Journal of Engineering Education Transformations,
Volume No 36, January 2023, Special issue, eISSN 2394-1707

10.16920/jeet/2023/v36is2/23039

Virtual Lab Development to Enhance Student Learning: A Quality Circle Approach

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***Abstract*—The COVID-19 pandemic has affected the student fraternity to physically access the laboratory and conduct experiments offline. Across the world, new platforms have been designed with ICT tools for the smooth conduction of academics specifically for laboratory courses. This article aims to provide quality circle-based guidance to the community to develop a Virtual Laboratory. The virtual lab is developed through an emphasis on Quality Circle methodology. The Quality Circle team has developed an instructional methodology known as the virtual laboratory (VL). It incorporates pedagogical techniques that help students to better understand the theoretical concepts in an effective and joyful way.**

***Keywords*— Virtual Lab, Virtual Lab Mobile App, Virtual Lab Website, Engineering Education, Quality Circle.**

***JEET Category*—Choose one: Research, Practice, or Op-Ed. (Please note, Op-Eds are by invite only. Refer to the Paper Submission and Review Guidelines for more details.)**

I. INTRODUCTION

The beginning of Quality Circle was in l940 to survive in the industrial world. Prof. Ishikawa, who was supposed to utilize the creative potential of workers, resulted in the invention of the Quality Circle movement which helped the Japanese industry to achieve milestones in creativity. A quality circle is a small group of employees who meet consistently and discuss, analyze and find solutions to work-related problems.

This activity not only enhances the performance of the organization but also improves the work culture of the employees. The concept of building people turned into the philosophy of quality circle. At regular intervals, presentations are given to the management by the Quality Circle team. Based on the presentation the management decides either to accept, modify or reject the proposal (Jayakumar&Krishnaraj, 2015).

Due to the Covid-19 pandemic, students could not physically access the laboratory and conduct experiments, which has led to academic loss to students. Thus, it has been decided to take up this as a problem for the quality circle (QC) and find a viable solution. A good lab facility and updated lab experiments are critical for any engineering college since the practical knowledge of the students directly impacts student placements. So, it is very important to provide the access to the lab for the students all the time without any space and time constraints (Budai & Kuggzmann 2018). The virtual lab is one of the options during situations like the COVID-19 pandemic to facilitate lab access and improve the skills of the students (Tüysüz 2019).

The Virtual Labs needs lack good lab facilities and well-trained teachers, to provide access to virtual labs in engineering Smaldino, Lowther and Russel (2012). They should also fulfill the curiosity and knowledge requirements of students Bose (2013). The virtual labs need to be student-centric. The virtual labs also permit the use of web resources, online video lectures, animations, self-learning and self-evaluation Kathane, Dahikar and Sharma, (2013). The virtual labs(VLs) can be available to students from all locations and at their convenience and at any time Reglitz (2020). This development is a paradigm shift in student-centric, online education. The coronavirus (COVID-19) disease has caused difficulties in all fields, including academics and research. The inability of undergraduate and graduate students to utilize laboratories and conduct studies has had a considerable negative impact. Because of the COVID-19 pandemic and other unanticipated events, students can conduct experiments at home and lab sessions can still normally go, thanks to the powerful instructional tool known as the virtual laboratory. The creation of a virtual lab is intended to allow students to conduct experiments using the internet and visual aids without having access to the necessary equipment. Bo (2011). Through cost-effective outreach and remote learning activities, the Virtual Lab Program offers a singular chance to improve the standard of engineering education, deepen knowledge, and give young minds the required practical skills. Wannous, Nakano & Nagai (2011). These VLs give users access to experiment video instructors, experiment-related

animation, supplementary web resources, and self-evaluation. Santoso (2009).

Access to the internet is quite common nowadays. Online laboratory conduction can be an easy solution Daniel (2020); O'Brien (2021). The web base lab is another advantage of it. The works of web-based laboratory resources in universities are reported in references Ngoyi (2013). Virtual labs are a useful tool for teaching. The students can practically verify the results. The virtual labs also allow e-learning and various universities are providing e-learning access Usman & Huda (2021). Such initiatives will be the turning points for strong and futuristic academic development.

Considering the benefits, easy access, and safety concerns, need for the lab in emergency conditions like Covid, this work provides a virtual laboratory development Zhai, Wang & Liu (August 2012). A virtual teaching and learning environment designed to improve students' laboratory abilities is referred to as a virtual lab. Students can conduct a variety of experiments in a virtual lab without being restricted by time or location. Virtual laboratories use a variety of instructional strategies to aid students in understanding the theoretical material Murphy, Delane,Hill (2016). These methods include narrative, gamification, visual learning, active learning, recall-based learning, and active learning (Budai & Kuggzmann 2018). To make it compatible with the ICT tools available, The Massachusetts Institute of Technology currently manages MIT App Inventor, an integrated development environment for online applications that was first made available by Google Yamasari (2010). The problem analysis revealed that the only answer for a situation of this nature is a virtual laboratory Zhai, Wang & Liu (August 2012). Across the world, new platforms have been designed with ICT tools for the smooth conduction of academics specifically for laboratory courses during the COVID-19 pandemic (Hatherly, Jordan, and Cayless 2009) The most crucial factor in the selection process is that the lab should benefit all engineering students Daniel (2020); O'Brien (2021).

Virtual labs are developed by using two platforms: -

1. MIT App Inventor: - MIT app inventor is an online platform or it's a virtual programming environment that allows users to build an android application for smartphones or tablets.
2. Visual Studio (VS) Code: - V S Code is software and also a platform that allows the user to build websites.

The laboratory taken is a basic Electrical Engineering laboratory that is common to all engineering branches. The work proves an effective and pedagogically active-leaning method for virtual laboratory conduction. This work is a part of a quality circle activity done by the faculty of the core electrical engineering stream.

The paper is organized as follows: Section II gives Problem Identification where the problem analysis part and causes have mentioned. Section III VL development methodology under which it details the selection of the lab, platform of implementation, experiment flow, and approach towards Outcome-based Based Education (OBE). Section IV provides on trial implementation of the virtual lab and feedback. Section V explains the final implementation of the virtual lab. Section VI provides the web-based implementation of a virtual lab. Section VII represents s conclusion.

II. PROBLEM IDENTIFICATION

Being a premier technical institution in a rural area, many problems have been observed and noted. As problem identification is an important part to peruse the solution. By using rating method, the major problem has identified and represented in pareto diagram as shown in Figure 1.

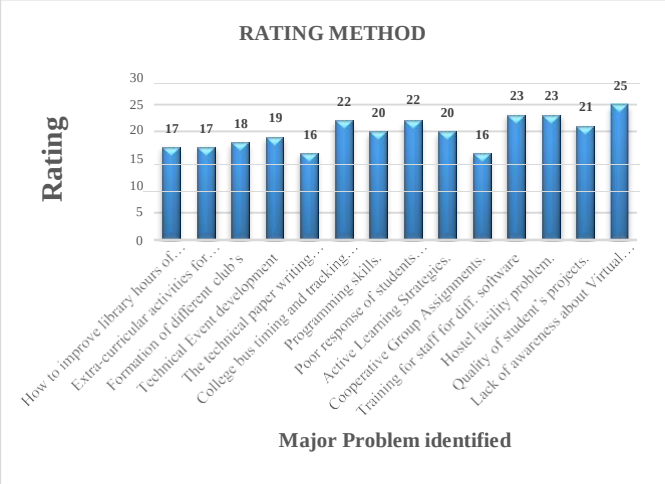
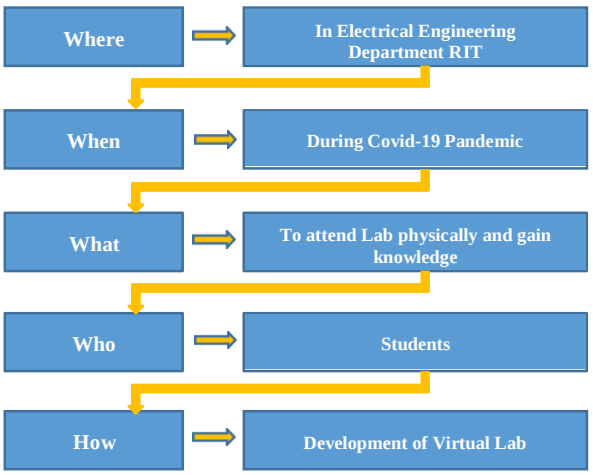


Fig. 1. Pareto Diagram

As an academic organization, the primary responsibility is to take a step towards delivering the content to the students by using various platforms even in pandemic situations. It



would be a great opportunity for the students if they would be able to learn the contents effectively from their homes. During a pandemic, the situation has come that to teach students by using the online platform for more than a year. The lecture can be managed with the help of active learning tools in an effective manner. Whereas, the main problem is in the conduction of laboratory courses. One way to conduct the same is to provide experiment videos to the students or provide some web resources. By utilizing the method called the 4W-1H principle as represented in Figure 2.

Fig. 2. Problem Analysis: 4W-1H principle.

It incorporates various pedagogical techniques that help learners to better understand the theoretical information and also to gain realistic lab experience to perform experiments and improve skills in a risk-free and interactive learning environment.

The following causes have been identified and categorized into causes related to students, faculty, and miscellaneous as represented in Table I. The primary step in this process is started with preparing a rough list of the causes and classifying the same into different categories for better logical findings, elaborations and findings as represented in Table I.

The main student-related causes are how to understand the practical concept through online mode, how to perform practical (Selection of parameters, the connection of wires, how to run the simulation) online, lack of motivation to learn the things online and some critical practicals need to be performed more than once. The main faculty-related causes are lack of knowledge of how to conduct practicals through online mode, how to develop virtual lab faculties, whether there is a requirement to know coding and programming of particular experiments, lack of awareness of the number of virtual labs available on the internet and how to keep track of communication between students and teachers. Along with the student and faculty-related causes some miscellaneous causes are also identified. The miscellaneous causes are, which method should have adopted for the online practical teaching-learning process, whether is it free to perform practicals through virtual lab or it may require charges, is it has the freedom to move between the components of the practical material and which ICT tools to be used.

TABLE I
CLASSIFICATION OF CAUSES

Student Related Causes	Faculty Related Causes	Miscellaneous Causes
How to understand practical concept through online mode without set up of practical	Lack of knowledge how to conduct practical through online mode	Which method should have adopted for online practical teaching learning process.
They didn't know how to perform practical (Selection of parameter, connection of wires, how to run simulation) on virtual lab	To develop virtual lab faculties should know coding and programming of particular experiments	Is it free to perform practical's through virtual lab or it may require charges?
Lack of motivation to learn the things online	Lack of awareness of number of virtual lab available on internet.	Is it have freedom to move between the components of the practical material
Student Related Causes	Faculty Related Causes	Miscellaneous Causes

Any complex problem can be tackled easily and effectively by understanding in-depth knowledge of the reason that leads to the problem.

III. VL DEVELOPMENT METHODOLOGY

A. Selection of lab

Numerous laboratories are involved in engineering.

Electrical Engineering, RIT College consists of 14 laboratories. So the following 56 virtual lab development problems were identified by brainstorming method. It applies to students in other branches as well, not only electrical engineering students. Thus, choosing the best Lab is a really difficult task for the QC team. The selection of specific labs has been done based on brainstorming and voting method. points consider for selection of Basic Electrical Lab for VL as Usefulness for all branch students, More Stakeholders, and also mother lab for all branch students. For the selection of the lab inter-department voting-based method has been implemented and the analysis has shown in Figure 3

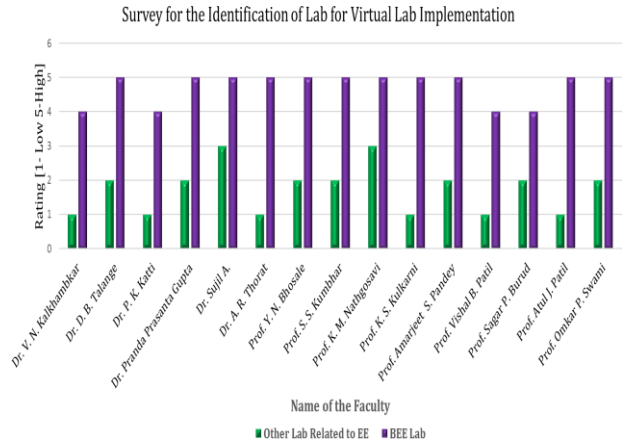


Fig. 3 Survey for selection of lab: Rating-Based Method

B. Selection of Platform

There are two options for VL, namely a website and a mobile app, by the given solution. So, based on the results of a staff and student poll, we pushed forward with building an app-based virtual learning environment. Its study is shown in Figure 4.

It helps students acquire practical lab experience that will enable them to conduct experiments and hone their abilities in a risk-free and engaging learning setting.

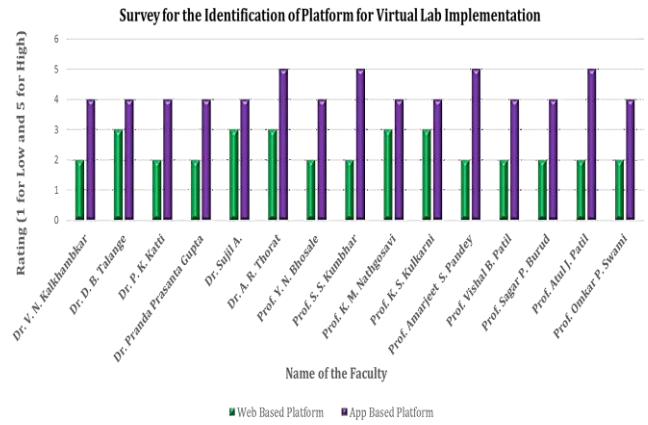


Fig. 4 Identification of platform: Rating-Based Method

C. Flow of Experiment

As per existing VL, some modification has been done for making it more lucrative such as Aim, Apparatus, Theory, Pre-Test, Circuit, Experiment, Observation, Results, Post-Test, Query tab, and also open source used hence, decided to use the MIT inventor process for lab development. The goal of the online platform MIT App Inventor is to introduce computational thinking ideas via the creation of mobile applications. People build apps by dragging and dropping components into a design view and programming application behavior in a visual programming language. The flow of the experiment has been finalized to achieve the best possible learning for students as mentioned below in Figure 5.

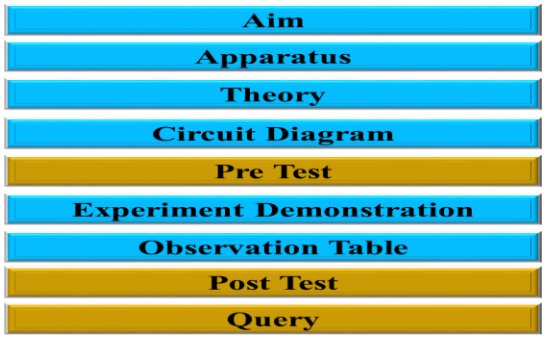


Fig. 5. Experiment sequence. (Follow for app development)

The above figure shows that the traditional practical journal has been modified by adding the Pre-test, Post-test and very unique Query Tab which will have great help to the user.

D. Approach to Promote OBE

The significance of the Pre-test and post-test are: Pre-test & Post-test improve student's Confidence, increase the amount of learning a student has acquired in a specific subject., Helps to identify pre-existing knowledge, and helps with goal setting in the classroom. As students are submitting queries after performing the experiment it is expected that faculty should solve or respond to the query for making a closed loop and promote a student-centric OBE philosophy.

E. Overall Methodology for Virtual Lab Development

Thus, a methodology was followed to design and develop the virtual lab. The quality circle team has followed a step-by-step predefined methodology as represented in Figure 6.

Fig.6. Twelve-Step Quality Circle Methodology.

IV. TRIAL VL IMPLEMENTATION

The first version of the android application was developed in the first phase and it is given to the selected students. After that, asked students to use this application for a few days and inform them to identify things that could be added to the application so that this application will help students to learn more about the laboratory. The first version of the application is shown below.

Fig.7 Front Tab of App-based VL

Figure 7 shows the first page of the application. On the first page, all the details about the virtual lab are written. Along with this, the information about Basic Electrical Lab is also written with all the details of the lab. On the first page, students can select any experiment by clicking on "Select Experiment Here". Once the student clicks on the given tab the student can see the all-experiment list. And students can select any one experiment from the given experiment list for learning.

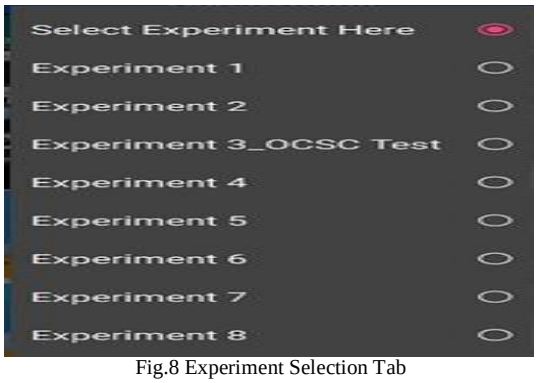


Fig.8 Experiment Selection Tab

Only one experiment is taken in the application for testing purposes as shown in Figure 8. The Open Circuit and Short Circuit test on Transformer (OC and SC Test) Experiment is selected as a test experiment. So in the experiment selection tab, only OC and SC Test experiment is visible and accessible. Once the student selects the experiment he can learn about Aim and Apparatus as shown in fig 7. Along with this data, students can learn about the Circuit diagram, Theory, and Observation Table by clicking the theory tab.

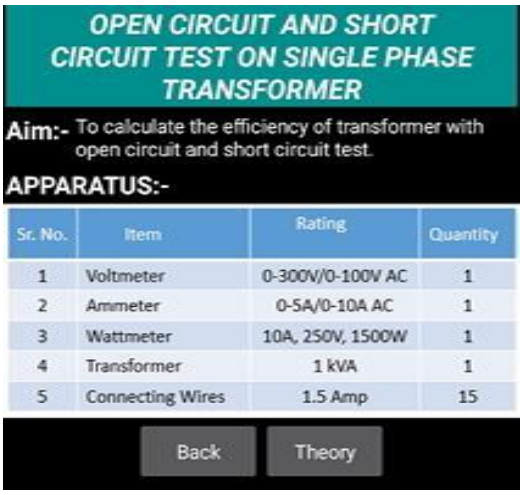


Fig.8 Experiment Aim and Apparatus Tab

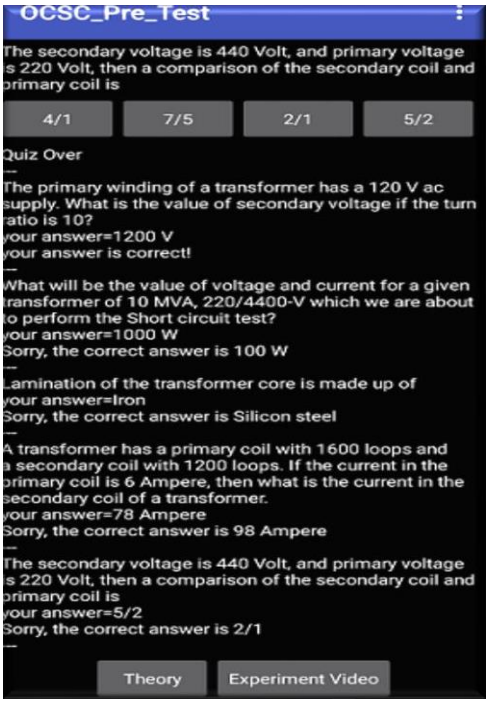


Fig.9 Pre-test Tab

As mentioned above in Figure .9, in the Pre-Test Tab there are 5 MCQs that will check the student's prerequisite knowledge after going through Theory. Also, the student can see which option is correct and how many he answered correctly/ wrongly.

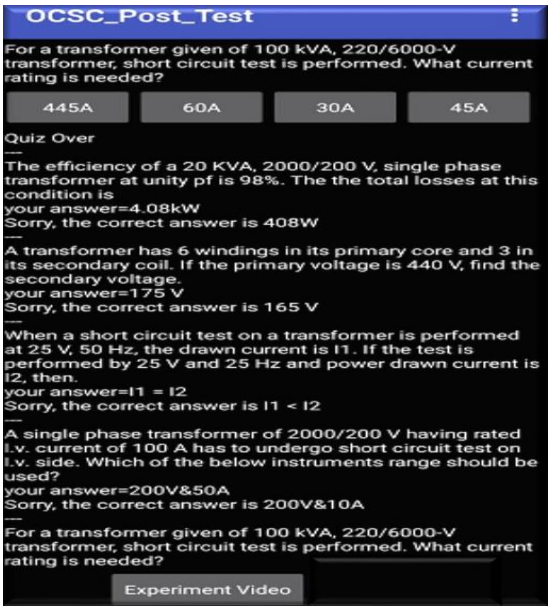


Fig.10 Post-test Tab

As with the pre-test, Post-Test Tab is there as shown in Figure 10, after the experiment video and there are 5 MCQs that will check the student's understanding after going through a demonstration video. The app has been structured as mentioned above and circulated among the students for testing and feedback purposes.

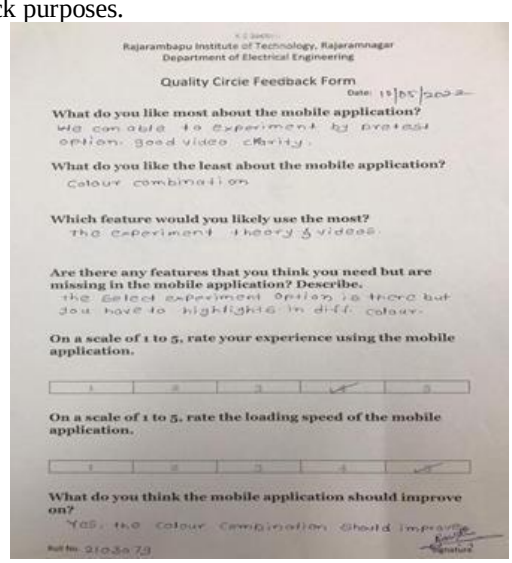


Fig 11. Student Feedback form after Version 1. App Implementation.

Feedback from students has been taken, and one sample of feedback has been there as shown in Figure 11. The use of certain methods such as discussions can help students interrogate, reflect on and revise their ideas.

By using the rating method, important observations have been taken out from feedback for improvement which focuses on some good insight like: -Color combination need to improve, Query tab should be there, Video should be full screen, assembling of circuit diagram should be there, Animation needs to improve, Theory is informative and test option is very helpful.

V. FINAL VL IMPLEMENTATION

After incorporating suggestions given by stakeholders, the final version of the application is developed as shown below. Figure 12 indicates the home page of the virtual lab mobile application from which is it very clear about the team and department. Along with this color combination of the first page is improved as per the feedback received from stakeholders.

Fig 12. The home screen of the virtual lab application.

After going through the home page it is essential to select a particular experiment. In the final implementation, all experiments have been converted into a simulation platform with all the credentials and the tabs have been framed as per Figure. 3 which clearly shows all 9 experiments as shown in Figure 13.

Fig. 13. Experiment selection tab

After selecting a particular experiment aim, the apparatus theory window will be there on a screen which is shown in Figure 14. Here Aim, apparatus, theory, circuit diagram and observation content are added together as per the feedback received.

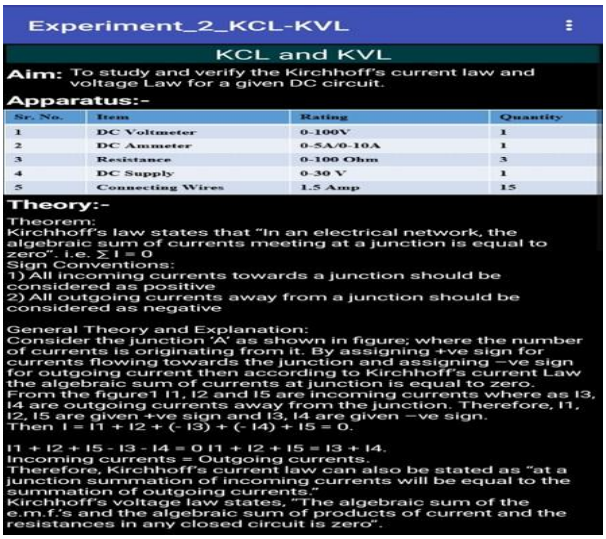


Fig. 14. Theory of Experiment no. 2

After going through the theory part of the experiment it is expected that students should be able to give a pretest. Fig shows Pretest tab. Where this test consists of 5 multiple Choice Questions (MCQ) questions with 4 options Students need to select any one option and submit the test. Immediately after submission student can get a result with correct answer and description as shown in Figure 15.

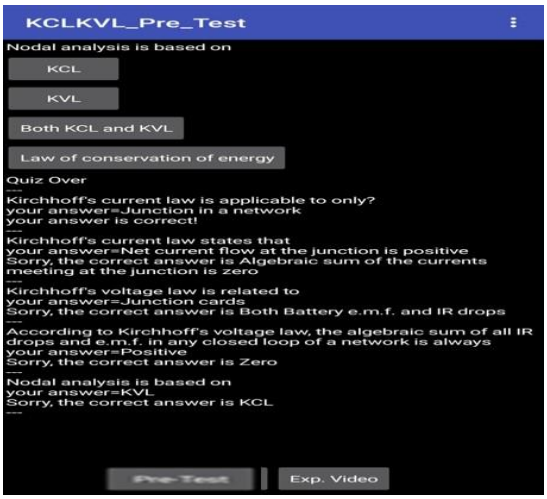
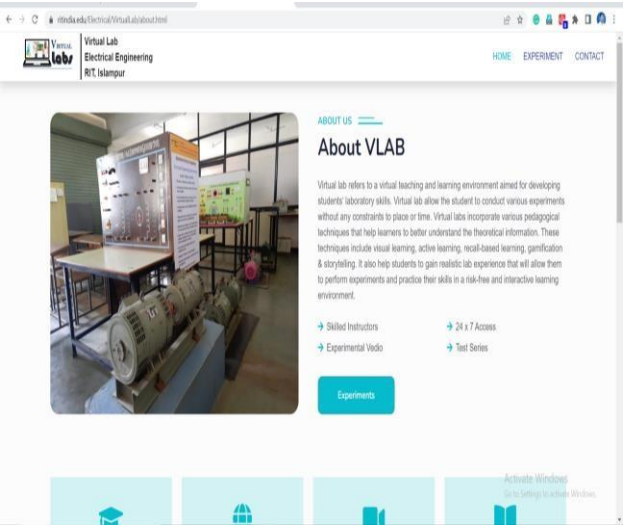


Fig 15. Pre-test window

After the pretest student can see the demonstration by using a video recorded by an expert faculty. After the video demonstration student can opt for simulation or appear for posttest as well as a student can submit a query with the help of various tabs present as shown in Figure 16. In the query tab student has to mention his roll number and his doubt. Once he submits the query then automatically that query is transferred to the another application (built for faculty to solve queries of the student) via the internet. This is how the student's queries can be solved using the application. Along with this once the student clicks on the simulation tab the student can able hands practice.



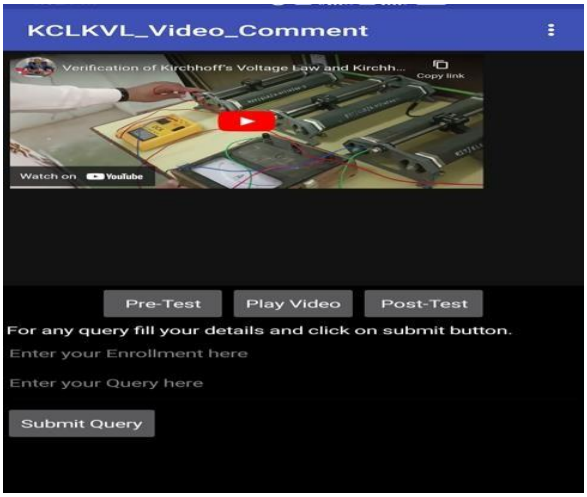


Fig. 16 Demonstration, query window

In this simulation tab, students can connect different elements by using their hands so that they can get an experiment performance feel as shown in Figure 17.

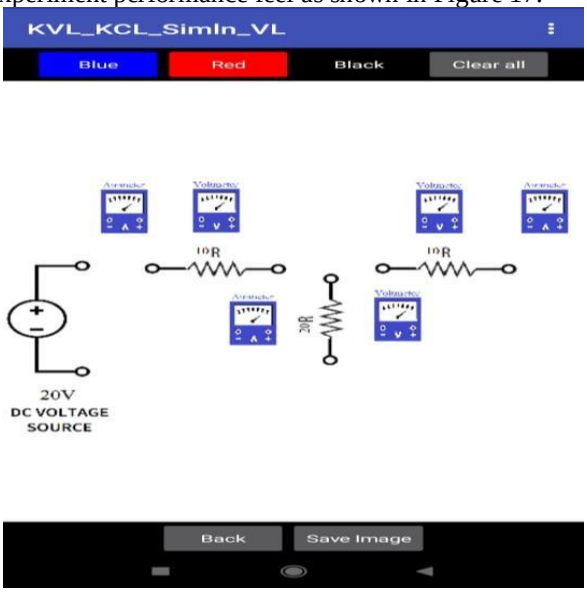


Fig. 17 Connection of circuit window

VI. WEB-BASED IMPLEMENTATION

In addition to the mobile application, one more facility has been provided as per stakeholder feedback and that is QC team developed website which is available on the RIT website under the electrical engineering tab as shown in Figure. 18.

Fig.18 Virtual lab website home screen

Additional features of the system are still under development and it is expected to get much better versions of the program shortly, as well as a management scheme for the controlled remote access of students to the experiments. The experiment developed on the mobile application was also put on the website for easy access by students as shown in Figure.19.

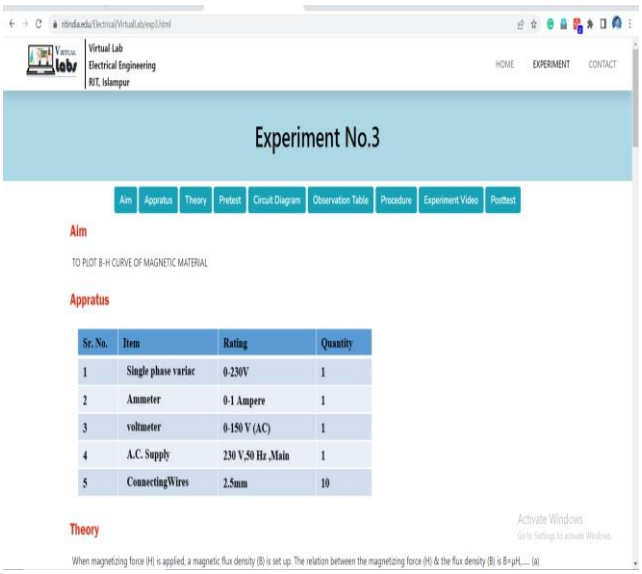


Fig.19. Virtual lab website experiment screen.

Although the target in this report is only the operation of a reduced-voltage starter for an AC motor, the model can be extended to other laboratory experiments for engineering education. Further work is currently directed towards the development of new web labs applying the same scheme described in this paper, improving them with the addition of features such as audio and video communication with the actual laboratory, and complementing the learning tasks with other online activities to increase the benefits of the web-based experience.

VII. CONCLUSION

An android and web site based application has been implemented as a part of quality circle work. The process of developing of virtual lab through a quality circle is easy and effective as compared with conventional virtual labs. Students can learn experiments by using this application. The virtual lab

development has been achieved by using student feedback and the effective learning requirement and interest of the student. Students' queries can be easily solved by the faculties. students can study from their homes which is useful in many situations such as the closing of college due to flu, medical emergency, etc. A system is a useful tool for distance learning where the physical laboratory is not feasible. So, this application completes the closed loop of learning which is a different way of conducting virtual labs.

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