootstrap-datepicker.min.js"></script>
<script src="https://cdnjs.cloudflare.com/ajax/libs/bootstrap-
datepicker/1.9.0/js/bootstrap-datepicker.min.js" integrity="sha512-
T/tUfKSV1bihCnd+MxKD0Hm1uBBroVYBOYSk1knyvQ9VyZJpc/ALb4P0r6ubw
VPSGB2GvjeoMAJJImBG12TiaQ==" crossorigin="anonymous"></script>
<script type="text/javascript">
$(document).ready(function() {
    $('#addtest').hide();
   $.fn.datepicker.defaults.format = "dd/mm/yyyy";
   $('.datepicker').datepicker({
      format: 'dd/mm/yyyy',
      startDate: '-3d'
    });
    var newt ='';
    var pnoo =0;let param  = []; let unit  = [];
   $("#addparameter").off('click').on('click', function() {
         //tname  ttype pno
      //var name = $.trim($('#tname').val());
      //var ttype = $.trim($('#ttype').val());
       pnoo = $.trim($('#pno').val());
        for (let index = 0; index < pnoo; index++) {
         /* $('#pcontainer').append(
            $(document.createElement('input')).prop({
               type: 'text',
               id: 'submit',
               //value: 'Submit',
               className: 'form-control'
            })
         ); */
         newt +='<div class="row form-group"><label class="col-lg-3 control-
label">Parameter '+ (index+1) +' Name:</label><div class="col-lg-
9"><input type="text" id="pname'+(index+1) +'" class="form-control"></div></div>';
         newt+='<div class="row form-group"><label class="col-lg-3 control-
label">Parameter '+ (index+1)  +' Unit:</label><div class="col-lg-
9"><input type="text" id="punit'+(index+1) +'" class="form-control"></div></div>';


      }
      //alert();
```

```
        $('#pcontainer').append(newt);
        $('#addtest').show();
        $(this).hide();
        $('#parad').hide();
    });
    $("#addtest").off('click').on('click', function() {
        var name = $.trim($('#tname').val());
        var ttype = $.trim($('#ttype').val());

        for (let index = 0; index < pnoo; index++) {

            var pn ='pname'+(index+1)+";
            var pu ='punit'+(index+1)+";

            if($('#pname'+(index+1)).val() == ''){
             swal("Error!", "Please supply Parameter "+ (index+1) +" Name!", "error", {
                button: "OK",
              });
             return;
            }
             if($('#punit'+(index+1)).val() == ''){
             swal("Error!", "Please supply Parameter "+ (index+1) +" Unit!", "error", {
                button: "OK",
              });
             return;
            }
            param[index]={pn: $.trim($('#pname'+(index+1)).val()),pu: $.trim($('#punit'+(
index+1)).val()) };



        }
        crosssite();
        if($('#tname').val() == ''){
            swal("Error!", "Please supply Test's name!", "error", {
                button: "OK",
              });
             return;
        }
         if($('#ttype').val() == ''){
            swal("Error!", "Please supply Test type!", "error", {
                button: "OK",
              });
             return;
         }
         $.ajax({
                type: 'POST',
                url: '/posttest',
                data:{_token : $('meta[name="csrf-
token"]').attr('content'), name:name, type:ttype, pno:pnoo, param:param },
```

```
            success: function (data) {
                console.log(data);
                if(data.msg==1){
                 swal("Success!", "New Client successfully Created!!", "success", {
                              button: "Success!",
                             });


                  window.location.href = '/home';


                }else{

                  swal("Error!",data.msg, "warning", {
                              button: "Okay!",
                             });

                }

            }
          });



});


 $("#addteacher").off('click').on('click', function() {

    //tdate tsex tphone temail tname
    var name = $.trim($('#tname').val());
    var email = $.trim($('#temail').val());
    var tdate = $.trim($('#tdate').val());
    var tsex = $.trim($('#tsex').val());
    var phone = $.trim($('#tphone').val());


    crosssite();
    if($('#tname').val() == ''){
        swal("Error!", "Please supply Client's name!", "error", {
          button: "OK",
          });
        return;
    }
    if($('#temail').val() == ''){
         swal("Error!", "Please Client's supply email!", "error", {
          button: "OK",
          });
        return;
```

```
        }
        if($('#tdate').val() == ''){
            swal("Error!", "Please supply Client's date of birth!", "error", {
              button: "OK",
            });
            return;
        }
         if($('#tsex').val() == ''){
            swal("Error!", "Please supply Client's sex!", "error", {
              button: "OK",
            });
            return;
        }
         if($('#tphone').val() == ''){
            swal("Error!", "Please supply Client's phone!", "error", {
              button: "OK",
            });
            return;
        }

            $.ajax({
              type: 'POST',
              url: '/posttest',
              data:{_token : $('meta[name="csrf-
token"]').attr('content'), name:name, email:email, sex:tsex, phone:phone,dob:tdate },
              success: function (data) {
                  console.log(data);
                  if(data.msg==1){
                   swal("Success!", "New Client successfully Created!!", "success", {
                              button: "Success!",
                            });


                    window.location.href = '/home';


                  }else{

                   swal("Error!",data.msg, "warning", {
                              button: "Okay!",
                            });

                  }

              }
            });

    });
    $.ajaxSetup({
  headers: {
```

```
    'X-CSRF-TOKEN': $('meta[name="csrf-token"]').attr('content')
  }
});
});
</script>
@endsection
```


Appendix III
Taketest

```
@extends('layouts.admin')
@section('title')
  MedLab
@endsection

@section('styles')
<!-- <script src="https://cloud.tinymce.com/stable/tinymce.min.js"></script>
 <script>tinymce.init({ selector:'textarea' });</script> -->
@endsection

@section('page')
<a href="{{url('/addclient')}}">Add New Test </a>
@endsection

@section('content')

        <section class="ls section_padding_top_50 section_padding_bottom_50 colu
mns_padding_5">
            <div class="container-fluid">

                <div class="row">
                   <div class="col-sm-12">
                      <h3>MedLab

                      </h3>
                   </div>
                </div>
                <!-- .row -->

                <div class="row">
                <div class="col-md-8">
                        <div class="with_border with_padding">

                            <h4>
                               Take Test

                            </h4>

                            <hr>

                            <div class="row form-group">
                               <label class="col-lg-3 control-label">Test Name: </label>
                               <div class="col-lg-9">
                               <select class="form-control with-selected" name="with-
selected" id="tname">
                               <option value=""></option>
                               @foreach ($test as $m)
                                  <option value="{{$m['uuid']}}">{{$m['test_name']}}</op
tion>
```

```
                        @endforeach
                            </select>
                        </div>
                    </div>

                    <div id="pcontainer">

                    </div>


                    <div class="row">
                        <div class="col-sm-12 text-right">
                            <button type="submit" id="addresult" class="theme_butto
n wide_button">Submit Result</button>

                        </div>
                    </div>
                    <!-- .row  -->

                </div>
                <!-- .with_border -->

            </div>
        <!-- .col-* -->
    </div>
    <!-- .row -->

    <!-- .row -->

</div>
<!-- .container -->
</section>

@endsection


@section('script')
<script src="../js/joseadebag.js"></script>
<script src="../js/bootstrap-datepicker.min.js"></script>
<script src="https://cdnjs.cloudflare.com/ajax/libs/bootstrap-
datepicker/1.9.0/js/bootstrap-datepicker.min.js" integrity="sha512-
T/tUfKSV1bihCnd+MxKD0Hm1uBBroVYBOYSk1knyvQ9VyZJpc/ALb4P0r6ubw
VPSGB2GvjeoMAJJImBG12TiaQ==" crossorigin="anonymous"></script>
<script type="text/javascript">
$(document).ready(function() {
    $('#addtest').hide();
   $.fn.datepicker.defaults.format = "dd/mm/yyyy";
   $('.datepicker').datepicker({
      format: 'dd/mm/yyyy',
      startDate: '-3d'
```

```
});
var id =@json($clients_id);
var newt ='';
var pnoo =0;let param  = []; let unit  = [];
var npo =0;
$("#tname").on('change', function(e){
    var optionSelected = $("#tname option:selected").val();
  //  var valueSelected =this.value;
   // alert(optionSelected);
   if (optionSelected== ""){
      return;
   }
   $.ajax({
            type: 'POST',
            url: '/testid',
            data:{_token : $('meta[name="csrf-
token"]').attr('content'), id:optionSelected },
            success: function (data) {
                //console.log(data);
                if(data.msg==1){
                   var ff =data.parameters.length;
                   /*  for(var i=0; i<ff; i++){
                       console.log( data.parameters[i]);
                   }  */
                   for(var index in data.parameters){
                     // console.log(data.parameters[index] );
                     // var jsonn=JSON.parse('data.parameters[index]');

                     for (key in data.parameters[index]){
                         if (data.parameters[index].hasOwnProperty(key)){
                            // console.log(key+"   "+data.parameters[index][key]);
                            newt +='<div class="row form-group"><label class="col-lg-
3 control-label"> '+key+' :</label><div class="col-lg-
9"><input type="text" id="p'+(index) +'" class="form-control"></div></div>';
                            npo++;
                         }
                     }
                     // console.log(jsonn);
                   }
                  // console.log(data.parameters.length );
                  $('#pcontainer').append(newt);
                   $('#addtest').show();
                   document.getElementById('tname').disabled = true;
                 //  $("#tname").css('disabled', 'disabled');
                }else{

                  swal("Error!",data.msg, "warning", {
                              button: "Okay!",
                            });
```

```
                }

            }
          });
    });

    $("#addparameter").off('click').on('click', function() {
        //tname  ttype pno
      //var name = $.trim($('#tname').val());
      //var ttype = $.trim($('#ttype').val());
       pnoo = $.trim($('#pno').val());
        for (let index = 0; index < pnoo; index++) {
        /* $('#pcontainer').append(
            $(document.createElement('input')).prop({
                type: 'text',
                id: 'submit',
                //value: 'Submit',
                className: 'form-control'
            })
        ); */
        newt +='<div class="row form-group"><label class="col-lg-3 control-
label">Parameter '+ (index+1) +' Name:</label><div class="col-lg-
9"><input type="text" id="pname'+(index+1) +'" class="form-control"></div></div>';
        newt+='<div class="row form-group"><label class="col-lg-3 control-
label">Parameter '+ (index+1)  +' Unit:</label><div class="col-lg-
9"><input type="text" id="punit'+(index+1) +'" class="form-control"></div></div>';


      }
      //alert();
      $('#pcontainer').append(newt);
      $('#addtest').show();
      $(this).hide();
      $('#parad').hide();
    });
    $("#addresult").off('click').on('click', function() {
      var name = $.trim($('#tname').val());


      for (let index = 0; index < npo; index++) {

        var pn ='p'+(index+1)+";


        if($('#p'+(index+1)).val() == ''){
         swal("Error!", "Please supply all parameters ", "error", {
            button: "OK",
          });
         return;
        }
```

```
            //alert($.trim($('#p'+(index)).val()));
            param[index]= $.trim($('#p'+(index)).val()) ;

            //alert(param);

        }
        crosssite();
        if($('#tname').val() == ''){
            swal("Error!", "Please supply Test's name!", "error", {
              button: "OK",
             });
            return;
        }
        $.ajax({
                type: 'POST',
                url: '/posttestresult',
                data:{_token : $('meta[name="csrf-
token"]').attr('content'), name:name,  pno:npo, param:param, client:id},
                success: function (data) {
                    console.log(data);
                    if(data.msg==1){
                     swal("Success!", "New Test Result successfully submitted!!", "succes
s", {
                                button: "Success!",
                              });
                      window.location.href = '/home';
                    }else{

                      swal("Error!",data.msg, "warning", {
                                button: "Okay!",
                              });

                    }
                }
            });
    });


    $("#addteacher").off('click').on('click', function() {

        //tdate tsex tphone temail tname
        var name = $.trim($('#tname').val());
        var email = $.trim($('#temail').val());
        var tdate = $.trim($('#tdate').val());
        var tsex = $.trim($('#tsex').val());
        var phone = $.trim($('#tphone').val());


        crosssite();
```

```
if($('#tname').val() == ''){
   swal("Error!", "Please supply Client's name!", "error", {
     button: "OK",
     });
    return;
}
if($('#temail').val() == ''){
     swal("Error!", "Please Client's supply email!", "error", {
      button: "OK",
     });
    return;
}
if($('#tdate').val() == ''){
    swal("Error!", "Please supply Client's date of birth!", "error", {
     button: "OK",
     });
    return;
}
 if($('#tsex').val() == ''){
    swal("Error!", "Please supply Client's sex!", "error", {
     button: "OK",
     });
    return;
}
 if($('#tphone').val() == ''){
    swal("Error!", "Please supply Client's phone!", "error", {
     button: "OK",
     });
    return;
}

     $.ajax({
       type: 'POST',
       url: '/posttest',
       data:{_token : $('meta[name="csrf-
token"]').attr('content'), name:name, email:email, sex:tsex, phone:phone,dob:tdate },
          success: function (data) {
              console.log(data);
              if(data.msg==1){
               swal("Success!", "New Client successfully Created!!", "success", {
                          button: "Success!",
                         });


               window.location.href = '/home';


              }else{

               swal("Error!",data.msg, "warning", {
```

```
                                button: "Okay!",
                            });

                    }

                }
            });

    });
    $.ajaxSetup({
  headers: {
    'X-CSRF-TOKEN': $('meta[name="csrf-token"]').attr('content')
  }
});
});
</script>
@endsection
```

Homecontroller

```
<?php

namespace App\Http\Controllers;

use Illuminate\Http\Request;
use Webpatser\Uuid\Uuid;
use App\Models\AddClients;
use App\Models\Addtest;
use App\Models\Results;
use PHPMailer\PHPMailer\PHPMailer;
use PHPMailer\PHPMailer\Exception;
use PHPMailer\PHPMailer\SMTP;
use Illuminate\Support\Facades\Auth;
//require '../vendor/autoload.php';

class HomeController extends Controller
{
    /**
     * Create a new controller instance.
     *
     * @return void
     */
    public function __construct()
    {
        $this->middleware('auth');
    }

    /**
     * Show the application dashboard.
```

```
     *
     * @return \Illuminate\Contracts\Support\Renderable
     */
    public function index()
    {
        $offices1 = AddClients::paginate(15);
        return view('medlab.home')->with(array('clients'=>$offices1));
    }

    public function addclient()
    {
        return view('medlab.addclient');
    }
    public function registerclient(Request $request)
    {
        if($request->isMethod('post')){// name  email sex phone dob
            $name = strip_tags($request->name);
            $sex = strip_tags($request->sex);
            $email = strip_tags($request->email);
            $dob = $request->dob;
            $phone = strip_tags($request->phone);
            $uuid = Uuid::generate(1);
            $combo = new AddClients();
            $combo->uuid =$uuid;
            $combo->name=$name;
            $combo->sex=$sex;
            $combo->email=$email;
            $combo->phone=$phone;
            $combo->dob=$dob;
            $combo->save();
            return response()->json(array('msg'=> 1), 200);
        }else{
            return response()-
>json(array('msg'=> 'An error occurred, please try again'), 200);
        }

    }
    public function addtest()
    {
        return view('medlab.addtest');
    }
    public function posttest(Request $request)
    {
        if($request->isMethod('post')){
            $name = strip_tags($request->name);
            $type = strip_tags($request->type);
            $pno = strip_tags($request->pno);
            $param = $request->param;
            //dd( strip_tags($param[0]['pn'])." ". strip_tags($param[0]['pu']));
            $sd = array();
```

```
            for ($i=0; $i <= (int)$pno-1 ; $i++) {
              // c2
              $sdd=array($param[$i]['pn'] => $param[$i]['pu']);
               array_push($sd,$sdd);
            }
            //var_dump( $sd);
           // uuid', 'test_name','test_type', 'parameters','created_by_id'
            $combo = new Addtest();
            $uuid = Uuid::generate(1);
            $combo->uuid =$uuid;
            $combo->test_name =$name;
            $combo->test_type = $type;
            $combo->parameters = json_encode($sd);
            $combo->created_by_id = Auth::user()->id;
            $combo->save();
             return response()->json(array('msg'=> 1), 200);
        }else{
            return response()-
>json(array('msg'=> 'An error occurred, please try again'), 200);
        }

    }
    public function taketest($id)
    {
        $id = strip_tags($id);
        if(isset($id) && Auth::check()){
            //$offices1 = Scombo::where('combination_uuid','=', $com[0]->uuid)->get();
            $offices1 = AddClients::where('uuid','=', $id)->get();
            $test = Addtest::all();
            return view('medlab.taketest')-
>with(array('contents'=>$offices1,'test'=> $test, 'clients_id'=>$id ));
        }else{
            return redirect()->intended(route('logout'));
        }
    }
    public function testid(Request $request)
    {
       if($request->isMethod('post') && Auth::check()){
            $id = strip_tags($request->id);
            if($id ==""){
            }else{
                $offices1= Addtest::where('uuid','=', $id)->get();
                return response()-
>json(array('msg'=>1,'parameters'=>json_decode($offices1[0]->parameters) ), 200);
            }
        }else{
            return response()-
>json(array('msg'=> 'An error occurred, please try again'), 200);
        }
    }
```

```
    public function posttestresult(Request $request)
    {
        if($request->isMethod('post') && Auth::check()){
            //name pno param
            $test_id = strip_tags($request->name);
            $pno = strip_tags($request->pno);
            $client = strip_tags($request->client);
            $param = $request->param;
            //dd( strip_tags($param[0]['pn'])." ". strip_tags($param[0]['pu']));
            $sd = array();
            for ($i=0; $i <= (int)$pno-1 ; $i++) {
              $sdd=array($param[$i]);
               array_push($sd,$sdd);
            }//'uuid', 'test_uuid', 'result','created_by_id'
            $combo = new Results();
            $uuid = Uuid::generate(1);
            $combo->uuid =$uuid;
            $combo->client_uuid =$client ;
            $combo->test_uuid =$test_id;
            $combo->result = json_encode($sd);
            $combo->created_by_id = Auth::user()->id;
            $combo->save();
             return response()->json(array('msg'=> 1), 200);

        }else{
            return response()-
>json(array('msg'=> 'An error occurred, please try again'), 200);
        }

    }
    public function viewprofile($id)
    {
        $id = strip_tags($id);
        if(isset($id) && Auth::check()){
          $offices1 = AddClients::where('uuid','=', $id)->get();
           $test = Results::where('client_uuid', '=',$id );
          return view('medlab.profile')-
>with(array('user'=>$offices1,'test'=> $test, 'clients_id'=>$id ));

        }else{
            return redirect()->intended(route('logout'));
        }
    }

    public function mailtest()
    {
         $to = "adebagbojoshua@gmail.com";
        $subject = "My subject";
        $txt = "Hello world!";
```

```
        $headers = "From: joshlaptop2015@gmail.com" . "\r\n" .
        "CC: somebodyelse@oluseye.i.ng";

        mail($to,$subject,$txt,$headers);
        // Instantiation and passing `true` enables exceptions
       /*  $mail = new PHPMailer(true);

        try {
            //Server settings
            $mail-
>SMTPDebug = SMTP::DEBUG_SERVER;                 // Enable verbose debug ou
tput
            $mail->isSMTP();                                        // Send using SMTP
            $mail-
>Host       = 'smtp.example.com';                // Set the SMTP server to send through
            $mail-
>SMTPAuth   = true;                             // Enable SMTP authentication
            $mail-
>Username   = 'joshlaptop2015@gmail.com';                 // SMTP username
            $mail->Password   = 'gentlesoul09';                         // SMTP password
            $mail-
>SMTPSecure = PHPMailer::ENCRYPTION_STARTTLS;        // Enable TLS encry
ption; `PHPMailer::ENCRYPTION_SMTPS` encouraged
            $mail-
>Port       = 587;                               // TCP port to connect to, use 465 for `PHPMai
ler::ENCRYPTION_SMTPS` above

            //Recipients
            $mail->setFrom('joshlaptop2015@gmail.com', 'Mailer');
             $mail-
>addAddress('adebagbojoshua@gmail.com', 'Joe User');     // Add a recipient
            /* $mail->addAddress('ellen@example.com');               // Name is optional
            $mail->addReplyTo('info@example.com', 'Information');
            $mail->addCC('cc@example.com');
            $mail->addBCC('bcc@example.com'); */

            // Attachments
           //  $mail->addAttachment('/var/tmp/file.tar.gz');         // Add attachments
            // $mail->addAttachment('/tmp/image.jpg', 'new.jpg');    // Optional name

            // Content
            /* $mail->isHTML(true);                                  // Set email format to HTML
            $mail->Subject = 'Here is the subject';
            $mail->Body    = 'This is the HTML message body <b>in bold!</b>';
            $mail->AltBody = 'This is the body in plain text for non-HTML mail clients';

            $mail->send();
            echo 'Message has been sent';
        } catch (Exception $e) {
            echo "Message could not be sent. Mailer Error: {$mail->ErrorInfo}";
```

```
}

 */
}

public function testnew( $filePath)
{

    // Recipient
    $to = 'Oluseyeakinmoluwa@gmail.com';

    // Sender
    $from = 'joshlaptop2015@gmail.com';
    $fromName = 'no-reply';

    // Email subject
    $subject = 'Pipeline Monitoring system';

    // Attachment file
    $file = $filePath;

    // Email body content
    $htmlContent = '
        <h3>Pipeline Monitoring</h3>
        <p>Kindly check your pipeline, face dectected along the infrastructure.</p>

    ';

    // Header for sender info
    $headers = "From: $fromName"." <".$from.">";

    // Boundary
    $semi_rand = md5(time());
    $mime_boundary = "==Multipart_Boundary_x{$semi_rand}x";

    // Headers for attachment
    $headers .= "\nMIME-Version: 1.0\n" . "Content-
Type: multipart/mixed;\n" . " boundary=\"{$mime_boundary}\"";

    // Multipart boundary
    $message = "--{$mime_boundary}\n" . "Content-
Type: text/html; charset=\"UTF-8\"\n" .
    "Content-Transfer-Encoding: 7bit\n\n" . $htmlContent . "\n\n";

    // Preparing attachment
    if(!empty($file) > 0){
        if(is_file($file)){
            $message .= "--{$mime_boundary}\n";
            $fp =    @fopen($file,"rb");
            $data =  @fread($fp,filesize($file));
```

```
                @fclose($fp);
                $data = chunk_split(base64_encode($data));
                $message .= "Content-Type: application/octet-
stream; name=\"".basename($file)."\"\n" .
                "Content-Description: ".basename($file)."\n" .
                "Content-
Disposition: attachment;\n" . " filename=\"".basename($file)."\"; size=".filesize($file).
";\n" .
                "Content-Transfer-Encoding: base64\n\n" . $data . "\n\n";
            }
        }
        $message .= "--{$mime_boundary}--";
        $returnpath = "-f" . $from;

        // Send email
        $mail = @mail($to, $subject, $message, $headers, $returnpath);

        // Email sending status
        echo $mail?"<h1>Email Sent Successfully!</h1>":"<h1>Email sending failed.
</h1>";
      }

   }
```

Appendix IV

Email Notification

```
public function senattach(Request $request){
   header('Content-type:application/json;charset=utf-8');  //email rid
       $email = $request->email;
       $rid = strip_tags($request->rid);
      // File::move($image, public_path("pipeline/"));
      // $this->mailmag("pipeline/", 'test.png');
      //$pdf = base64_decode($image );

   /*    header('Content-type:application/json;charset=utf-8');

       $image = $request->file('pdf');

      $imageName = Uuid::generate(1);
      $pdf = base64_decode($image ); */
     /*  $fname = "test.pdf";
      $file = fopen("/".$fname,  'w');
      fwrite($file, $pdf);
      fclose($file);  */
     //  file_put_contents( public_path("/"), $pdf );

     // $image->move( public_path("pipeline/"), $imageName.".pdf");
    // dd($image->getClientOriginalExtension());
     // File::move($pdf, "pipeline/");
      // $this->mailtestt("pipeline/$imageName".".pdf");


      $mail = new PHPMailer();
      $mail->IsSMTP();
      $mail->Mailer = "smtp";
      $mail->SMTPDebug  = 1;
      $mail->SMTPAuth   = TRUE;
      $mail->SMTPSecure = "tls";
      $mail->Port       = 587;
      $mail->Host       = "smtp.mailtrap.io";//"smtp.gmail.com";
      $mail->Username   = "a4a62d1a4e0a9c";//"a4a62d1a4e0a9c";
      $mail->Password   = "1675230f6e7f10";
      $mail->IsHTML(true);
      //$mail->AddAddress("adebagbojoshua@gmail.com", "Joshua");
      $mail->SetFrom("joshlaptop2015@gmail.com", "Medlab  Notification System");
      $mail->AddReplyTo("Oluseyeakinmoluwa@gmail.com", "oluseye");
      $mail->AddCC("Oluseyeakinmoluwa@gmail.com", "oluseye");
     // $mail->addAttachment( $filepath,'Face detected');\
     //$base = explode('data:application/pdf;base64,', $_POST['data']);
     //$base = explode("data:application/pdf;base64,", $image);
     //$base = base64_decode($image);
    // $mail->addAttachment($pdf,'pdfName.png');
```

```
 // $mail->addAttachment($pdf, 'attachment.png');
   $mail->Subject = "Here is your MedLab test result";
   $content = $email;
   $mail->MsgHTML($content);
   if(!$mail->Send()) {
   echo "Error while sending Email.";
   var_dump($mail);
   } else {
   echo "Email sent successfully";
   }
    return response()->json(array('msg'=> 'Email sent successfully'), 200);
}
public function mailtestt($filepath)
{
   $mail = new PHPMailer();
   $mail->IsSMTP();
   $mail->Mailer = "smtp";
   $mail->SMTPDebug  = 1;
   $mail->SMTPAuth   = TRUE;
   $mail->SMTPSecure = "tls";
   $mail->Port       = 587;
   $mail->Host       = "smtp.mailtrap.io";//"smtp.gmail.com";
   $mail->Username   = "a4a62d1a4e0a9c";//"a4a62d1a4e0a9c";
   $mail->Password   = "1675230f6e7f10";
   $mail->IsHTML(true);
 //  $mail->AddAddress("adebagbojoshua@gmail.com", "Joshua");
   $mail->SetFrom("joshlaptop2015@gmail.com", "Medlab  Notification System");
   $mail->AddReplyTo("Oluseyeakinmoluwa@gmail.com", "oluseye");
   $mail->AddCC("Oluseyeakinmoluwa@gmail.com", "oluseye");
  // $mail->addAttachment( $filepath,'Face detected');
   $mail->addAttachment($filepath, 'attachment.pdf');
   $mail->Subject = "Here is your test result";
   $content = "<b>Here is your test result.</b>";
   $mail->MsgHTML($content);
   if(!$mail->Send()) {
   echo "Error while sending Email.";
   var_dump($mail);
   } else {
   echo "Email sent successfully";
   }


}
```

Appendix V

Questionnaire

Questionnaire on view of the staff on the performance of the Computerized Laboratory Support Application

NB: for your response below, the following are the meaning of the acronyms used

SA = Strongly Agree, A = Agree, D = Disagree, SD = Strongly Disagree.

Tick appropriately ☑

S/N	Item Statement	SA	A	D	SD
1	I found the application easy to use				
2	I think I would like to use this application frequently				
3.	I found that the various function of this application is well integrated				
4.	I think there are too much inconsistency in this application				
5	I feel this application is too cumbersome to use				
6	I felt confident using the application				
7	I think this application is saving a lot of time and fast compared to the manual method				
8	I feel I will need various trainings on how to use this application because of its technicality				
9	I feel the old manual system is better off than this new application in terms of data saving and effectiveness				
10	Generally I think this application will solve unending queues in the laboratory and promote effectiveness				

Biodata

Personal Data

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Nationality: Nigerian.

Name and Address of next of Kin: Victoria Toyin ADEGBIJI.

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Saint John Anglican primary School Akinmoorin , Oyo State.	1976 - 1982
Ladigbolu Grammar School, Oyo, Oyo State	1982 - 1987
The Polytechnics Ibadan	1990 - 1992
Ladoke Akintola University of Technology, Ogbomoso, Oyo State.	1994 - 1999
University of Ado Ekiti, Ado Ekiti, Ekiti State	2002 - 2004

Work Experience with Dates

1. **Position,** Assistant lecturer
   Place of work: Emmanuel Alayande Collge of Education, Oyo
   Date: 2002 till Date.

Membership of Professional Body

Member - Teacher Registration Council of Nigeria (TRCN)

Signature _____ **Date** _____

University Compliance Certificate

This is to certify this thesis by Abiodun Timothy ADEGBIJI with the Matriculation number LCU/PG/MSC/CIS/15/0001 in the Department of Computer and Physical Sciences, Lead City University, Ibadan, is in FULL compliance with the approved University format and style.

Signature	**Date**