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Effective Conduction of Laboratory Courses in Online Learning using Virtual Lab

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***Abstract*—**
In the Covid 19 pandemic, education shifted from offline to online, impacting a lot of technical education. The online theory courses were conducted effectively, but there were a lot of problems the faculty faced in conducting laboratory courses. This problem includes an ineffective demonstration of lab experiments, difficulty in time management, monitoring, and assessment, inability to tackle the issues of various students' learning styles, and unavailability of a common platform for online lab conduction. In technical education, the lab course plays a vital role. We found that a virtual laboratory is the best solution to address these issues. Many virtual labs are available for programming courses but need a customized Virtual lab for core courses. In this paper, we have carried out 16 surveys through Google forms to get inputs/feedback from faculties and students to get difficulties in online lab conduction and how we can make the best use of virtual labs online to conduct the lab experiment online mode. We designed and created the virtual laboratory for the Computer Networks Lab course with various learning materials, including theory, simulation videos, pre-test & post-test, and the procedure to conduct the lab experiment, which benefited the students. The implemented virtual lab found more effective. We found the significant impact on the result of CN Lab after using the customized virtual lab for CN Lab course.

***Keywords*—** Virtual Lab, Learning Style, Effective online engagement, Student Learning, Online Monitoring, Assessment, Time Management, Cross platform, CodeIgniter, Responsive web page, Wireshark, Cisco Packet tracer

I. INTRODUCTION

The COVID-19 epidemic showed the shortcomings of conventional teaching strategies. By taking into account the skill set that must be instilled in the students, teaching in the online form has grown to be a significant problem for faculty. Due to their inability to attend both the theory lectures and the labs, the students were severely impacted. Manca, F., & Meluzzi, F. (2020), aacademic institutions made the decision to switch the teaching and learning process from offline the online form. The online lectures were delivered using different active teaching-learning methods and tools through the platforms like MS Teams, Zoom, etc., but it was a big challenge to conduct the lab session for the students in online mode.

Due to the COVID-19 epidemic, most classroom instructions were transferred off-campus, and students were allowed to complete their coursework from home via the internet. To retain their high academic standards, educational institutions took the necessary steps to shift their instruction, particularly laboratory courses, into an online or blended mode of delivery. In higher education, laboratory experimentation was crucial. That made the laboratory instruction conduction challenging across the higher education environment. Students had not received face-to-face instruction, and access to lab resources had been restricted or nearly impossible. Due to their inability to use the lab's facilities or actually conduct the experiments there, students suffered significantly. There were several issues, such as poor internet connection, low bandwidth, student engagement, lack of ICT resources etc., while conducting the laboratory classes online. As there was not a convenient platform accessible, effective delivery was impossible. The current online teaching modality was unable to monitor, record, and evaluate students' performance. Answering questions about lab experiments in online mode proved challenging. As there was not a convenient platform accessible, effective delivery was impossible. The current online teaching modality was unable to monitor, record, and evaluate students' performance. Answering questions about lab experiments in online mode proved challenging. These situations lacked the ability to conduct lab experiments using concepts, simulations, prerequisites, demo experiments, pre-post evaluations, and the ability to determine whether or not the lab experiments were carried out by students.

The success of the science learning process was supported by a number of favorable effects of the growth of digital-era technology. Information technology could be utilized in place of interactive laboratories in schools to meet their demands. A virtual laboratory was one effect of the development of the digital era that could be applied to the field of education. R. Md Zahidur (2014), the virtual lab offered fun lab processing and simulation features, tool simplicity, and more precise results.

A virtual lab was a teaching tool that enabled more effective experimentation, interactive virtual environments, and direct experimental visualization.

According to Scheckler, R. K. (2003) & Tatli, Z., & Ayas, A. (2013), students could individually expand their understanding by repeating the incorrect experiment as part of the virtual lab exercise.

In actuality, virtual labs offered a number of advantages in reaching the desired learning objectives. The utilization of virtual laboratories solved some of the issues that arise in

conventional laboratories and helped students achieve their learning objectives as per Tüysüz, C. (2010).

Virtual laboratories offered practical learning possibilities at a lower cost and with the greater security said Moral Pérez, M. E. D., & Villalustre Martínez, L. The virtual laboratory used computerized models, simulations, and several other instructional tools to replace traditional lab operations as per Scheckler, R. K. (2003).

II. LITERATURE REVIEW

Moral Pérez, M. E. D., et al., the right design of learning-promoting activities, the range of teaching resources employed, content interactivity, etc., were among the positive attributes cited by the professors and students who participated in the virtual education processes. The primary flaws were the absence of practical recommendations that effectively foster group learning through involvement and interaction among all students, as well as the absence of individualized remarks of support and encouragement regarding students' learning progress.

Many educational institutions all across the world switched to a distance learning method known as "Emergency Remote Teaching" as a result of the COVID-19 outbreak. Many issues had arisen in educational settings as a result of the pressing transition process. The topic of measuring and evaluation was one of the issues. Numerous institutions had implemented various online assessment systems to undertake measurements and assessments online in conjunction with the epidemic, and researchers have studied these online assessment systems. This study examined the key aspects of online assessment systems and their trends throughout the Emergency Remote Teaching period with an emphasis on their features. The most well-known online assessment systems had been identified for this purpose by methodically examining academic papers released in 2020, and the following research questions have been sought: platforms they supported, security features they offered, and common features they had, to name a few. In order to select and/or create an online assessment system for use in online measurement and evaluation, practitioners, decision-makers, researchers, and system developers were expected to use trends in the characteristics of online assessment systems as a reference as per Topuz, A. C., et al. (2022).

This paper presented the results of an extensive (n = 987) exploratory factor analysis study that took into account several ideas that were shown to be crucial success criteria for online learning from the viewpoint of the students in the literature. It then assessed their hierarchical relevance. Seven variables were shown to be significant and reliable: Basic Online Modality, Instructional Support, Teaching Presence, Cognitive Presence, Online Social Comfort, Online Interactive Modality, and Social Presence. When students thought about convenience and schedule, regression analysis showed that the three most important determinants for enrolment in future sessions were Online Social Comfort, Cognitive Presence, and Basic Online Modality. A minimum of Basic Online Modality, Teaching Presence, Cognitive Presence, Online Social Comfort, and Social Presence were desired by students who voluntarily enrolled in or embraced online courses. Students regarded online interactive modalities and instructional support more highly since they preferred face-to-face classes and demanded a comparable experience. There were suggestions for future study, policy, and course design for online learning as per Montgomery, V. W., et al. (2020).

According to Kwon, S., et al. (2021), the ways of teaching and learning had changed to technology-integrated modes like blended and flipped learning, which was more than simply moving from face-to-face to online. This had not happened because of an unanticipated global pandemic, but rather due to the emergence of educational technology and pedagogical innovation. However, many institutions that still used the traditional residential teaching methods or learning management systems (LMS) as supplemental tools were finding it difficult to adapt to the new setting. In that work, it was contended that for authentic online teaching and learning, the identities of three components—instructor, learner, and LMS—must alter.

According DeCoito, I., & Estaiteyeh, M. (2022), Global school closures due to the COVID-19 epidemic forced a rapid switch to online/distance learning or emergency remote learning (ERT). Curriculum, pedagogy, and student results had been impacted across a range of disciplines as a result of teachers and students switching from face-to-face interaction to online settings. The authors of this study concentrated on Canadian science/STEM teachers' experiences with online teaching and learning during the epidemic. 75 Science/STEM teachers teaching grades 1–12 in a Canadian province were given an online questionnaire to complete between May and July 2020, which was used to gather both qualitative and quantitative data. The authors investigated i) curriculum preparation and implementation in online environments, ii) assessment techniques and their efficacy, and iii) student outcomes as perceived by the teachers using the TPACK framework and self-efficacy theory. The findings showed that teachers employed a variety of platforms, and their decision to use a particular platform was mostly influenced by its usability, interactive-ness, or administrative decision-making. Despite teachers planning online courses during ERT, TPACK framework and self-efficacy deficiencies were found, which had an impact on teachers' curriculum preparation, pedagogical techniques, and assessment procedures. Pre-recorded videos and self-directed learning, in which teachers gave pupils specified tasks to complete on their own, were two common teaching strategies. Teachers placed a higher priority on teaching curriculum objectives and topic content than on innovative student-centred pedagogical strategies. Teachers considered the used assessment methods to be unreliable and ineffective in general. Teachers also mentioned having trouble addressing students' needs and skills, which made it challenging to deliver inclusive and equitable online instruction.

In terms of student involvement and outcomes, online teaching was generally perceived negatively by teachers.

Irwanto, I. (2018), it took a solution to address educational issues because they were so complex, especially in the twenty-first century. Teachers must be able to create technology-based learning materials that were related to the school curriculum in addition to using 21st century technology to communicate knowledge. The digital era's revolution of technology had a wide range of positive consequences on the way people learn science. Virtual laboratories were a significant advance in the digital age that can be used in science teaching. A virtual laboratory was a form of media that enabled practical

experimentation, interactive virtual environments, direct experimental visualizations, more effective experimentation, and the ability to forego the purchase of experimental equipment. Without attending class, learning could also be done anytime and anywhere by using a virtual laboratory. This study aimed to ascertain how students' thinking abilities, skills, and attitudes toward science were affected by a virtual laboratory-based learning paradigm. The qualitative descriptive research method was applied in this study. The data analysis methods employed make reference to the Huberman, A. M., & Miles, M. B. (1994) data analysis model, which has the following components: reduce data, show data, draw conclusions, and verify. This report evaluated 23 studies on students' scientific attitudes, reasoning capacities, and skills in relation to virtual laboratories. The findings demonstrated that the virtual lab could improve students' problem-solving abilities, critical thinking, creativity, conceptual comprehension, science process skills, lab skills, motivation, interest, and learning outcomes.

Therefore, in order to enhance the effectiveness of instruction and student learning outcomes, educators must use virtual laboratories.

The purpose of the study was to evaluate how well the e-learning platform's virtual lab functions. The purpose of the study was to evaluate how a virtual lab had improved students' conceptual understanding and their ability to acquire new material. The study also looked to see if the virtual lab encouraged more independent learning on the part of the pupils. The research techniques used were expert interviews and surveys. The study's findings indicated that the majority of students were aware of virtual laboratories and highly valued them. For learning purposes, students chose computer-assisted tools over textbooks. According to the study, schools should be implemented virtual labs to encourage pupils to think creatively as per Rajendran, L., et al. (2010).

The spread of the new coronavirus was disrupting education at a significant number of colleges around the world, either completely or partially (COVID-19). As a result, more and more colleges made the necessary changes to their curriculum, including turning laboratory workshops into online or blended learning environments. Universities must continue to uphold their high academic standards and offered a high-quality student experience in order to deliver the learning outcomes connected with each degree program, regardless of the actions that were taken. This posed a problem for the higher education sector as a whole, forced academics to use other methods for delivering laboratory instruction and remote teaching. In light of the COVID-19 epidemic, this research examined several strategies used by universities to deliver classroom instruction and laboratory procedures online while also taking into account potential negative effects on the educational experience of students. Based on published materials, including books, this evaluation was largely concerned with the domains of engineering, science, and technology. It also examined institutional and national policy documents as well as web-based offerings from a few selected colleges as per Gamage, K. A., et al. (2020).

According to Aljuhani, K., et.al (2018), by allowing students to gain practical skills through experiments and by offering them the chance to have a deeper grasp of the subject matter, laboratory activities were significantly aiding scientific learning sectors.

Virtual laboratory activities could save money, time, and effort despite the fact that physical laboratory activities were costly and time-consuming. The Virtual Science Lab (VSL) was a web-based platform created to enhance teaching methods by providing middle school pupils in Saudi Arabia with a secure and engaging lab setting. During user trials, VSL was discovered to be a stimulating, practical, and fun learning environment. It enabled users to carry out their own tests and repeated them repeatedly if necessary.

According to Gamage, S. H., et al. (2022), digital resources can be created, managed, and distributed using a variety of learning management systems (LMSs) for both in-person and online instruction. Through the LMS, students were given access to individualised e-learning possibilities that interacted with conventional teaching techniques and digital learning resources. E-learning has expanded significantly after the COVID-19 pandemic, which curtailed face-to-face teaching chances for many educational institutions worldwide in 2020. Educational institutions have been compelled to adapt since the majority of traditional modalities of education, evaluation, research, and scientific discourse have been hindered by restrictions on physical interaction.

According to Kwon, S., et al. (2021), the identity of the instructor in online learning and teaching was changed from "a didactic purveyor of information" to "an interactive educator" (Park, 2011, p. 179). Heuer and King (2004) asserted in their empirical study on instructor identity that instructors hold multiple identities, including those of a leader who served as an example of active participation, a coach who encouraged learners to form teams, a facilitator who was responsible for the success and engagement of learners, and a communicator who promoted communication and collaboration. In a related study, Bonk et al. (2018) concluded that instructors should be involved in a pedagogical domain for interactive teaching and learning tactics such giving feedback, fostering discussion, synthesising student comments, and connecting to outside resources and experts.

III. Problem Description and Problem Analysis

The COVID-19 pandemic had brought uncertainty to education, with most teaching moved off campus and students learning online at home.

The educational institution had taken the steps necessary to transform their teaching, including laboratory courses into an online or blended mode of delivery to maintain their high academic standards. Laboratory experimentation plays an essential role in higher education. This had created a challenge across the higher education landscape, to achieve effective laboratory delivery. As a result, students had not been receiving face-to-face teaching, and access to laboratory facilities has been limited or nearly impossible. The students are affected significantly as they are not able to use the laboratory facilities to experiment.

The major problems while conducting laboratory courses in online mode were as follows:

- Students affected significantly as they were unable to use the laboratory and perform the experiments.
- Effective delivery was not possible due to the lack of

available convenient platforms.

- With the existing online teaching mode, teachers were not able to monitor, record, and assess the performance of students effectively.
- It was difficult to address the student's queries related to a lab experiment in the online mode.
- Teacher was not able to recognize whether lab experiments were performed by students themselves.
- Unavailability of a single platform for conducting lab experiments which include concepts, simulation, pre-requisite, demo experiments, and pre-post evaluations.

Problem Analysis:

The problem analysis was used to diagnose the problem that occurred. Data collection and the 5W-1H principle were used to analyze the problem.

Data Collection:

During the COVID-19 pandemic, many course instructors were faced with the challenge of adapting or replacing the in-person laboratory components of their courses to suit the remote learning environment. To get what exactly was the problem; the data was collected from the faculties about the difficulty in conducting the online lab courses.

Faculty Survey feedback questionnaire were as below:

1) Do you feel any difficulty while conducting lab courses in online mode?
2) Do you experience any difficulty while demonstrating experiments in online mode?
3) Do you face technical issues in online Lab conduction?
4) Could you be able to conduct the online labs of core courses like Operating Systems, Database Management Systems, Computer Networks, Digital Electronics, etc. effectively?
5) Are you able to conduct online labs effectively for programming courses like C, C++, Python, Java, R Programming, Mobile Application development, and .Net?
6) Are you able to manage the lab time effectively in online mode?
7) Are you able to monitor the student's engagement effectively in online lab conduction?
8) Are you able to evaluate students' performance in online labs effectively?
9) Is there any online platform available for the conduction of laboratory courses you teach?

The survey was taken from all faculties of the Information Technology department through Google Forms.

The observations were mentioned as follows:

1. The instructors faced difficulty while conducting lab courses in online mode.
2. More challenges were in the conduction of online labs of core courses like Operating System, Database Management System, Computer Networks, Digital Electronics, etc.
3. The instructors were not able to manage time, not able to monitor the engagement of students during lab, and were not able to assess the performance of the students effectively.

Based on the above observations it was understood that the online Lab conduction leaded to **'Ineffective delivery of Laboratory course'.**

5W-1H Principle:

5W-1H Principle is most commonly used tool for analysis of the problem. 5W-1H Principle was applied to address the following questions:

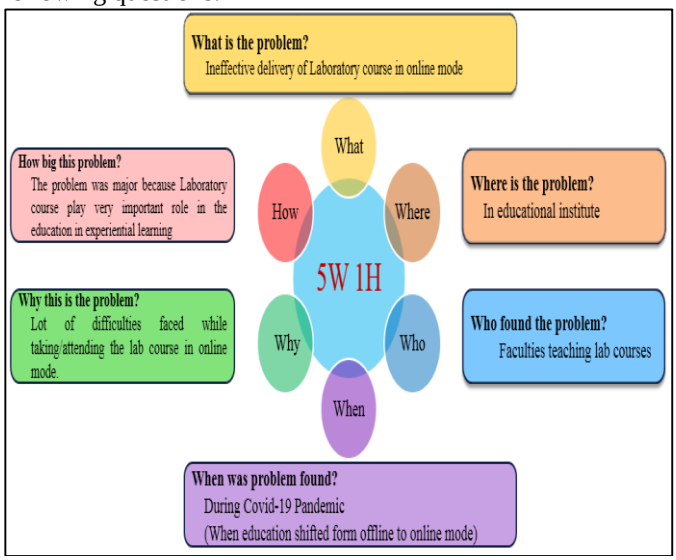

Figure 1: Problem Analysis using the 5w-1H principle

"Ineffective delivery of Laboratory course in online mode" this problem was faced by faculties in the educational institutions during the COVID19 pandemic because the faculty faced a lot of challenges and issues for the same. As the laboratory impacted more on technical education, there was a need to resolve the issue.

Identification of the causes:

The Fishbone / Ishikawa diagram was used to identify the cause of the problem. The reasons for the Ineffective delivery of Laboratory courses in online mode were expressed through the cause-and-effect diagram in figure 2.

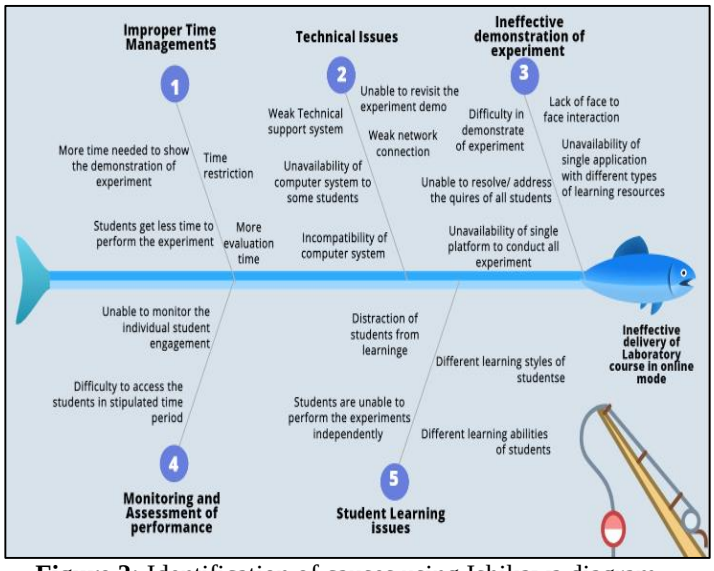

Figure 2: Identification of causes using Ishikawa diagram

The major causes like improper time management, technical issues, ineffective demonstration of experiments, different learning styles and improper monitoring and assessment of student lead towards the effect i.e., 'Ineffective delivery of Laboratory course in online mode'.

To find the root cause, the WHY-WHY analysis was applied to the overall causes identified during the problem analysis. It was found that the following were the root causes for the Ineffective delivery of lab courses in online mode.

Table 1: WHY-WHY analysis

Why1: Why is ineffective delivery of Laboratory courses in online mode?	Ans1: Unable to demonstrate the experiment properly.
Why2: Why is it not possible to demonstrate the experiment properly?	Ans2: There were technical and other issues while conducting of a lab in online mode.
Why3: Why technical and other issues are there?	Ans3: Unavailability of a single platform/application to conduct all experiments with different kinds of learning resources to address the different learning styles.

The Why-Why analysis leaded towards the root cause of the problem. The root cause we found is the "**Unavailability of a single platform/application to conduct all experiments with different kinds of learning resources**"

The preventive solution for the analyzed problem is the "**Development of Virtual Laboratory**".

The objectives of the work were as follows:

- To identify the lab course to design the Virtual Laboratory by taking surveys from faculties and students.
- To design and develop the customized web based virtual lab application for identified lab course.
- To use the simulations and modern tools for demonstrations as a part in virtual lab.
- To provide the single platform/application available for the students for online lab conduction with variety of resources, simulation, demonstration, pre-post tests etc.

IV. Design and Development of Solution

According to S. O'Brien (2021), laboratory courses were essential in engineering education but were exceedingly challenging to implement in online mode. Therefore, a system was required for conducting the laboratory at a distance. There were a lot of problems faced by teachers and students in the conduction of laboratory courses in online mode.

The best solution was that the traditional laboratories could be replaced by virtual laboratories, which allowed to do the experiments in a remote place without an instructor.

When students were not physically on campus, virtual laboratories, remote control labs, or video-based labs were good options, as per Zhai, G. et al. (2012).

Usman, M., et al. (2021), mentioned that modern technological advancements enabled distant learning using tools like virtual labs.

Ngoyi, L. (2013), asserted that a virtual teaching and learning environment was designed to improve students' laboratory skills through the use of a virtual lab. In contrast to the limitations of real labs, a virtual lab enabled the learner to conduct a variety of experiments without any restrictions on location or time.

The virtual lab allowed to perform the experiment in a remote place. The students could perform the same experiment many times without any constraint of time and place with the latest technology and learning feasibility.

The faculty survey was conducted through Google forms to collect information about the difficulties of conducting lab in online mode. According to the survey, there were many difficulties in demonstrating the experiment, time management, and monitoring the engagement of students' assessments. Also, there were a lot of challenges in conducting core laboratory subjects.

To tackle the issue of difficulty in conducting lab online, there was a need to develop a virtual laboratory as a solution.

Figure 3 showed two approaches that were used solve the problem.

- To make use of available virtual labs for programming courses.
- To design and develop the customized virtual lab as per syllabus for core courses.

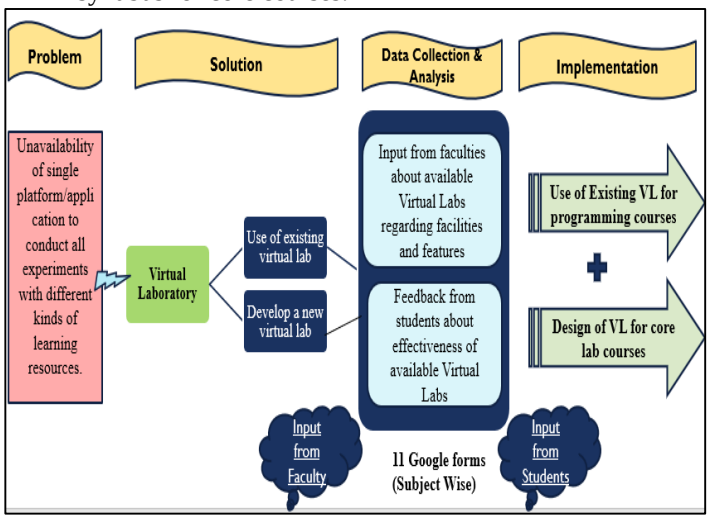

Figure 3: Development of Solution

The data was collected from the faculties and students to know about which existing virtual labs can be used, how effective and useful these labs were according to the syllabus and which labs needed to design as a solution to the problem.

Questionnaire for survey feedback from students:

1. Does this Virtual Lab Platform cover your course's lab experiments as per the syllabus?
2. Is the content of the experiment informative?
3. Is Simulation/Animation/Video helpful for a better understanding of the topic and helps in conducting the experiment?
4. Are you able to perform the program(s) as per the experiments in the virtual lab?
5. Whether the GUI of this Virtual Lab Platform is user-friendly?
6. Give the overall rating for this virtual lab?

Based on the above questionnaire, the feedbacks were collected from S.Y. B. Tech, T, Y. B Tech and Final Year B. Tech Classes.

Table 2: Input /Feedback collection from Students

Course Name	No. of

	Responses collected
Class : SY(CSIT)	
Computer Networks Lab	63
Data Structures and Algorithms Lab	63
Digital Electronics Lab	63
Object Oriented Design & Programming Lab	60
Class : TY(CSIT)	
JAVA Programming Lab	119
Database Management System Lab	112
Operating System Lab	111
Mobile Application Development Lab	32
Front End Web Technology Lab	64
R Programming Lab	33

Questionnaire for survey feedback from Faculties:

1) Mention the name of the lab Course.
2) Is any virtual laboratory available for your lab course?
3) How much of the lab course content was covered in the available virtual laboratory?
4) Is enough learning material given in the available virtual laboratory?
5) Is any simulation of the concept given in the available virtual laboratory?
6) Are any prerequisite checks (in the form of pre-test) existing available in the virtual laboratory?
7) Are any Post checks (in the form of post-test) existing in available in the virtual laboratory?
8) Is any online compiler given for coding to experiment?
9) Is this Virtual laboratory useful for a student for your course?

From the analysis of the survey taken, it was observed that many of the available virtual labs were very useful and informative for the programming course. But there was a need to design the virtual laboratory for core courses like Computer Networks, Database Engineering, Operating System, Digital Electronic, etc.

This paper contributed the experience of the design and development of the virtual laboratory for the Computer Networks Laboratory Course in a customized way as per the prescribed syllabus for that course.

Development of Virtual laboratory for Computer Networks Laboratory Course:

As per conducted surveys, it was found that there were a lot of virtual labs available already for programming courses as compared to core courses. Out of different core courses, the Computer Networks Laboratory course from S. Y. B Tech class was selected for the creation of a customized web-based application as a virtual lab.

Hardware and Software requirements for web application:

- **Hardware Requirement:**
  - Operating System: Windows Server 2016 Standard 64-bit
  - Processor: Intel(R) Core (TM) i5-2400 CPU @ 3.10GHz (4 CPUs), ~3.1GHz
  - Memory: 8192MB RAM
- **Software Requirement:**
  - Language used: Front end HTML, CSS and JavaScript.
  - Back end: PHP and MySQL.
  - Web Server: XAMPP.
- **Framework:**
  - CodeIgniter.

Designing of the Experiment in Computer Networks Lab:

For the Computer Network Lab course, 11 experiments were designed for the concepts like Networking components, Network topologies, Network connectivity testing utilities, framing methods, Error detection method, Error correction method, Routing algorithms, IP addressing, TCP and UDP socket programming and Network packet capturing and analysis. Each of these experiments were consisted of different sections, as shown in Table 3.

Table 3: Sections in each experiment of VLlab of CN.

Section in Designed VL	Description
Title	Give the Title of Experiment
Aim	Describe the aim of experiment
Objectives	List the Objective of implementation
Relevance	Describe the use of experiment
Pre-Test	Pre-Test before going perform the experiment
Procedure	Procedure to perform the experiment
Simulation video	Video to demonstrate how to perform experiment
Steps to perform in the lab	Steps to perform the experiment
Post-Test	Post-Test after performing the experiment
Conclusion	Conclusion of experiment conduction

The created web application consisted of the following modules:

Landing module: The http://172.22.34.79:2918/ritvlab/ URL is used to get the landing module (home page), as shown in figure 4.

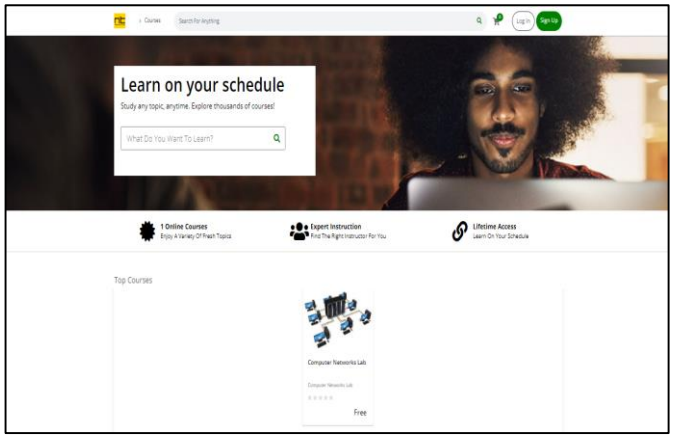

Figure 4: Landing Module of Web application

Signup and Login module: Signup is used for registration of users (Instructor and students) and login module is used by registered users by providing the username (Email_id) and password, as in figure 5.

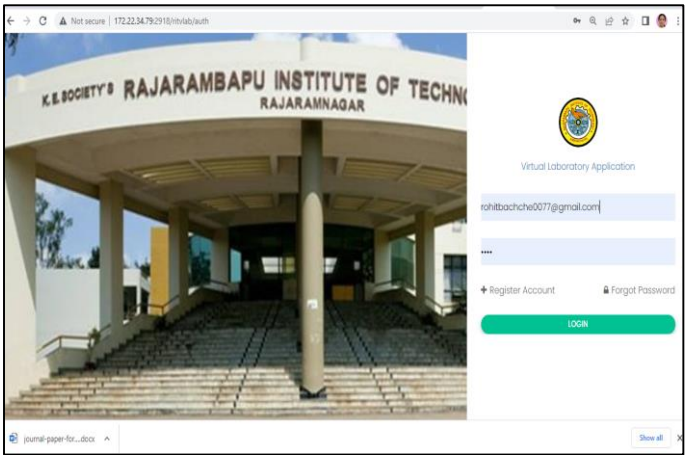

Figure 5: Sign-Up and Login Module

Admin Module: Admin module was used to manage the web application, including course and instructor management and student enrollment, as shown in Figure 6.

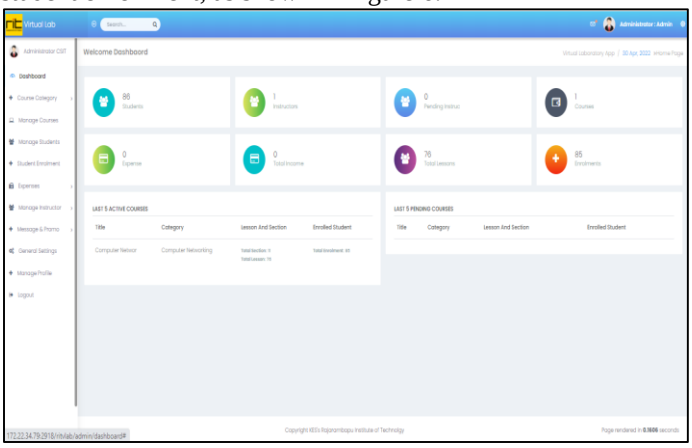

Figure 6: Admin Module

Instructor Module: Manage the course content. The instructor module is shown in Figure 7.

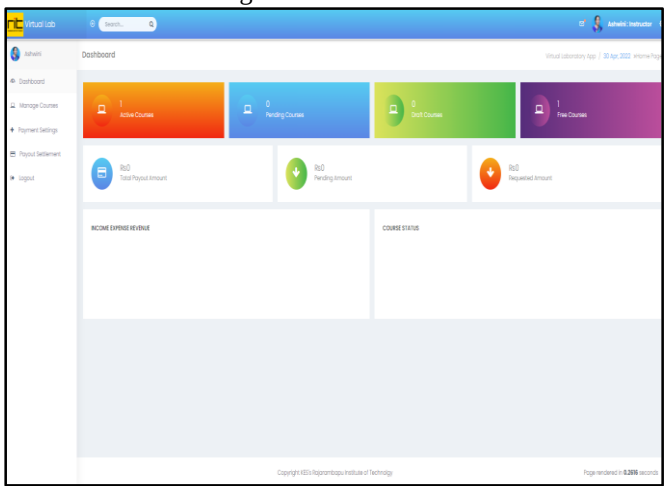

Figure 7: Instructor Module

User Module: The user module allowed users to log in and use the virtual lab course content. Figure 8 shows the user module. The user can start the particular lab course.

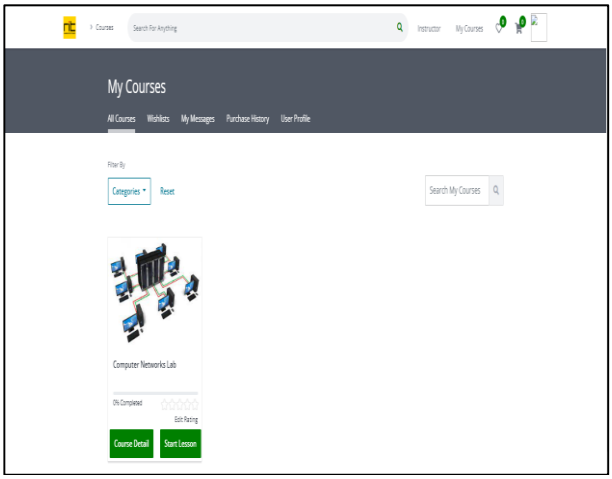

Figure 8: User Module (Home Page)

Each experiment of the lab course consisted of different sections like Title, Aim, Objectives, Relevance, Theory, Pre-Test, Procedure, Simulation Video, Take to Perform in Virtual Lab, Post-test, and Conclusion of the experiment. Users could click on any section to get the details and be able to perform experiment.

Figure 9 showed the theory section of the experiment, Figure 10 showed the quiz section of the experiment, and Figure 11 showed the simulation video of how to perform the experiment.

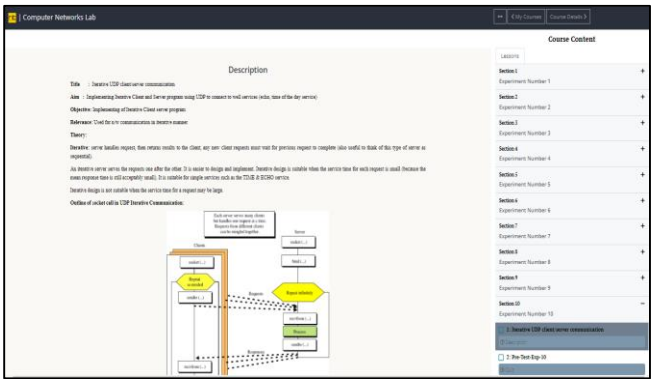

Figure 9: User Module (Experiment Page)

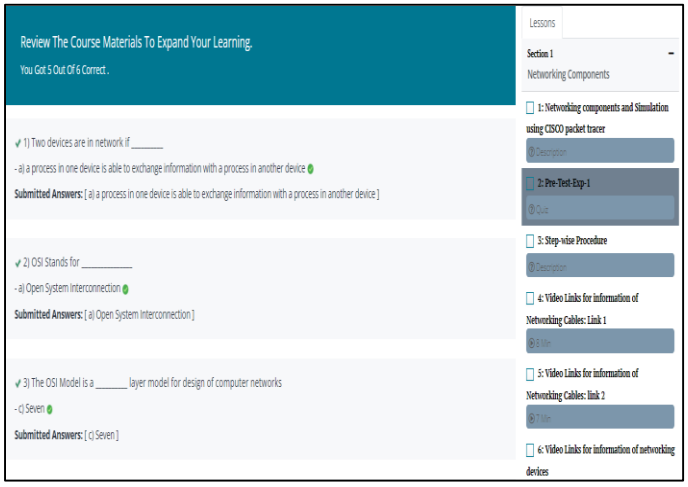

Figure 10: User Module (Quiz in Expt.)

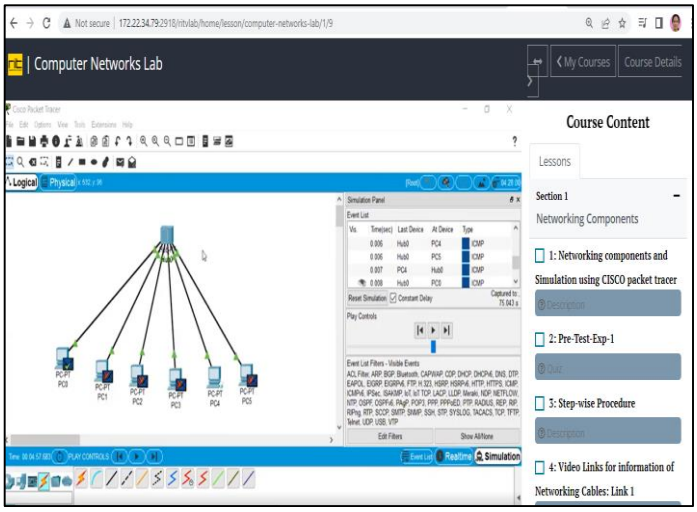

Figure 11: User Module (Simulation Video)

Trial implementation:

To test the performance of implemented VLab of CN the steps were taken as shown in Figure 12.

- ✓ **Deployment of CN Virtual lab**

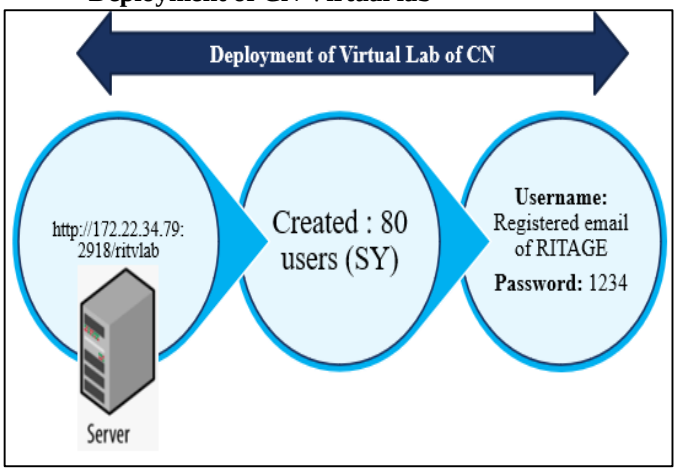

Figure 12: Deployment of VL

Created VL was deployed on a server in the intranet which can be accessible by URL "http://172.22.34.79:2918/ritvlab/". 80 users were created for testing and usage of the virtual lab.

- ✓ **Standardization of Solution:**

The developed web application was,

- ❖ Cross Platform Application
- ❖ Responsive Web Application
- ❖ Deployed on Server: http://172.22.34.79:2918/ritvlab
- ❖ Created: 80 users (SY)
  - o **Username:** Registered email of RITAGE
  - o **Default Password:** 1234

- ✓ **Demonstration of VL in the class**

The demonstration of how to use the virtual lab of the CN Lab course for Second Year students of the Academic Year (AY) 2021-22 was given in the classroom as shown in snap of Figure 13.

Figure 13: Demonstration in the class.

- ✓ **Use of Virtual lab by the students:**

78 Students of S. Y. B. Tech class used the created Virtual Lab of Computer Network Lab course for their lab experimentation. To analyze the solution, the feedback was taken from the students and tested their performance by analyzing the result of the CN lab course for AY 2020-21 and 2021-22, which was discussed in the result and discussion section of this paper.

V. RESULT AND DISCUSSION

The feedback regarding the implemented Virtual Laboratory of Computer Networks lab course was conducted through Google form.

Following was the questionnaire used for the feedback:

1) This Virtual Lab Platform covers lab experiments of the Computer Networks Lab course as per the syllabus.
2) The content of the experiment of Computer Networks Lab is informative.
3) Simulation/Animation/Video are helpful for better understanding the topic and helped for conducting an experiment in the Computer Networks Lab.
4) Are you able to perform the program(s) of the Computer Networks Lab as per the experiments in the virtual lab?
5) The GUI of this Virtual Lab Platform is user-friendly.
6) Is this virtual lab useful for you for a better understanding of the Computer Networks Lab course?
7) Your overall rating for this virtual lab of Computer Networks.
8) How do you rate this implemented Virtual lab of CN as compared with existing Virtual Labs of CN?
9) Do you recommend using such a virtual lab in the future?
10) Give your valuable suggestion for further improvement in the implemented Virtual Lab of Computer Networks.

Figure 14 showed the review of feedback collected from students.

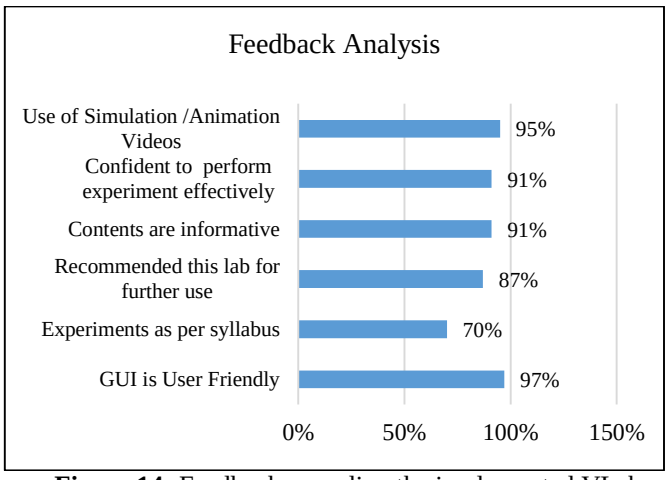

Figure 14: Feedback regarding the implemented VLab

Benefits of CN VLab to Students:

Figure 15 showed the benefits of VLab of the CN lab course.

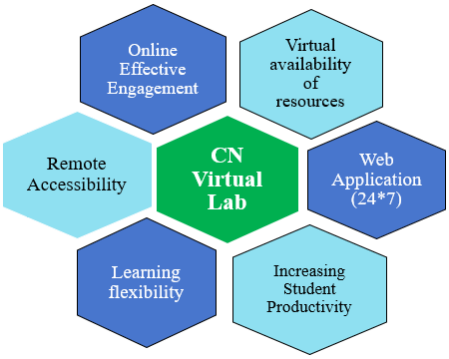

Figure 15: Benefits of VLab of CN Lab

There was a significant impact on the result of the CN lab course after using the customized virtual lab.

The result of the CN Lab course for AY 2020-21 and 2021-22 was compared together; and found significant improvement. Figure 16 showed the grade distribution chart and Figure 17 showed passing percentage of CN Lab course for AY 2020-21 and 2021-22.

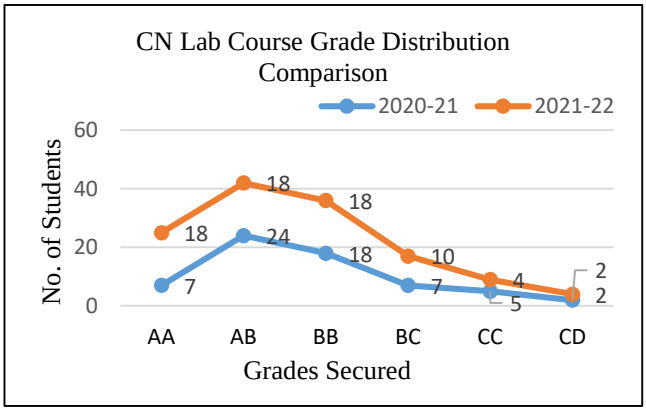

Figure 16: Grade Distribution in the result of CN Lab Course

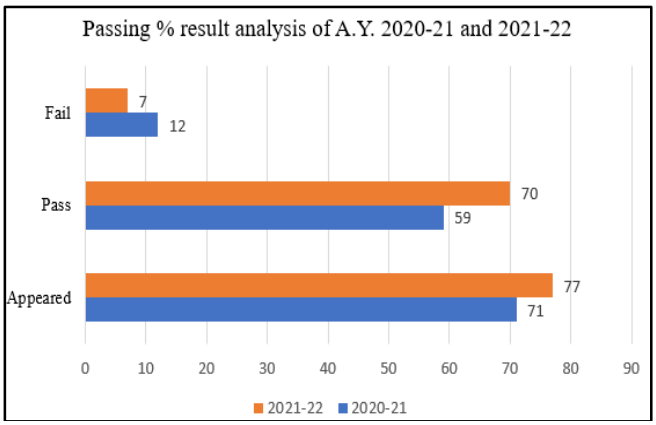

Figure 17: No. of Students Appeared, Passed and Failed

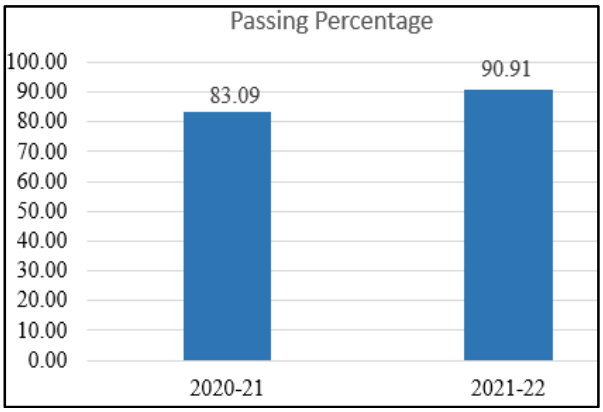

Figure 18: Passing percentage of CN Lab Result

Figure 18 shows the comparison of the passing percentage of AY 2020-21 and 2021-22. According to the result analysis of AY 2020-21 and 2021-22, it was acknowledged that the virtual lab was beneficial for students to improve their engagement in learning for the lab course in online mode.

Future work was to make available this Virtual Lab of CN on Internet with additional features like discussion forum, maintaining logs of students and adding third party support to compiler.

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VI. Conclusion

As per review feedback taken from faculties and students, it was found that there were lot of technical problems and other issues challenged during conduction of a core laboratory courses in online mode. The use of virtual laboratories was very effective solution for conduction of laboratory course in online mode. A lot of virtual laboratories were already available for programming courses, but there was a need of customized virtual laboratory for core courses.

Based on our need, a customized web based virtual lab was developed for Computer Networks (CN) lab course which was an effective solution to conduct the Computer Networks experiments with the help of simulation, demonstration, pre & post-tests. The simulation and experiments were designed with

different modern tools and techniques like CISCO packet tracer, Wireshark, Network Troubleshooting Utilities, Socket Programming and C Programming.

The designed virtual lab helped the students to perform the experiments more than once on single platform with the help of latest technologies and learning flexibility without any constraints of place or time. The virtual lab is also beneficial in blended learning mode to conduct the flipped labs even after the post covid. Use of the designed virtual lab course of CN created significant impact on the result of CN lab course in online mode. Our future work is to design the virtual labs for other core courses like Operating Systems, Database Management Systems, Digital Electronics etc.

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