A PRELIMINARY PROJECT REPORT ON

Lab-as-a-service

SUBMITTED TO THE SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE IN THE PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF ENGINEERING
(COMPUTER ENGINEERING)

SUBMITTED BY

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Modern College of Engineering

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CERTIFICATE

This is to certify that the following students of Final Year Computer Engineering of PES’s, Modern College of Engineering have successfully completed the preliminary analysis and design of project “**Lab-as-a-service”** under the guidance of Prof. J.M.Kanase.

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This is in partial fulfillment of the award of the degree Bachelor of Computer Engineering of Savitribai Phule Pune University.

Date:

(Prof.J.M.Kanase)	(Prof. Dr. Mrs. S. A. Itkar)	
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Acknowledgement

It gives us pleasure in presenting the partial project report on **‘Lab-as-a-service’**.

Firstly, we would like to express our indebtedness appreciation to our internal guide **Prof. J.M.Kanase**. Her constant guidance and advice played very important role in making the execution of the report. She always gave us his/her suggestions, that were crucial in making this report as flawless aspossible.

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Also, we wish to thank our Principal, **Prof. Dr. Mrs. K. R. Joshi** and all faculty members for theirwhole hearted co-operation for completion of this report. We also thank our laboratory assistants for their valuable help in laboratory.

Last but not the least, the backbone of our success and confidence lies solely on blessings of dear parents and lovely friends.

Ashutosh Sudhir Kumbhar
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Abstract

The proliferation of cloud computing and web-based technologies have made it possible for universities to expand their academic networks reaching a wider range of students. In an effort to expand offered services while reducing costs, universities began exploring the use of distributed software platforms and middleware infrastructures to make laboratories accessible over the Internet. Through this framework, which we call Lab-as-a-Service (LaaS), students can remotely execute labs designed by instructors. LaaS incorporates a middleware approach in which it can be used universally across a wide range of experimentation types. Seamless experience of software development and learning can be made easy.

The LaaS Framework enables students to engage more actively in courses that need hands-on components. Throughout this paper, we have demonstrated at a small scale how the LaaS framework can be used to transform a traditional learning experience to a remote learning experience that can complement existing MOOCs. This helps to promote courses that require lab facilities to also be incorporated to the online learning environment. For future work, we plan to extend the LaaS framework to take into consideration scalability and complexity of more sophisticated lab equipment that are required for courses in engineering, science, among others.

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List of Abbreviations

HTTP.. Hyper Text Transfer Protocol

UML .... Unified modeling language

SaaS .... Software-as-a-service

LaaS………………………………. Lab-as-a-service

ER…………………………………. Entity-Relationship Diagram

VM………………………………….Virtual Machine

S3…………………………………. Aws S3 bucket

DB…………………………………. Database

1.

Introduction

1.1 Motivation

Virtual Labs will provide to the students the platform to perform assignments and do code in a required environment provided by an instructor. Modeling the required environment on the virtual machine and providing the access of these virtual machine to students so that they can perform assignments. This can, at-the-best, provide an approximate version of the ‘real-world’ computer environment. Remotely triggering a virtual machine with environment in an actual lab and providing the student the result of the experiment through the computer interface. This would entail carrying out the actual lab experiment remotely.

Physical distances and the lack of resources make us unable to perform experiments, especially when they involve sophisticated instruments. Also, good teachers are always a scarce resource. Web-based and video-based courses address the issue of teaching to some extent. Conducting joint experiments by two participating institutions and also sharing costly resources has always been a challenge.

With the present-day internet and computer technologies the above limitations can no more hamper students and researchers in enhancing their skills and knowledge. Also, in a country such as ours, costly instruments and equipment need to be shared with fellow researchers to the extent possible.

Web enabled experiments can be designed for remote operation and viewing so as to enthuse the curiosity and innovation into students. This would help in learning basic and advanced concepts through remote experimentation. Today most equipment has a computer interface for control and data storage. It is possible to design good experiments around some of this equipment which would enhance the learning of a student.

Internet-based experimentation further permits use of resources – knowledge, software, and data available on the web, apart from encouraging skillful experiments being simultaneously performed at points separated in space (and possibly, time).

To provide remote-access to Labs in various disciplines of Science and Engineering. These Virtual Labs would cater to students at the undergraduate level, post graduate level as well as to research scholars.

To enthuse students to conduct experiments by the arousing their curiosity. This would help them in learning basic and advanced concepts through remote experimentation.

To provide a complete Learning Management System around the Virtual Labs where the students can avail the various tools for learning, including additional web-resources, video-lectures, animated demonstrations and self-evaluation.

To share costly equipment and resources, which are otherwise available to limited number of users due to constraints on time and geographical distances.

Virtual Labs will be made more effective and realistic by providing additional inputs to the students like accompanying audio and video streaming of an actual lab experiment and equipment. For the ‘touch and feel’ part, the students can possibly visit an actual laboratory for a short duration.

1.2 Problem Definition

To develop a Lab as Service solution that enhances the learning and assessment experience of learners remotely. It will allow users to access the lab environment beyond working hours. It will eliminate the dependency on particular lab facilities. It will readily provide an integrated development environment for students without worrying about development setup and dependencies. Through this framework, which we call Lab-as-a-Service (LAAS), students can remotely execute labs designed by instructors. Can reduce the gap between high and low computation. It can incorporate a middleware approach in which it can be used universally across a wide range of experimentation types

To develop an LAAS (Lab as a Service) application. To increase productivity and level of student interaction when executing experiments. To provide a user-friendly platform for performing lab assignments. To control lab processing unit's sequence state, dependency, and behavior. Easy access to computing power for the students.

2.

Literature Survey

2.1 Literature Survey

SR. NO	PROJECT NAME	AUTHOR NAME	ABSTRACT
1.	Internet-Accessible Laboratories	Eyhab Al-Masri	The proliferation of cloud computing and web-based technologies have made it possible for universities to expand their academic networks reaching a wider range of students. In an effort to expand offered services while reducing costs, universities began exploring the use of distributed software platforms and middleware infrastructures to make laboratories accessible over the Internet.
2.	A Component-Based Evolution Model for ServiceBased Software Architectures	Eduardo Berrio-Charry, Jeisson Vergara-Vargas and Henry Umaña-Acosta	Microservices architecture has emerged as an architectural style which focuses on the design and development of software systems as a set of small independent services. Although MSA is inspired by the Service-Oriented Architecture style (both are service-based architectures), it presents important differences.
3.	E-Learning System Model for University Education	Ayman R. Mohammed, Sally S. Kassem	High quality education should be the top priority for any nation seeking prosperity. This paper aims to present a conceptual model for an e-learning system for developing countries. This is achieved by adopting an object-oriented approach and Unified Modeling Language (UML). The functional and dynamic views of the system

			are presented and explained within this framework.
4.	Container-Based Lab-as-a-Service Application	M. Sanjay Babu, K Sabari Priya S Padmavati	Lab setup with diverse requirements restricts the users to depend on the lab facility. In order to allow the users to access the lab environment beyond the working hours and eliminate the dependency on a particular lab facility, number of solutions leveraging virtualization and cloud services have been provided in the past. However, these approaches have few drawbacks. The virtual images are quite heavy. Though portable, it takes quite some time to configure the virtual images. Similarly, cloud-based solutions may not be affordable for every institution and given the scale of usage, the cloud services may be expensive.
5.	Kubernetes-Oriented Microservice Placement with Dynamic Resource Allocation	Zhijun Ding Song Wang Changjun Jiang	Microservices and Kubernetes are widely used in the development and operations of cloud-native applications. By providing automated placement and scaling, Kubernetes has become the main tool for managing microservices. However, existing work and Kubernetes fail to consider the dynamic competition and availability of microservices as well as the problem of shared dependency libraries among multiple microservice instances

6.	Application deployment on the SaaS platform	Hong He	SaaS (Software as a Service) is a kind of application services which is provided via Internet, and customers can order and receive their peculiar types of software application services from the SaaS provider via the Internet according to their actual needs. This paper analysis current development of SaaS, by means of comparing SaaS model with traditional software model, a new engineering method is illustrated. Besides, this paper assays the architecture of SaaS-based software application, what's more, the approach of data separate and the implementation of UI is present. The instance of service outsourcing public technica1 platform at Weihai illustrates design of SaaS architecture.

3.

Software Requirements Specification

3.1 Introduction

The proliferation of cloud computing and web-based technologies have made it possible for universities to expand their academic networks reaching a wider range of students. In an effort to expand offered services while reducing costs, universities began exploring the use of distributed software platforms and middleware infrastructures to make laboratories accessible over the Internet. Through this framework, which we call Lab-as-a-Service (LaaS), students can remotely execute labs designed by instructors. LaaS incorporates a middleware approach in which it can be used universally across a wide range of experimentation types. Seamless experience of software development and learning can be made easy.

3.1.1 Project Scope

1) It will allow users to access the lab environment beyond working hours.

2) It will eliminate the dependency on particular lab facilities.

3) It will readily provide an integrated development environment for students without worrying about development setup and dependencies.

4) Through this framework, which we call Lab-as-a-Service (LAAS), students can remotely execute labs designed by instructors.

5) Can reduce the gap between high and low computation.

3.1.2 User Classes and Characteristics

Users that are going to use this software belongs to following category/roles:

1) Student
2) Admin
3) Instructor

Students: Students will be able

1) To join a software coding laboratory.
2) Perform assignments on virtual machines / labs

Instructor: Instructors will be able**:**

1) Create Virtual labs
2) Create Lab Batches
3) Evaluate Student Performance
4) Create Development Environment.

Admin: Admin will be able to:

1) Manage user permissions
2) System Maintenance
3) Evaluate staff/instructor performance

3.1.3 Assumptions and Dependencies

1) Since the application is a web-based application there is a need for the internet browser. It will be assumed that the users will possess decent internet connectivity.
2) It is assumed that students using labs keep knowledge of programming, and basics of internet.
3) Moreover, the user is expected to know how to use Android or IOS mobile devices and to be able to write and read messages and use buttons

3.2 Functional Requirements

3.2.1 Authentication System

A straightforward process, user authentication consists of three tasks:

1. **Identification.** Users have to prove who they are. (Email Address Verification)
2. **Authentication.** Users have to prove they are who they say they are.
3. **Authorization.** Users have to prove they're allowed to do what they are trying to do.

User authentication can be as simple as requiring a user to type a unique identifier, such as a user ID, along with a password to access a system.

3.2.2 User Management

User management is an organizational function that enables users to access and control digital assets, such as applications, devices, networks, and cloud services

Users those are going to use this software are categorized as follows:

1) Admin
2) Instructor
3) Student

3.2.3 Online Compiler

The user friendly ***online compiler*** that allows you to Write code and run it online. The text editor also supports taking input from the user and produce output on the console.

The online compiler supports multiple languages and provides high computational power to the users for smooth development experience.

3.2.4 Virtual Machines

This feature will provides a wide selection of instance types optimized to fit different use cases. Instance types comprise varying combinations of CPU, memory, storage, and networking capacity and give you the flexibility to choose the appropriate mix of resources for your applications. Each instance type includes one or more instance sizes, allowing you to scale your resources to the requirements of your target workload.

3.2.5 Storage System

An S3 customer first creates a bucket in the AWS region of his or her choice and gives it a globally unique name. AWS recommends that customers choose regions geographically close to them to reduce latency and costs.

Once the bucket has been created, the user then selects a tier for the data, with different S3 tiers having different levels of redundancy, prices and accessibility. One bucket can store objects from different S3 storage tiers.

3.2.6 Database Management System

PostgreSQL is used as the primary data store for storing user data in tabular format. Student's data like codes, profiles, and results are stored in database.

3.3 External Interface Requirements (If Any)

3.3.1 User Interfaces

User interface of our application will be easy to use and understandable. Moreover, the user is expected to know how to use Android or IOS mobile devices and to be able to write and read messages and use buttons. User interfaces are explained in details below:

1) **Login Interface**

In this interface, there will be a button register. If user have not registered to the application, s/he will use register button and register to it.

2) **Register Interface**

In this interface user register to the system by giving information of himself in a provided text field. There will be a button register. After user filled the required fields with his/her related information (username, password, gender etc.), click to the register button and be able to login the application.

3) **Development Environment Interface**

Enrolled students get to develop/perform assignments of their respective laboratories, using online integrated development environment. Each student get his one instance for development, performing assignments. The online compiler supports multiple languages and student can choose their desired programming language.

4) **Dedicated file manager for assignments.**

The performed assignments get stored on online drive. This will help them to back up their progress in the phase of development.

3.3.2 Hardware Interfaces

1. 8 GB Ram

2. intel core i5 processor

3.3.3 Software Interfaces

1. Front-End: HTML5, CSS3, BootStrap5, Angular 12
2. Back-End: (Python) Django Rest Framework, Spring Boot
3. Database: PostgreSQL, Redis
4. Storage System: AWS S3
5. Cloud Service Provider: AWS
6. Other: Docker, Kubernetes, Git/GitHub, Jenkins (CI-CD)

3.3.4 Communication Interfaces

For this application we are using HTTP protocol. As a request-response protocol, HTTP gives users a way to interact with web resources by transmitting hypertext messages between clients and servers.

3.4 Nonfunctional Requirements

In this section, last group of the requirements which is non-functional requirements will be explained in detail. Non-functional requirements include performance requirements, security requirements and portability requirements.

3.4.1 Performance Requirements

Since this software is going to web – based, it does require a powerful server machine with high band internet access. Server machine should have a powerful CPU and high-speed internet access so that it can handle multiple users at the same time. Another performance requirement is the storage space. Higher storage space means more user and bigger workspace per user so higher the storage, better the performance. Performance requirement by the user side is, web application should be developed as a lightweight web app so that it can work on almost any platform even with slower internet connections.

3.4.2 Portability Requirements

Main purpose of developing lab as a service is to improve the portability of software development process. To improve portability, software should run on variety of platforms and variety of connection speeds. As explained in the performance requirements section, software should be lightweight so that it can run on a machine with slow internet connection. To make the web application lightweight, simple libraries and tools should be used at developing phase.

3.4.3 Security Requirements

Since this software will be hosted on cloud server, all the user data will be kept on the cloud server. Product should be able to protect privacy of user data. Workspace of the user should only be accessed through user own credentials and any other user should not be able to access to the user private data. Since execution will also be done in the machine in the cloud, user should be restricted in terms of user rights. User should only access to his own workspace and should not access to any other workspace with the programs they run on the cloud. Also, rights of the user should be restricted so that user can not harm to system by the programs they run or by the commands they run on terminal. Since all the data will be transferred on the web, system should also use an encryption and decryption mechanism only intended user can decode the data and work on the data

3.4.4 Software Quality Attributes

Product will be used via a web browser. Each user will have his own workspace, and must be logged in to the server to access his workspace. This product will be available 24/7 to the students and teachers. Moreover, software will run on variety of platforms and variety of connection speeds making it more portable. It will have very user-friendly UI which will help students to access the lab with ease. Students use virtual programming lab as an easy-to-use tool with zero installation and configuration, concentrating their efforts on the problem and not on the tools used.

3.5 System Requirements

3.5.1 Database Requirements

Database requirements for this application will be PostgreSQL and Redis. PostgreSQL is a powerful, open-source object-relational database system that uses and extends the SQL language combined with many features that will help this application to safely store and scale the most complicated data workloads. Redis handles large volumes of workload more comfortably and it is single-threaded which means it runs on a single core.

3.5.2 Software Requirements

1. Front-End: HTML5, CSS3, BootStrap5, Angular 12
2. Back-End: (Python) Django Rest Framework, Spring Boot
3. Database: PostgreSQL, Redis
4. Storage System: AWS S3
5. Cloud Service Provider: AWS
6. Other: Docker, Kubernetes, Git/GitHub, Jenkins (CI-CD)

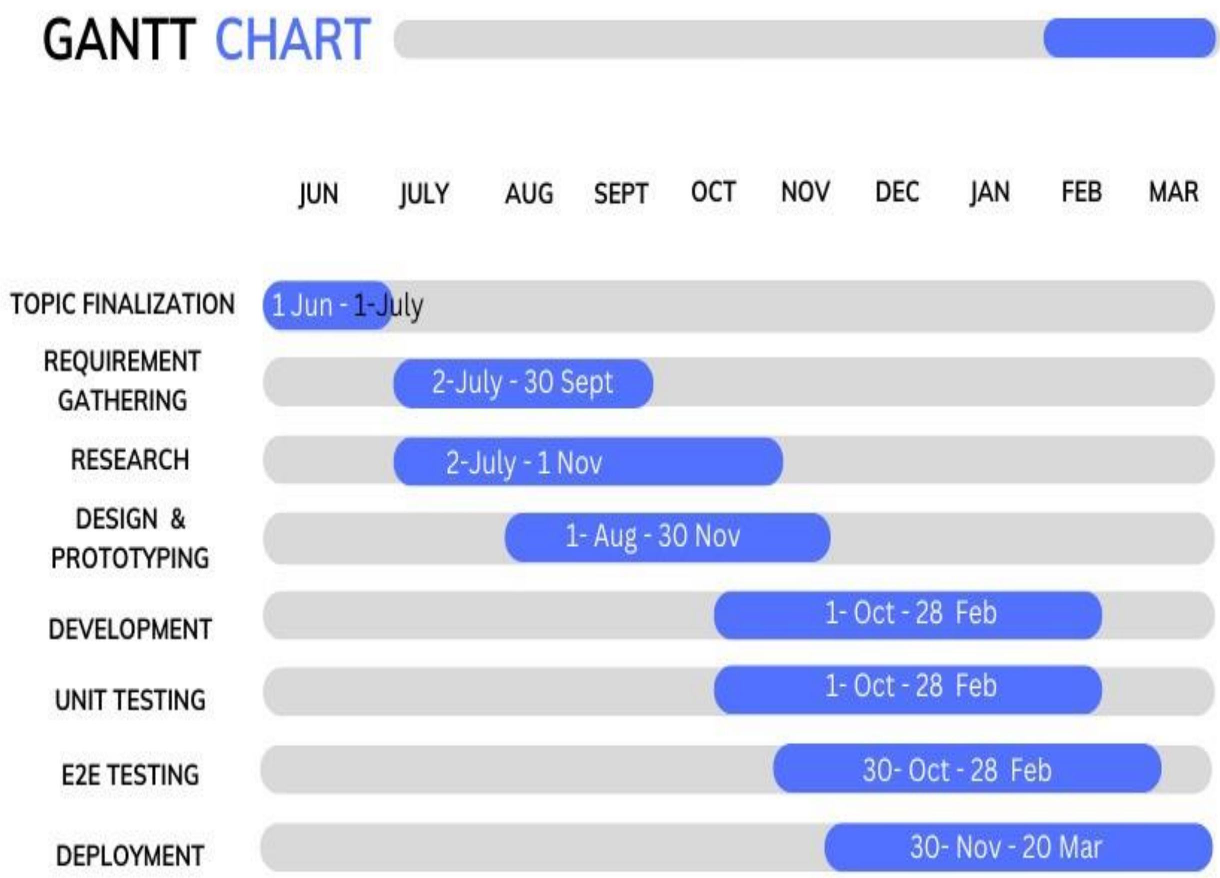
3.5.3 Hardware Requirements

1. 8 GB Ram
2. intel core i5 processor

3.6 Analysis Models: SDLC Model to be applied

Among various models of Software Development Life Cycle, we will apply agile model for our Lab as a Service application since our software will be developed in incremental, rapid cycles. This is why, system can respond quickly to changing requirements. Since agile model is based on iterative approach, each iteration involves planning, requirement analysis, design, implementation and testing. Each iteration will take 4 weeks. After we successfully build prototype of our application, our project's development will be continued according to agile model in the second semester. The pictorial representation of the Agile model is as follows.

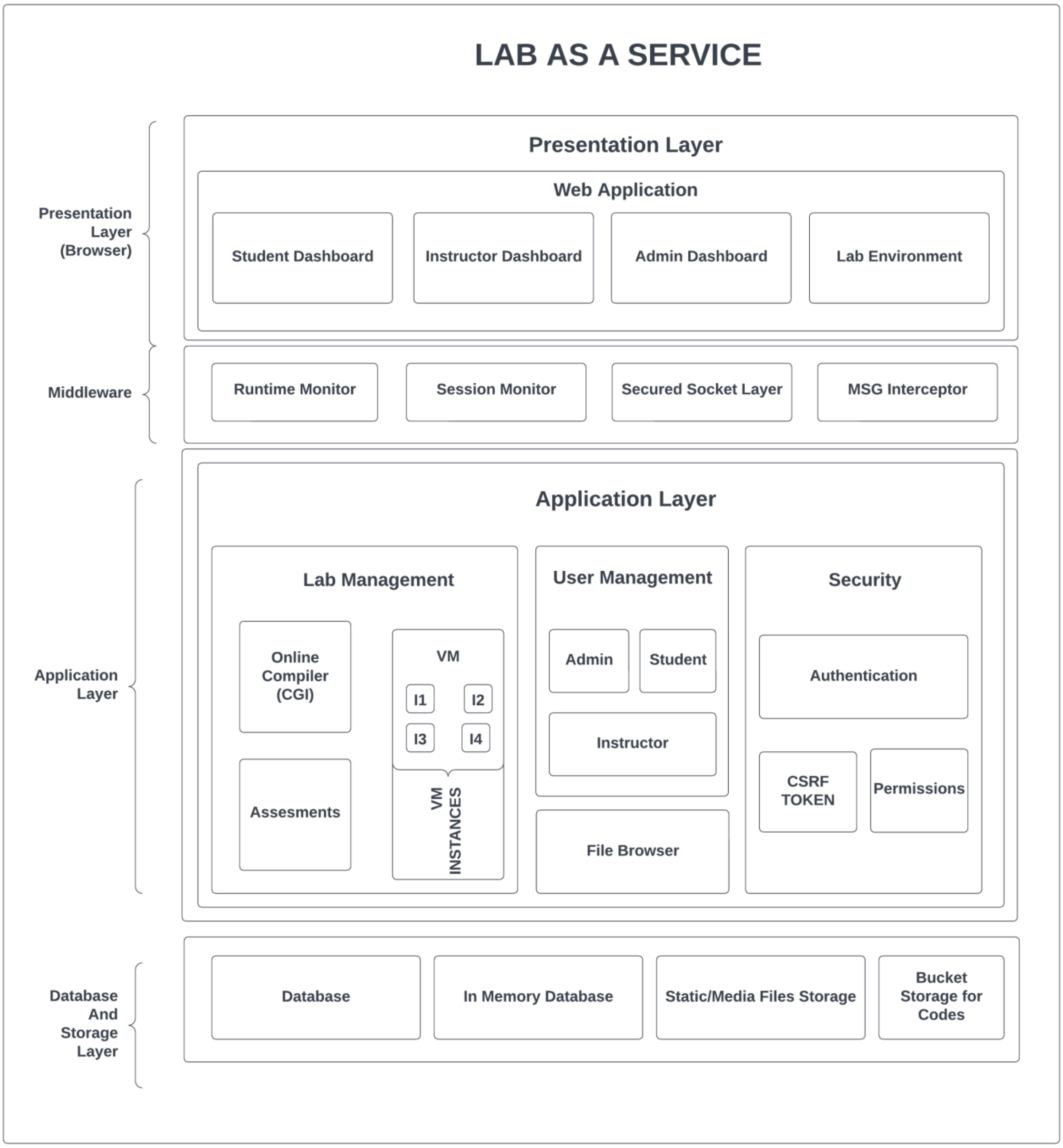
3.7 System Implementation Plan



4.

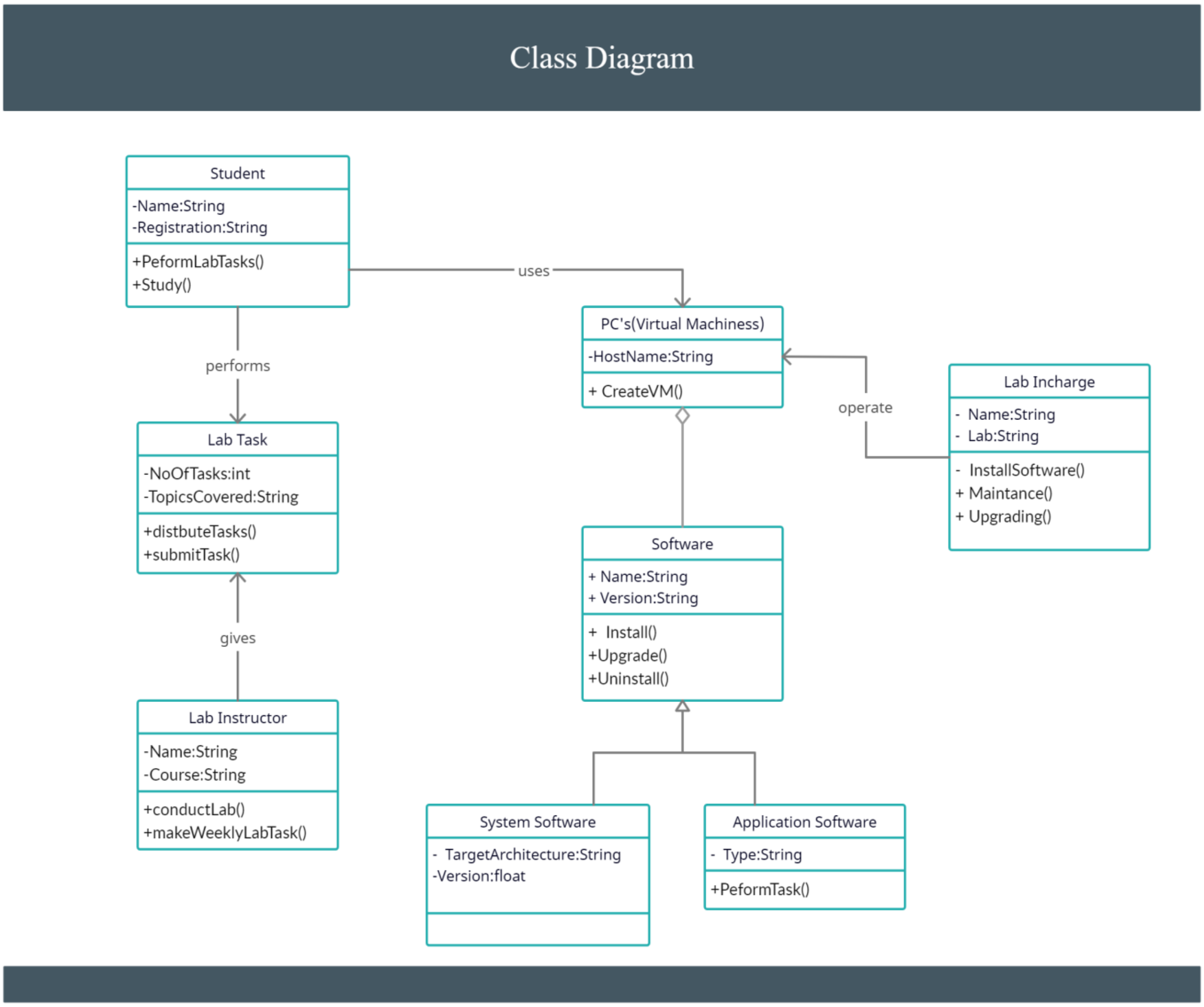
System Design

4.1 System Architecture

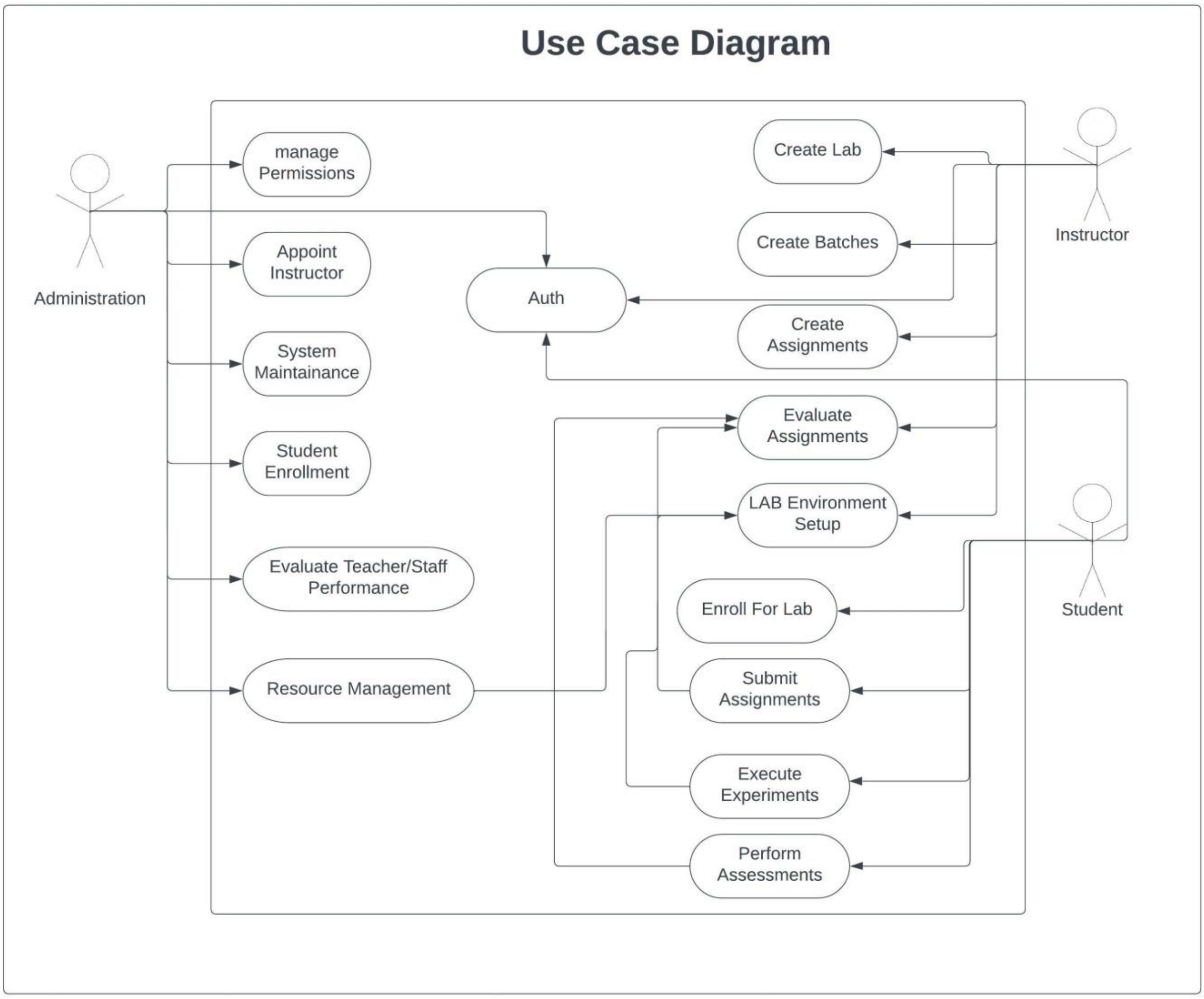


4.2 UML Diagrams

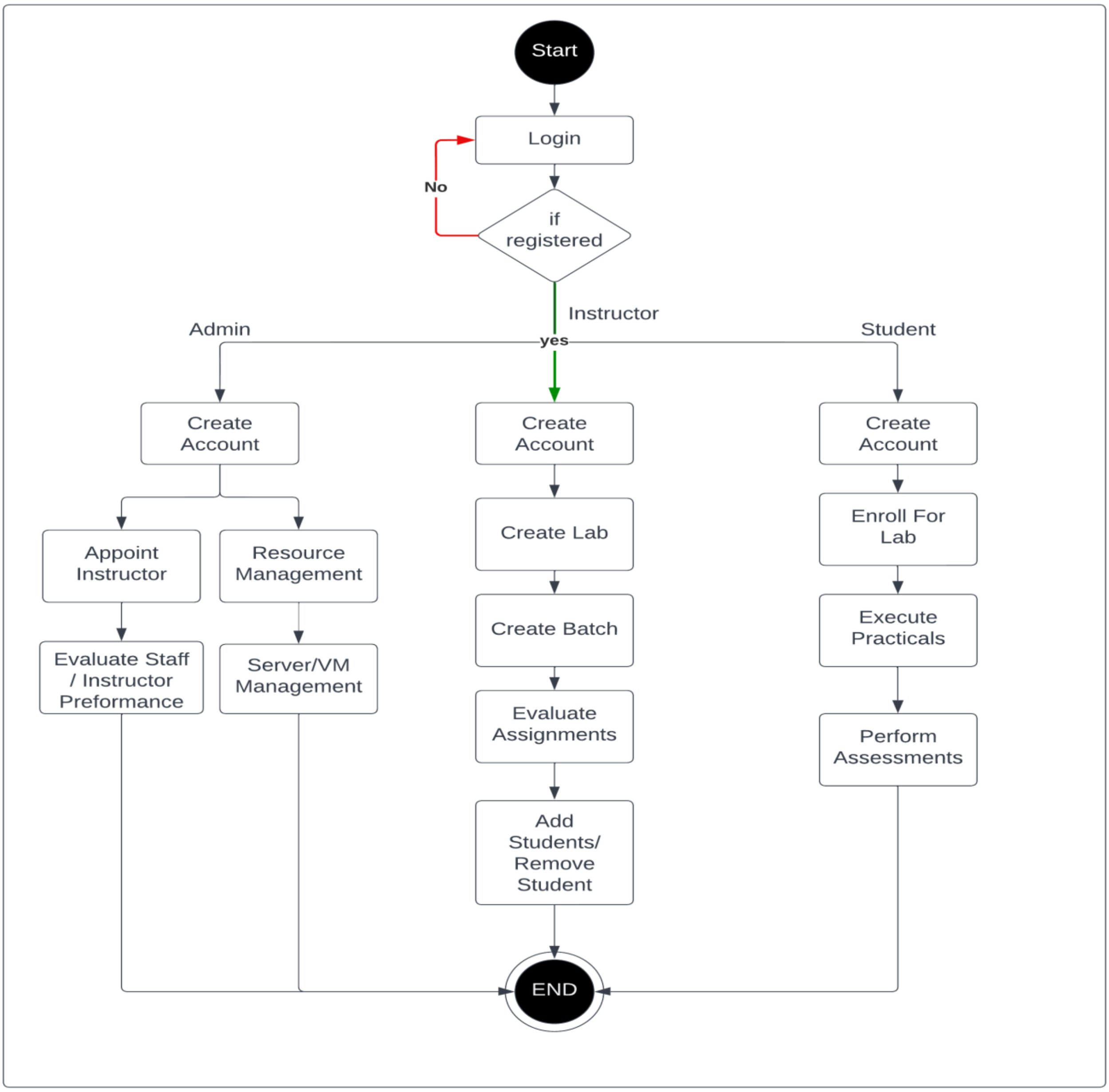
Class Diagram-



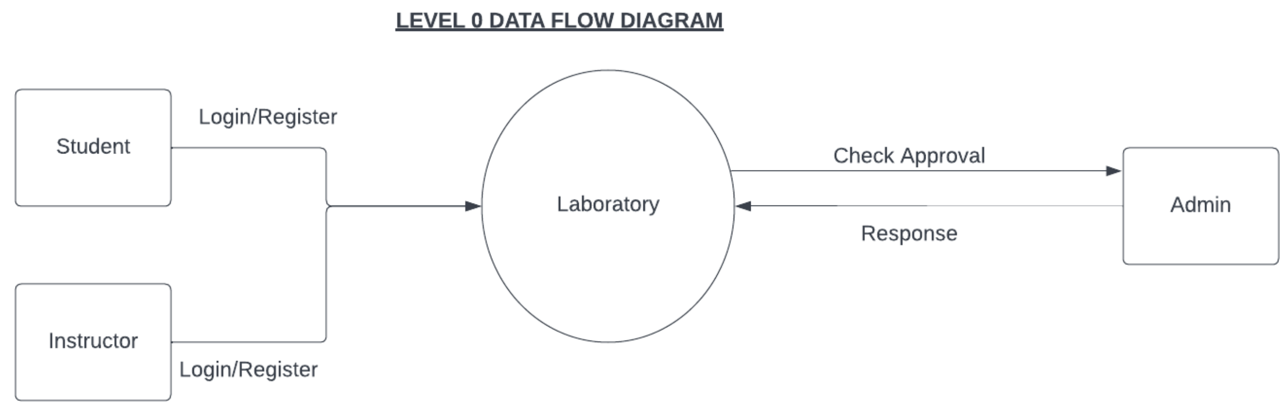
Use case Diagram-



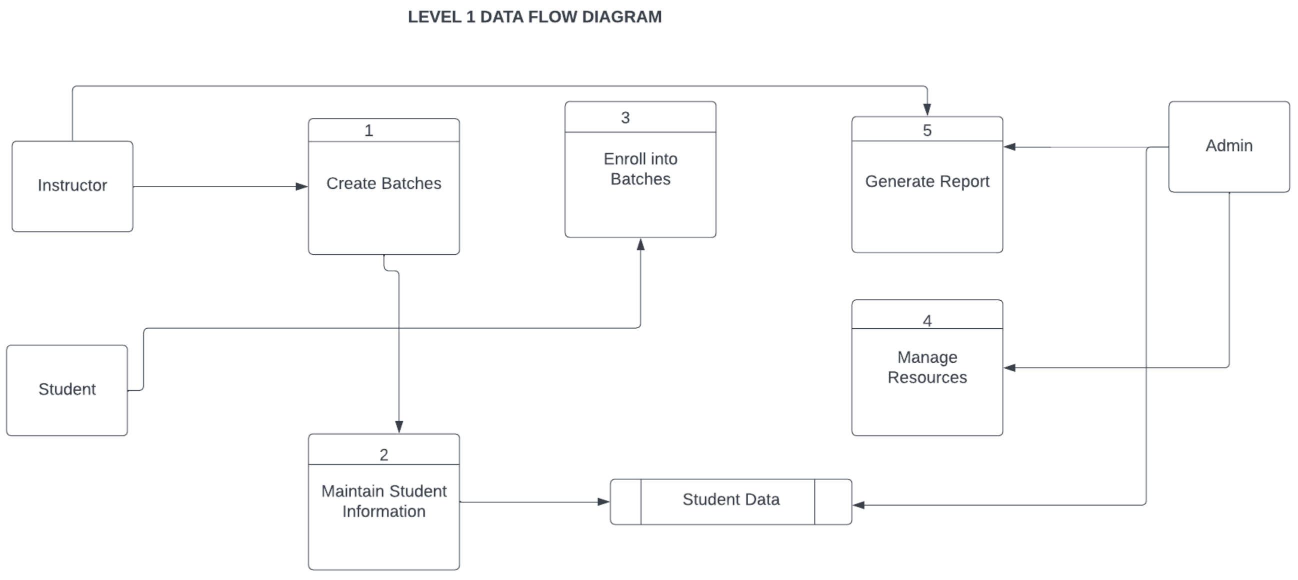
Activity Diagram-



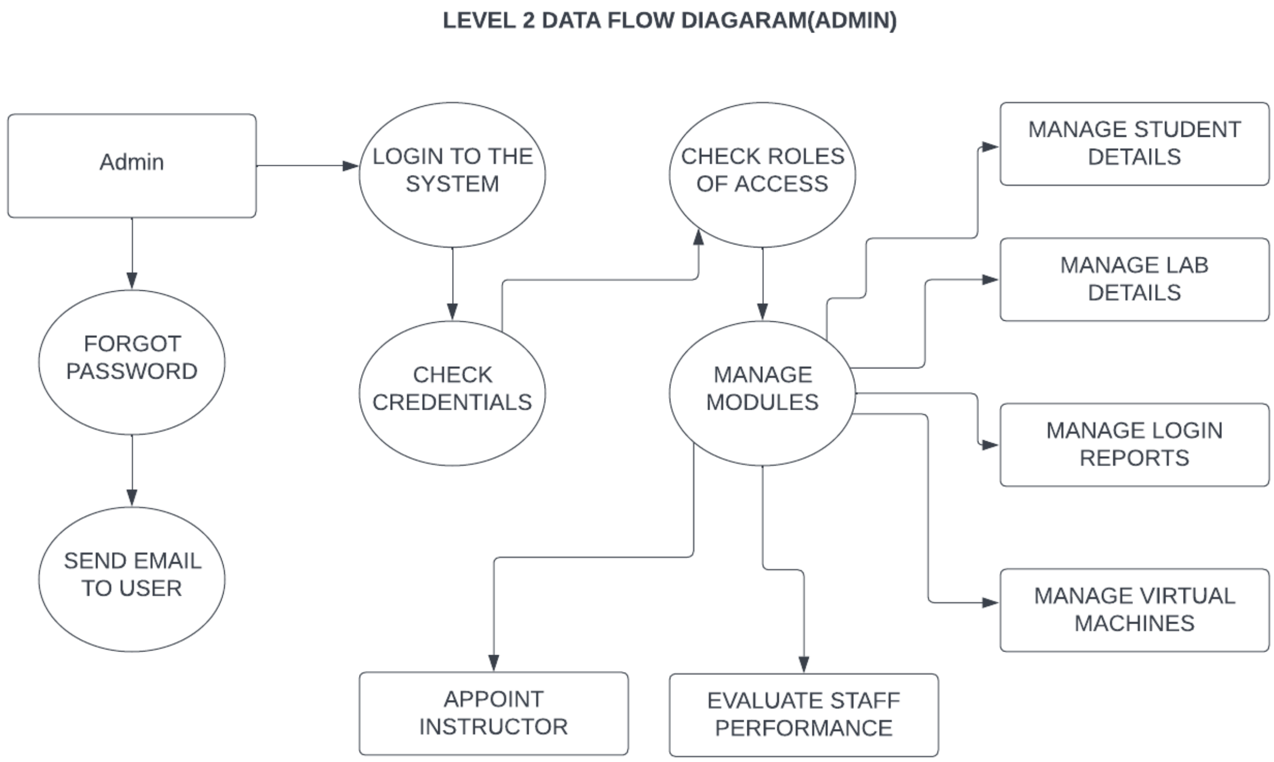
Data flow Diagram (Level 0)



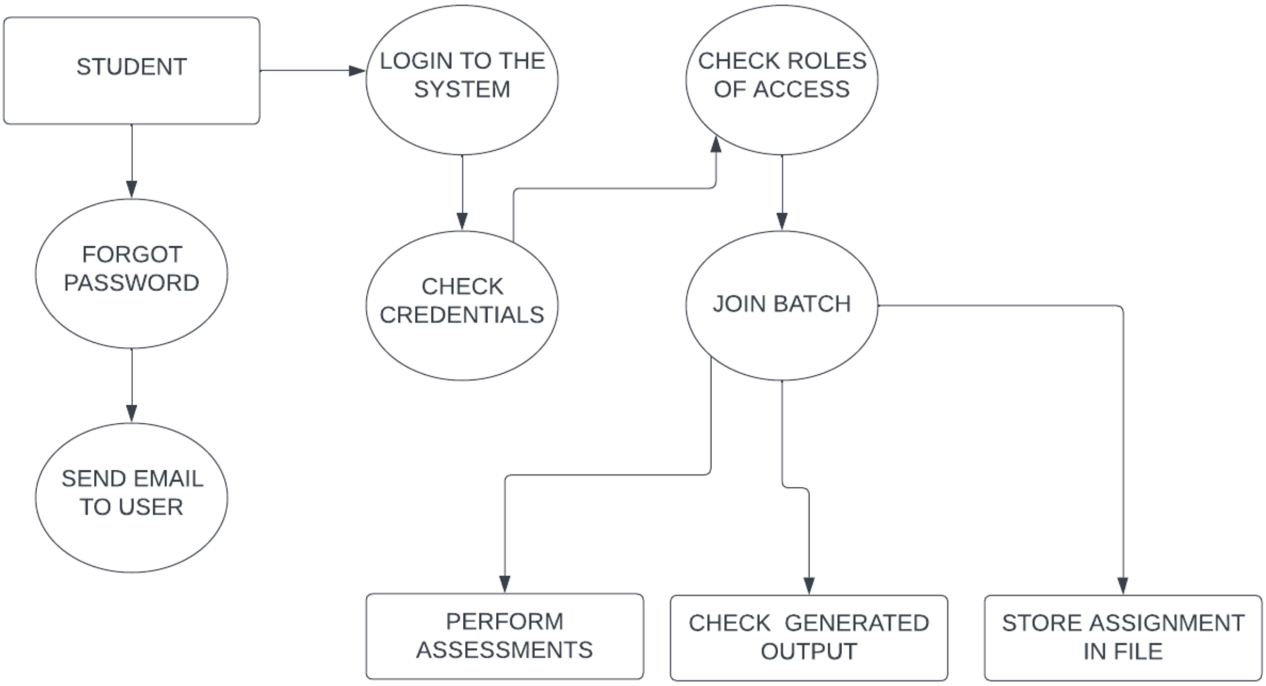
Data flow Diagram (Level 1)



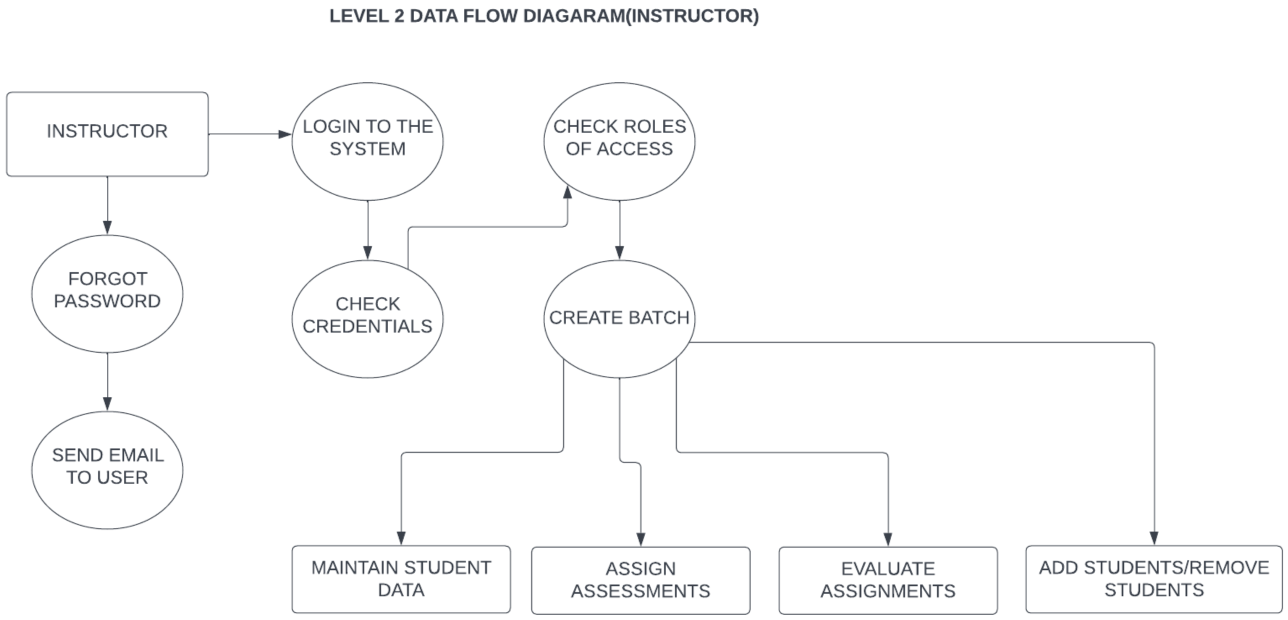
Data flow Diagram (Level 2 - Admin): -



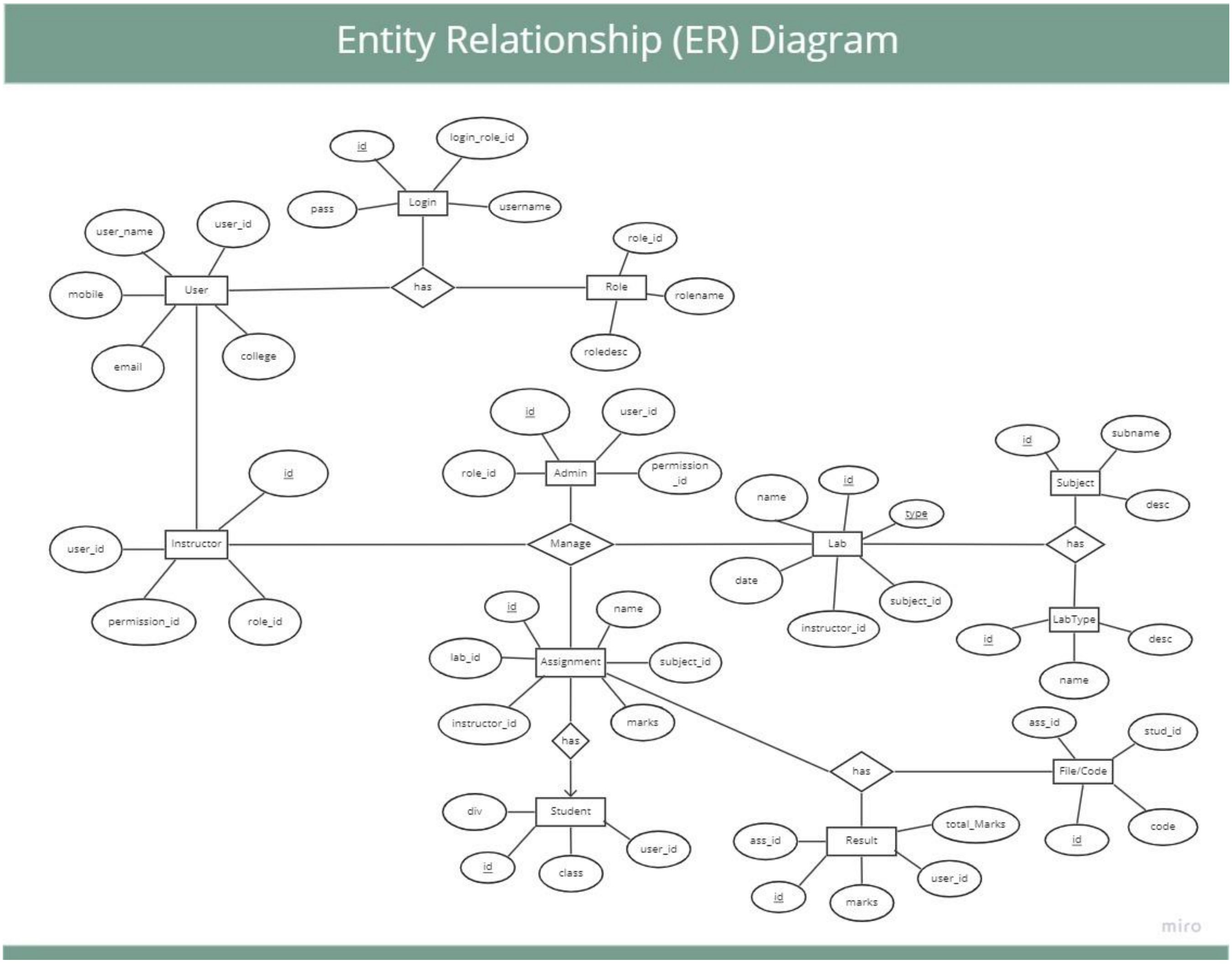
Data flow Diagram (Level 2 - Student): -



Data flow Diagram (Level 2 - Instructor): -



4.3 Entity Relationship Diagrams



5.

Other Specification

5.1 Advantages

1.2.1 Better Immersion

Students can now learn concepts through an immersive visual experience that can make the whole learning process more impactful as well as simpler for students to understand. Furthermore, it offers the synchronization required between explaining the practical applications and theoretical ideas.

1.2.2 Futuristic Equipment

Virtual labs offer students of all ages easy access to cutting-edge technology for the purpose of experimentation. Tools like Simulations and Virtual Microscopes provide futuristic solutions to science students. Learners don’t have to settle for outdated equipment with a virtual lab because that equipment’s software can be built however expensive the actual cost is.

1.2.3 Engages Students Immensely

Watching presentations and listening to lectures about experiments can become disinteresting for students. Virtual labs help instructors capture the attention of learners by helping them to test all those procedures in an online setup easily. Students can conduct the same experiment several times to make sure that they completely understand the concept.

1.2.4 Offers Instant Feedback

A major advantage of virtual labs is that it helps students to recreate the experiments. Unlike in the case of a traditional lab, experiments no longer have a single chance option in virtual labs. Students can analyze their mistakes, find out what went wrong, and try the experiment once again. Since all the experiment results are recorded, keeping track of communication between students and teachers becomes more efficient.

1.2.5 Allows Flexibility in the Learning Process

One of the common benefits of online learning, in general, is that students can learn at their own time and pace. The same applies to virtual laboratories also. It helps students’ study, prepare and perform lab experiments at any time and place according to their convenience. Since all virtual labs are either accessible via the internet or cloud-based, they offer students unrestricted access to the platform whenever they desire. Students can also access the laboratory on any device from any location, making them indispensable for contactless learning.

1.2.6 Personal Immersive Experience

Unlike in the case of a physical lab, the experience of a student who attends virtual labs is one that is personal. Each person’s individual experience is unique and is characterized by their learning curve. This allows them to learn the laboratory setup and experiment with a personal touch.

1.2.7. Affordable as Compared to Physical Labs

Online or virtual labs are far less expensive compared to traditional ones. One single lab platform can help an entire school or institution without them having to spend a massive number of resources on the equipment, preservation, and maintenance of the same. development.

5.2 Limitations

1. They require computer devices with high specifications in order to simulate the exact phenomena with full details and create a three-dimensional virtual lab.

2. One of the negative effects of Virtual Labs is that it reduces the direct interaction between students and each other, and between students and teachers, given that the communication between them is electronically most of the time.

3. Developers should also be careful about the privacy of users. Since product will be cloud application, all user data will be kept on cloud server and necessary precautions should be taken to protect user data.

4. product will be cloud application and all user programs will be executed on cloud server, developers should limit the privileges of the users so that they cannot harm other users' data and system server.

5.3 Applications

1. The virtual labs are considered as one of the most important applications of e-learning in educational and research institutions. They provide students with the opportunity to conduct experiments without exposure to any risk and without human supervision, by using computer applications in different fields of science

2. Also they save a lot of time and effort for students and teachers as well, where they can conduct experiments and anywhere and anytime.

3. On the institutional side, they save a lot of money that will, otherwise, be wasted in the maintenance operations of devices and equipment or the purchase of materials necessary to conduct various experiments.

4. They help students and teachers to conduct and prepare experiments without being restricted to laboratory locations or official study dates.

5. Virtual labs help the teacher cover all aspects of the course with practical applications and help the student to understand all the points of the course with experience, which is difficult to provide when there is lack of equipment and funding.

6. The student is given the opportunity to control the inputs of the experiment, change the different parameters, and observe the changes in the results without human supervision

7. Virtual labs help the teacher to evaluate the students electronically, easily guide them, and monitor their progress in conducting experiments.

8. They also save time and effort on the researchers, as they prevent them from moving between different laboratories locations.

9. It has been used in many universities and schools around the world to keep up with the technological development we are witnessing in the digital age, which is reflected in various forms in the fields of distance learning and e-learning.

6.

Conclusion

It will allow users to access the lab environment beyond working hours. It will eliminate the dependency on particular lab facilities. It will readily provide an integrated development environment for students without worrying about development setup and dependencies. Through this framework, which we call Lab-as-a-Service (LAAS), students can remotely execute labs designed by instructors. It will reduce the gap between high and low computation. It can incorporate a middleware approach in which it can be used universally across a wide range of experimentation types This helps to promote courses that require lab facilities to also be incorporated to the online learning environment. For future work, we plan to extend the LaaS framework to take into consideration scalability and complexity of more sophisticated lab equipment that are required for courses in engineering, science, among others.

7.

Appendix - A

For a number of years, traditional learning meant that the acquisition of knowledge and learning would be confined to fixed locations (i.e. classrooms). In this form of learning, teaching mainstream involved one-way learning such that instructors spend majority of their time lecturing or delivering course materials. However, this form of learning is gradually and constantly changing. Thanks to advancements in client- and server-side technologies that now make it possible to create rich internet applications (RIAs) powerful enough not only to ensure the successful delivery of courses online but also provide capabilities to control devices in a remote manner. With the use of technologies (e.g. JavaScript, AJAX, AngularJS, PHP, Python, among many others) it is now possible for instructors who use learning management systems (LMSs) to extend the knowledge acquisition form across multiple locations and not through a fixed environment. Although the number of online courses is rapidly increasing, the proliferation of online learning faces many challenges that must be taken into consideration to ensure the successful delivery of all types of courses including those that offer lab components.

Many courses often incorporate a lab component for students to conduct experimentation and gain some practical, hands-on experience where they can apply theoretical ideas into practice. Offering the theoretical portion of such courses can be achieved via online learning platforms where instructors post course materials (e.g. lectures, multimedia content, articles, among others). However, the challenge of offering the lab component portion of such courses in a remote manner remains a major problem that requires solving. This prompted us to explore the use of existing state-of-art technologies that can potentially solve existing challenges.

To overcome many of the existing limitations associated with offering online courses that have a lab component, our paper introduces a new framework called Lab-as-a-Service (LaaS) that takes advantage of cloud computing and service-oriented concepts to build IoT- and CPS- based systems for enabling students to remotely conduct experimentations or labs from a distance. We believe that our LaaS framework will help advance the expansion of offering online courses that have a lab component and in improving the online learning experience.

8.

Appendix - B

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