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CEMCA

Evaluation Report of the Capacity Building Workshops on VIRTUAL LABS

Commonwealth Educational Media Centre for Asia, New Delhi

The Commonwealth Educational Media Centre for Asia (CEMCA) is an international organisation established by the Commonwealth of Learning (COL), Vancouver, Canada, to promote the meaningful, relevant and appropriate use of Information and Communication Technologies to serve the educational and training needs of Commonwealth member states of Asia. CEMCA was granted diplomatic privileges and immunities by the Government of India under Section 3 of the United Nations (privileges and immunities) Act, 1947.

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Table of Contents

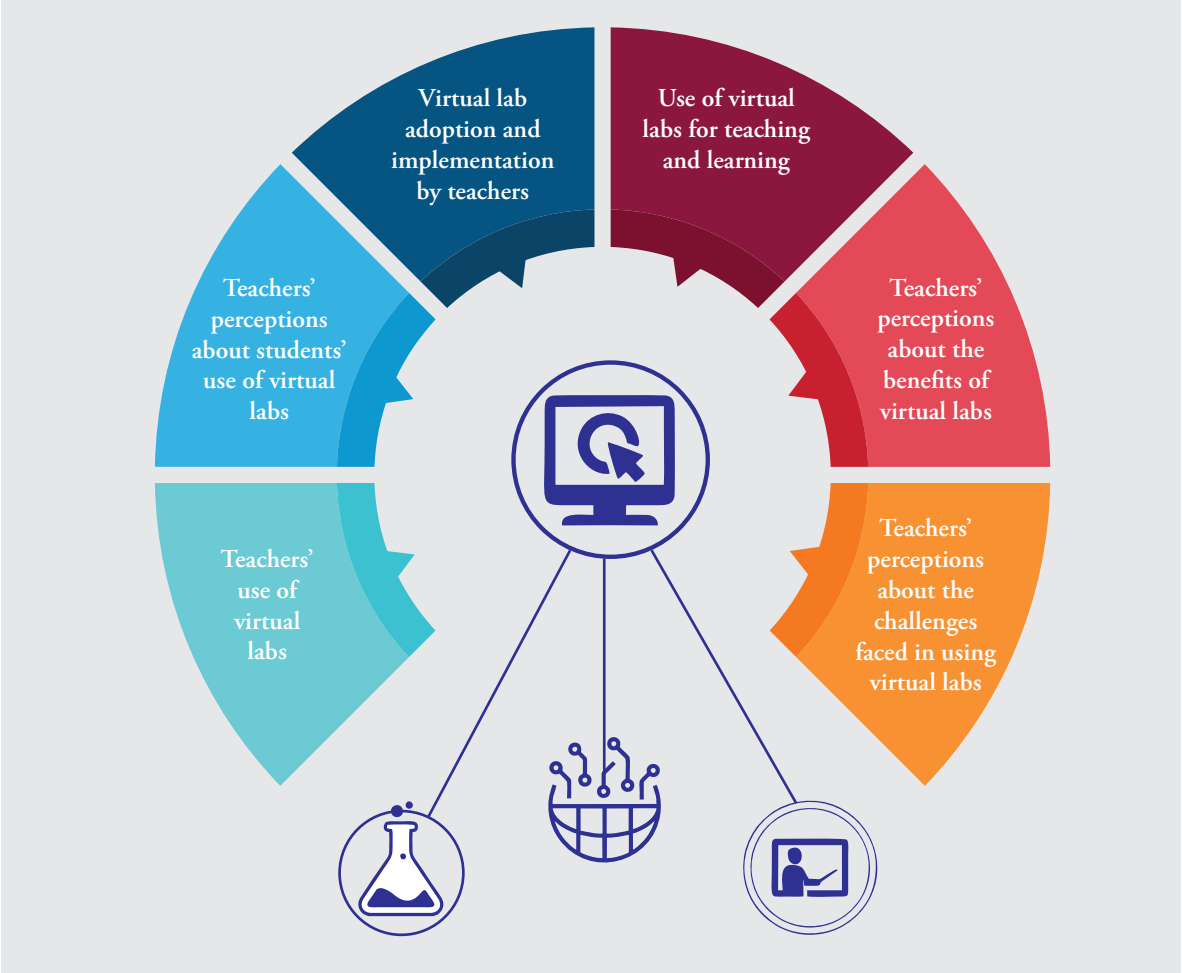
Table of Contents

Executive Summary

Virtual labs provide opportunities for continued flexible and distance learning through laboratory experiments. Taking cognizance of the need for improved access, use, and integration of virtual labs, the Commonwealth Educational Media Centre for Asia (CEMCA) facilitated five capacity building workshops on virtual labs. CEMCA's programmes on capacity building in virtual labs reached 468 teachers from open and formal universities and schools across India, Malaysia, the Maldives, and Bangladesh. These programmes, which were conducted with expertise support from the Amrita Vishwa Vidyapeetham, aimed to create awareness about virtual labs for internet-based experiments with a focus on enabling teachers and teacher educators to use virtual labs and integrate them effectively in their teaching practices.

This study evaluates the capacity building workshops on virtual labs organized by CEMCA. It presents an overview of virtual labs and CEMCA's capacity building initiatives on the use of these virtual labs.

The objectives of the study were, examining:



The study analysed participant feedback from an end-of-workshop evaluation and a follow-up evaluation. It presents various dimensions of the study such as teachers' use of virtual labs, teachers' perceptions about students' use of virtual labs, virtual lab adoption and implementation by teachers, use of virtual labs for teaching and learning, teachers' perceptions about the benefits of virtual labs, and teachers' perceptions about the challenges faced in using virtual labs. The report also includes suggestions for promoting the use of virtual labs made by the respondents. The study used a mixed methods approach combining quantitative methods with a qualitative analysis of the interview feedback.

The main findings of the study are:

End-of-workshop Survey

An online survey was conducted at the end of each virtual lab workshop to obtain feedback from the participants about the workshop and the perceived effectiveness of virtual labs. The participants were requested to fill up the post-workshop feedback form designed using Google Form. The feedback link was shared via WhatsApp groups and the Zoom chat box at the end of the session. A total of 366 responses were received from 468 participants. Of the respondents, 53.27 per cent were male and 46.73 per cent were female.

i. Most of the participants rated the overall quality of the workshops as 5 (42.90 per cent) or 4 (47.60 per cent) on a scale of 1-5 (where 1 represented poor and 5 represented excellent).

ii. Most of the participants (76 per cent-85 per cent) rated the virtual labs as excellent or very good in terms of quality of content, lab procedures, simulator, and theory description.

iii. 90 per cent of the participants reported that they were well-informed about the objectives of the workshops, found the content relevant, and that the workshops were designed as per their expectations.

As part of the workshop feedback, participants were encouraged to share their suggestions for modifying and improving the workshops in the future. The participants shared the following suggestions:

- Many of the participants **(56.45 per cent)** requested more training sessions for each discipline.
- **165 (45.12 per cent)** of the participants reported that they required more time to practice in virtual labs.
- **141 (38.66 per cent)** of the participants suggested including more experiments based on their syllabus.
- **27 per cent** of the participants suggested that subject area topics and simulations could be provided through apps.
- **24 per cent** of the participants, primarily from the Maldives, suggested that online labs for primary grades should also be included.
- **61** of the participants **(16.78 per cent)** expressed the need for more activities on how to use virtual labs.

Follow-up Evaluation

Data was collected with the help of two tools designed for the study - a survey questionnaire and an interview schedule. The survey questionnaire was designed to capture aspects such as teachers' use of virtual labs, teachers' perceptions about students' use of virtual labs, virtual lab adoption and

implementation by teachers, use of virtual labs for teaching and learning, teachers' perceptions about the benefits of virtual labs, and teachers' perceptions about the challenges faced in using virtual labs.

116 teachers from four countries - India, Bangladesh, Malaysia, and the Maldives - submitted their responses for the online survey questionnaire which was distributed to 366 participants (56.9 per cent male and 43.1 per cent female).

i. 86.21 per cent of the respondents strongly agreed/agreed that the training workshops had enhanced their awareness about virtual labs with 79.32 per cent reporting a positive change in their experience and insights about virtual labs after participating in the training workshops on virtual labs.

ii. 87.75 per cent of the respondents reported that they had used virtual labs primarily from the Amrita platforms for virtual and online labs. 56.03 per cent of the respondents had used 1-10 virtual lab experiments; 34.48 per cent had used 11-20 virtual lab experiments, while 9.49 per cent had used 21-30 virtual lab experiments.

iii. Respondents were in strong agreement about the benefits of virtual labs, particularly as a valuable instructional tool (mean score=4.26), which enabled teachers to explore different teaching methods (mean score=4.28). 84.48 per cent of the respondents strongly agreed/agreed that virtual labs can help improve students' understanding of critical concepts and ideas.

iv. The study's findings indicate that different features of virtual labs were incorporated in teaching and learning. 74.12 per cent of the respondents reported that they had used virtual lab simulations for their teaching; while 75.84 per cent reported that they had used animations from the virtual labs for teaching experiments. The lowest percentage of responses (62.92) was for the use of assignments based on virtual labs for assessing students.

v. Respondents strongly agreed/agreed that there was a positive overall effect of adopting virtual labs in their teaching (mean score = 3.96).

vi. 66.37 per cent of the respondents strongly agreed/agreed that students had access to the devices and internet connectivity needed for virtual labs.

vii. Challenges in the use of virtual labs which were perceived as relatively more important include 'cannot find existing virtual labs on topics of my interest' and 'limited training and capacity building opportunities in virtual labs.'

viii. Most of the respondents (75 per cent) suggested that more training opportunities on virtual labs should be provided for teachers to promote the use of virtual labs.

ix. The study's findings show no statistically significant difference in perceptions about virtual labs with respect to age, gender, or years of teaching experience of the respondents.

x. A semi-structured interview was conducted to get insights into teachers' knowledge and perceptions about virtual labs. The interview schedule was designed to enhance an understanding of the responses received from the survey. Three experienced science teachers were interviewed for this. The interviewees appreciated CEMCA's role in supporting their institutions by organizing online workshops on virtual labs.

The results of this study show that the participants were positively inclined towards the use, adoption, and implementation of virtual labs. The findings highlight the role of virtual labs in providing quality opportunities for laboratory-based education.

Introduction

Laboratory experiments are an integral component of science and engineering education. However, access to lab equipment is often limited due to geographical distances and resource constraints. Virtual or online labs provide an alternative to physical hands-on labs where such labs are not present or they augment existing access to experiments. Further, virtual labs, as innovative interactive multimedia platforms for online and blended learning, can enhance the teaching and learning experience and outcomes. There is, therefore, an urgent need for effective deployment, use, and integration of virtual labs in the curricula. Recognizing this need, the Commonwealth Educational Media Centre for Asia (CEMCA) organized five awareness and capacity building workshops on virtual labs for teachers in Commonwealth Asia between 2020 and 2022.

Overview of Virtual Labs

Virtual labs are innovative, immersive e-learning environments that provide a media-rich, interactive user interface that teachers can use for supplementing the curriculum (Diwakar et al., 2016; Liu et al., 2015). These labs are located on an open webpage that can be accessed by anyone through a web browser on any internet-connected computer anywhere in the world. A variety of laboratory experiments can be conducted virtually using animations, simulations, or remotely triggered hardware. Laboratory experiments are modelled very close to real-life experiments and when used as a learning tool these virtual labs allow students to learn the material more efficiently and can make practical experiments easier.

The Government of India's Initiatives for Virtual Labs

The Virtual Labs Project is an initiative of the Ministry of Education, Government of India under the National Mission on Education through Information and Communications Technology (NME-ICT). It provides an opportunity for all students to use virtual labs free of cost. The aim is providing high quality remote laboratory access in science and engineering disciplines to students and teachers for undergraduate (BSc, BTech, and BE) and post-graduate (MSc, MTech, and ME) levels. Virtual labs include experiments in physical sciences, biological sciences, chemical sciences, computer science and electronics, and mechanical engineering. Virtual labs have been developed by a consortia of 12 institutes including the Amrita Vishwa Vidyapeetham, IIT Delhi, IIT Bombay, IIT Kanpur, IIT Kharagpur, IIT Madras, IIT Roorkee, IIT Guwahati, IIIT Hyderabad, Dayalbagh Educational Institute, NIT Surathkal, and the College of Engineering, Pune.

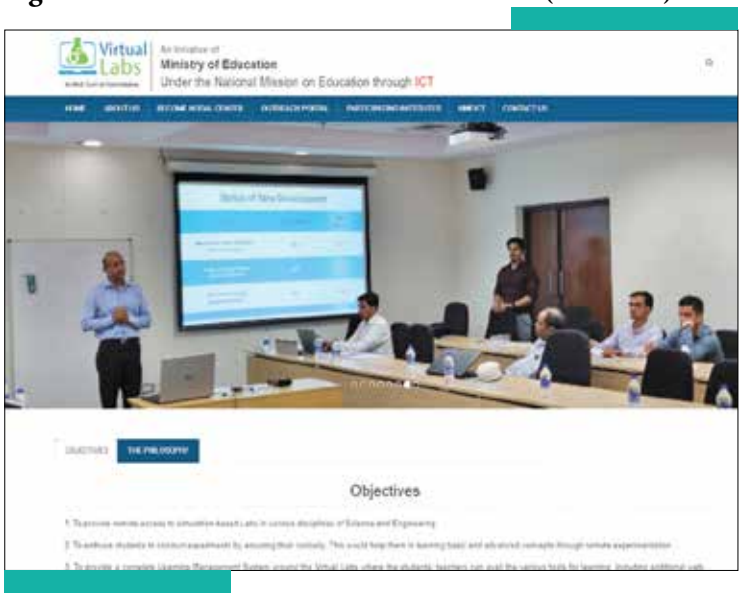
The academic disciplines for which virtual labs are available include:

- Electronics & Communications
- Computer Science & Engineering
- Electrical Engineering
- Mechanical Engineering
- Chemical Engineering
- Biotechnology Engineering
- Civil Engineering
- Physical Sciences
- Chemical Sciences

VALUE @ Amrita

In response to the Ministry of Education's (MoE) National Mission on Education through the Information and Communication Technology (NME-ICT) initiative, the Virtual Amrita Laboratories Universalizing Education (VALUE @ Amrita) Virtual Labs Project was initiated to provide laboratory-learning experience to college and university students across India who may not have access to adequate laboratory facilities or equipment. The Virtual Labs project provides virtual laboratory experiments that directly support the All-India Council for Technical Education (AICTE) and the University Grants Commission's (UGC) model curricula for engineering and science undergraduate and post-graduate programmes.

Figure 1: Screenshot of the Virtual Lab website (vlab.co.in)



Each virtual lab has several experiments. Virtual labs do not require any additional infrastructure for conducting experiments at user premises. Only one computer terminal with broadband internet connectivity is needed for performing the experiments remotely. All these virtual labs and associated virtual lab experiments can be accessed from the Virtual Lab website https://www.vlab.co.in/(Figure 1) or from the Amrita University Virtual Lab website http://vlab.amrita.edu/(Figure 2).

Figure 2: Screenshot of the Amrita Virtual Lab website (vlab.amrita.edu)

Online Labs for Schools

Amrita Online labs (OLabs) is an educational initiative pioneered by Amrita CREATE (Centre for Research in Advanced Technologies for Education) at Amrita Vishwa Vidyapeetham in partnership with CDAC, Mumbai, under a research grant from the Ministry of Electronics and Information Technology, Government of India. This initiative provides an opportunity to students of Classes IX to XII to understand and perform online laboratory experiments free of cost. The aim is providing high quality laboratory access in science, mathematics, and English disciplines for students and faculty members. The labs host virtual experiments in physics, chemistry, and biology developed by Amrita CREATE for students of Classes IX to XII with content aligned to NCERT/CBSE and State Board syllabi. Mathematics and English labs have been developed by CDAC Mumbai (OLabs: http://www.olabs.edu.in/).

OLabs include the study and use of mathematical techniques to demonstrate various complex functions in diverse areas of science using complex user-interactive simulations and detailed animations. OLabs combine technology resources, automation, and tried-and-true training concepts. These are richly featured platforms meant to provide a compelling and personalized experience for learners, one that goes beyond just looking at content or interacting with simulations. They enable hands-on training whenever and wherever needed.

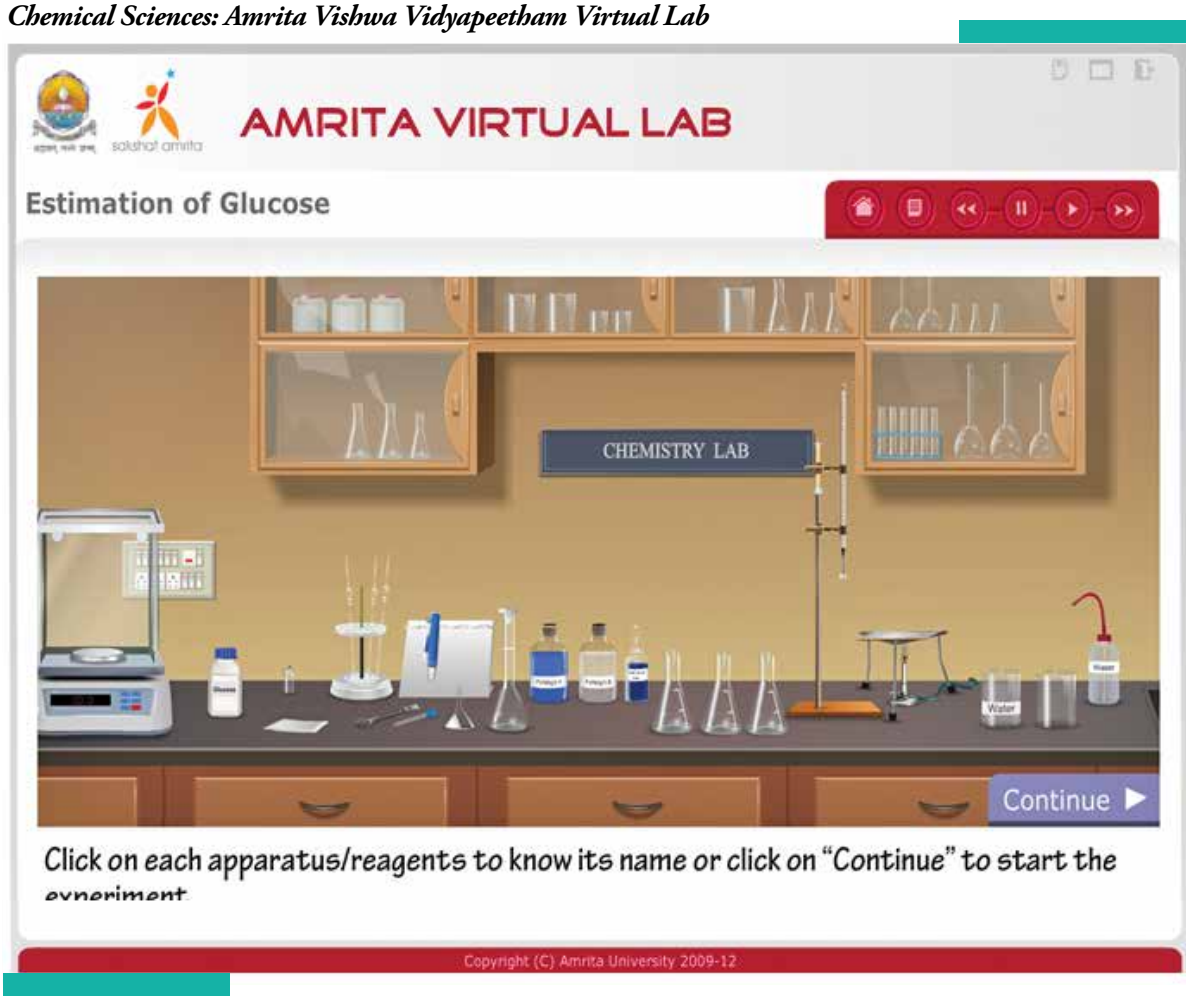
Types of Virtual Labs

There are four types of virtual labs: Animations, Interactive Animations, Simulations, and Remote Triggered Experiments.

Animations

Animation-based labs are designed to provide basic concepts behind procedures and calculations for performing experiments in a real laboratory. Step-by-step instructions allow students to follow the procedures and complete the experiments in the real laboratory. Figure 3 gives a screenshot of an animation of the estimation of a glucose experime nt from the chemical science virtual labs. These labs are based on a graphics-rich learning environment. A real lab set-up is virtualized via animations or graphics-based emulations to provide the user with a real feel of the laboratory environment. The step-by-step procedure is animated to supplement traditional classroom learning. Graphical animations use a 2D Adobe Flash player in an anytime-anywhere mode for reconstructing a realistic lab scenario. For accessing the Adobe Flash content, the user needs to download the Adobe Flash debugger from the adobe.com website (https://www.adobe.com/support/flashplayer/debug_downloads.html) and the flash content link provided in the experiment procedure tab. A user needs to copy the flash content link from the experiment procedure tab and paste the link in the Adobe Flash debugger (https://vlab.amrita.edu/?pg=topMenu&id=143).

Figure 3: Animation screenshot of *Estimation of Glucose (Procedure): Organic Chemistry Virtual Lab: Chemical Sciences: Amrita Vishwa Vidyapeetham Virtual Lab*



Interactive Animations

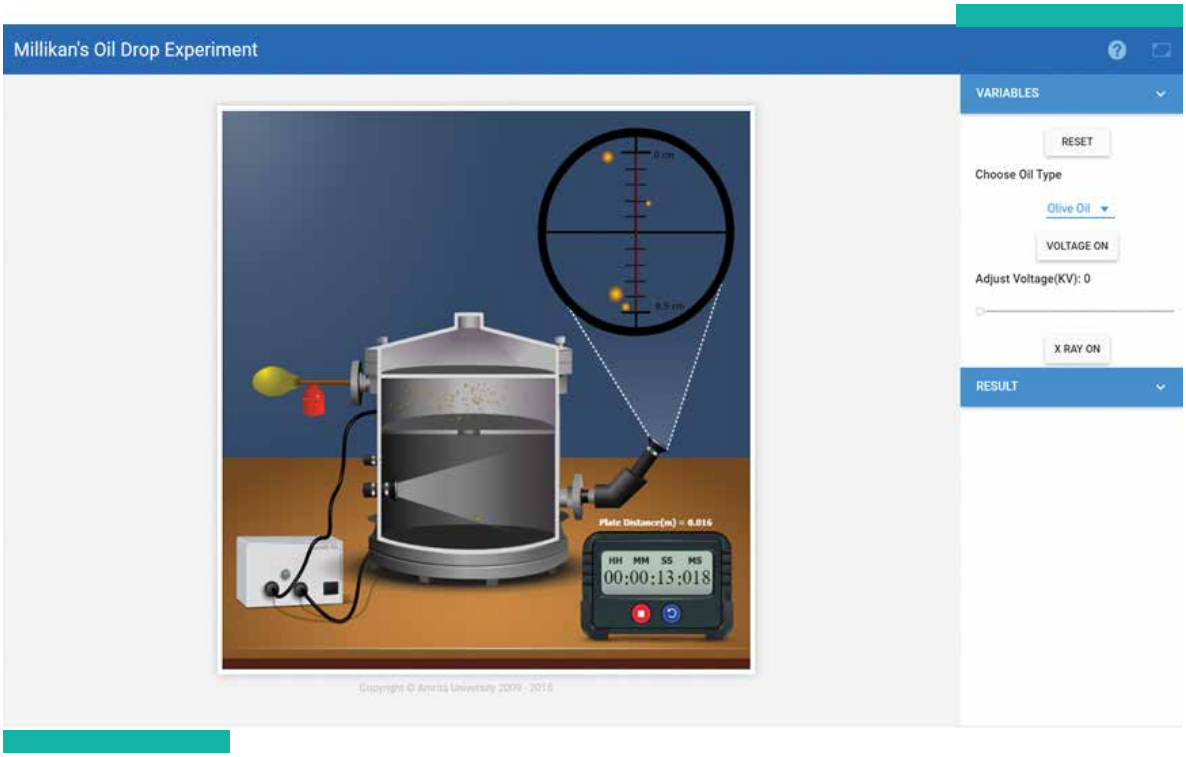
As the name suggests, these are experiments with certain levels of interactivity added to the animations where the learner can interact with the platform and follow the procedure to attain the results of an experiment. The results can either be true/false or the procedure can continue/be repeated based on the interaction. Interactive animations reduce the cognitive load on the learners by helping them perform important steps required to complete the experiment. Figure 4 gives a screenshot of an interactive animation experiment–blood grouping from biotechnology and biomedical engineering virtual labs. The hand represents the interactive section of the animation, the user can control the hand using a computer mouse and complete the experiment.

Figure 4: Interactive animation screenshot of the *Blood Grouping Experiment (Animation): Immunology Virtual Lab I: Biotechnology and Biomedical Engineering: Amrita Vishwa Vidyapeetham Virtual Lab*

Simulations

Simulations are schematic representations of a real laboratory where the user can vary the parameters of the experiment to observe the real-time effect of these changes. The user can engage in laboratory sessions by following the instructions provided in the web graphical user interface. Figure 5 gives a screenshot of the simulation on Millikan's oil drop experiment from the physics virtual lab.

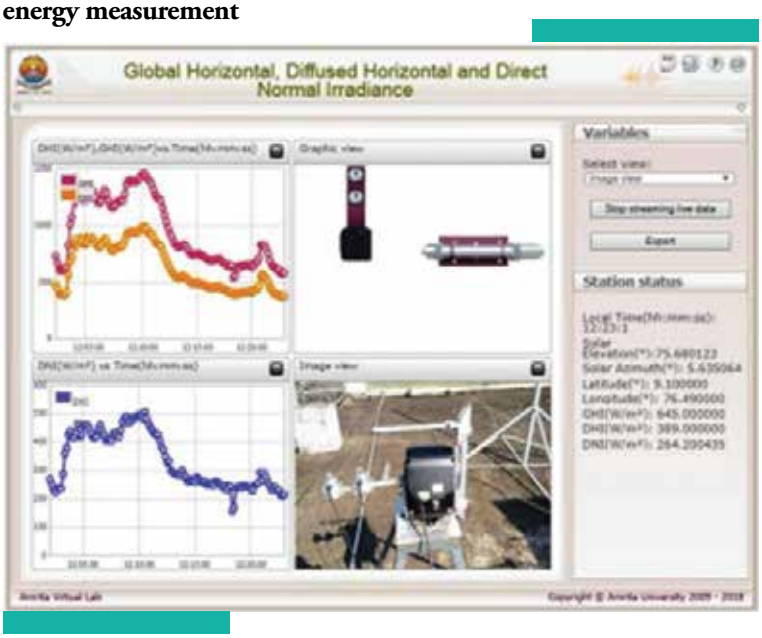
Figure 5: Screenshot of Millikan's Oil Drop Experiment ***(Millikan's Oil Drop Experiment (Simulator): Modern Physics Virtual Lab: Physical Sciences: Amrita Vishwa Vidyapeetham Virtual Lab***



Remote Triggered Experiments

Using remote triggered labs, users can perform experiments with real apparatus and simultaneously see the output data of the experiment as a graphical representation in the virtual lab portal. Remote laboratories (Cooper & Ferreira, 2009) not only allow greater accessibility but have the potential to bridge the gap in the development of laboratory skills by allowing individual students to work with the physical laboratory equipment remotely (Achuthan et al., 2020, 2021; Lowe et al., 2013). Remote labs offer an effective solution for providing the traditional hands-on laboratory session over the internet. It requires complex engineering techniques to provide users with online access to lab equipment. The experiments under the remote panel are designed to provide remote access to a single user at a time. A slot booking system is used for managing users and equipment usage. The data can be downloaded in a CSV file format and analysed. Figure 6 gives a screenshot of a remote triggered experiment on solar energy measurement.

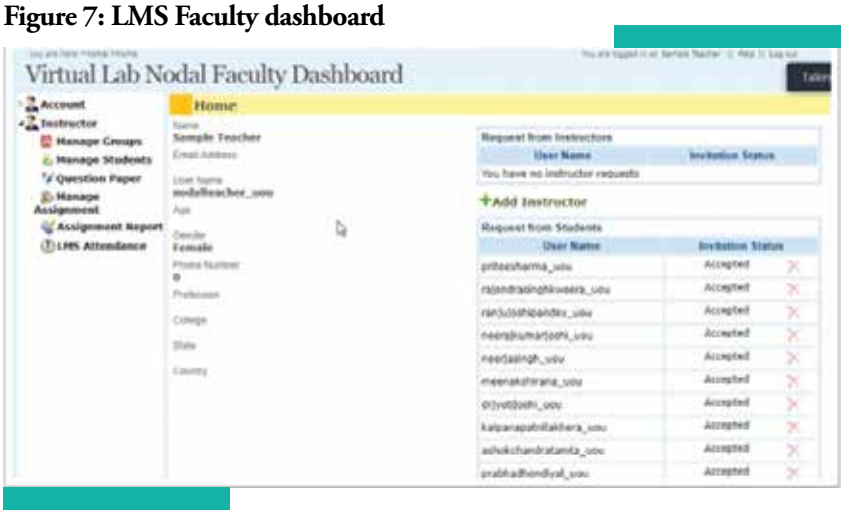
Figure 6: Screenshot of a remote triggered experiment on solar energy measurement



The Virtual Lab Learning Management System (LMS)

The Virtual Lab Platform provides a Learning Management System (LMS) for faculty members to conduct online assessments and manage student learning. LMS modules (Figure 7) enable faculty members to create different groups of students, create online questionnaires, assign questionnaires to specific groups of students, and allow the results to be exported.

Figure 7: LMS Faculty dashboard



Why are Virtual Labs Important in Teaching and Learning?

The internet, digital simulations, and virtual labs have revolutionized the way technology is used for promoting student learning in science (Shegog et al., 2012). In recent years, the development of virtual laboratories has increased due to an increase in distance education (Moudgalya, 2010). While laboratories for carrying out physics or chemical sciences experiments are possibly available in larger numbers (Devyatkin, 2018; Gambari, 2018), virtual laboratories have also been designed to bring specialized education to students (Soriano, 2019; Wen, 2018). Virtual laboratories emerged as a need for reducing installation, maintenance, and operation costs without sacrificing student experience (Miranda, 2020). Computers, with the advancement of information technologies, have emerged as powerful tools for developing students' abilities to query and to support science teaching (Fetaji et al., 2007). The use of virtual laboratories has shown promise in helping expand the capabilities of laboratory education. Virtual laboratories as a supportive factor for real laboratories enrich students' learning experience and offer students opportunities to do experiments, control material and equipment, collect data, perform the experiment interactively, and prepare reports for the experiment and develop experimenting skills (Reeves & Crippen, 2021). Results of a study by Radhamani (2014) show that virtual labs improved students' performance when used as a learning tool or as a textbook reference. The impact of virtual labs on students and institutions has been studied and reported in several publications available on the Amrita virtual labs webpage (https://vlab.amrita.edu/index.php?pg=topMenu&id=98).

During the COVID-19 outbreak, educational institutions were shut down and learners did not have access to physical laboratories. Beyond classrooms, adoption of technology-based education was crucial for laboratory courses to cope with social distancing related to the COVID-19 lockdown. In the absence of face-to-face classroom teaching, virtual laboratories were perceived and used as Massive Open Online Courses (MOOCs) where the role of the instructor was reduced and training experience was oriented towards participation and practice in online experiments (Radhamani et al., 2021).

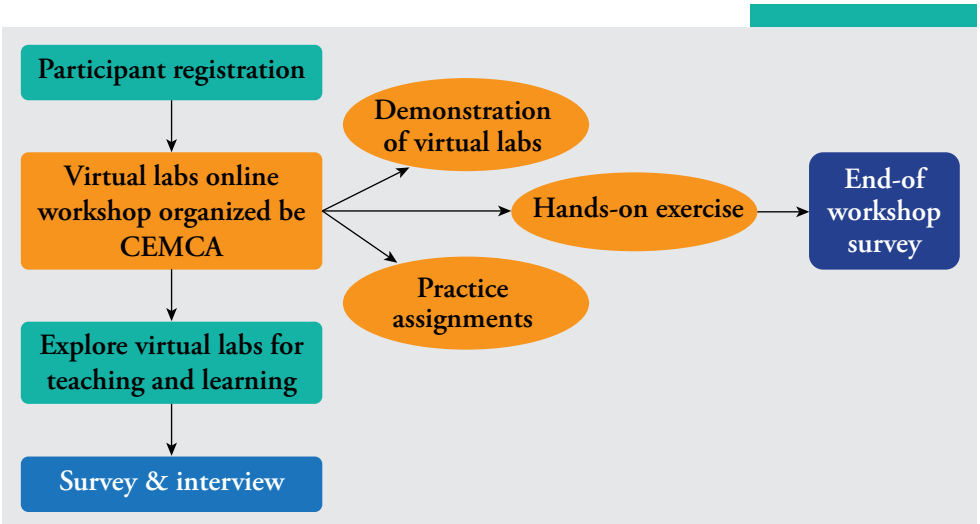
Objectives

This study evaluates CEMCA's capacity building workshops undertaken for promoting awareness about virtual labs. The objectives of the study are, examining:

Study Design

The study analyses the feedback obtained from teachers in schools and higher education institutions in India, the Maldives, Bangladesh, and Malaysia who attended online workshops on virtual labs organized by CEMCA. Figure 8 represents the study design. Participants were pre-registered for attending the online workshops on virtual labs. During the workshops, an expert resource person provided an overview of virtual labs, demonstrated the experiments, facilitated hands-on exercises, and engaged the participants in assignments to encourage exploration and practice in virtual labs. Feedback was collected immediately after each workshop as well as through a follow-up evaluation conducted during October-December 2021 (Figure 8). End-of-workshop feedback was collected through an online survey. The follow-up evaluation was conducted using two tools -- a survey questionnaire and an online interview. Internal consistency of the survey instrument and interview questions was validated with the help of four experts from a higher education institution in India who had 8 to 10 years' experience in the field of quantitative study and education pedagogy. Modifications in the instruments were carried out based on the suggestions made by the experts before using them for data collection. The relevant part of the survey instrument that sought to study teachers' perception was further analysed to seek a Cronbach Alpha score ($\alpha = 0.79$) to establish internal consistency of the items. A semi-structured interview was conducted with teachers for analysing their perceptions about the adoption, implementation, and promotion of virtual labs.

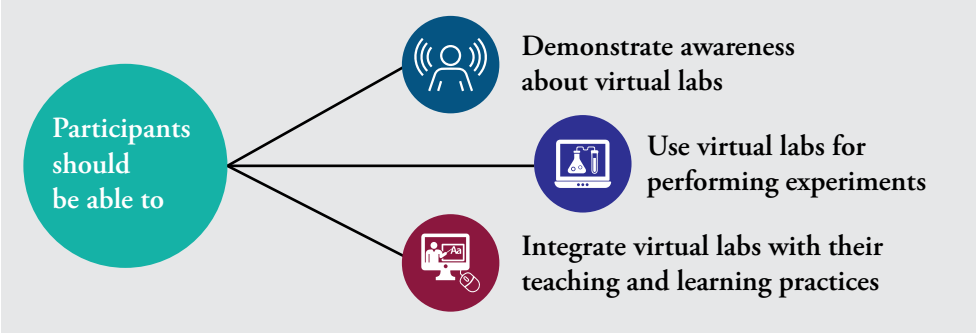
Figure 8: Study design



Methodology
CEMCA's Training Programmes for Using Virtual Labs

CEMCA organized five capacity building programmes on virtual labs aimed to create awareness about virtual labs for internet-based experimentation and to enable teachers to use virtual labs and to integrate them effectively in their teaching practices; 468 faculty members attended these workshops.

Workshops' Objectives



Virtual Lab Workshops Organized by CEMCA

Table 1 presents the number of virtual lab workshops organized by CEMCA in 2020 and 2021. The first programme, organized in partnership with Uttarakhand Open University, India on 9-10 November 2020, was attended by 62 participants. The second workshop was conducted on 17-18 December with 71 participants from open universities in India. The largest number of participants (194) attended the online workshop for teachers and teacher educators from the Maldives organized in collaboration with the National Institute of Education (NIE), Maldives on 1-3 April 2021. 43 faculty members participated in a workshop organized in collaboration with HELP University, Malaysia in April 2021. This was followed by a workshop with Chittagong University, Bangladesh which was attended by 98 faculty members. Comprehensive reports with details for each of the training programmes are available on the CEMCA website.

Table 1: Number of virtual lab training programmes organized by CEMCA, New Delhi

Sl No.	Date	Country	University/Organization	No. of participants
1	9th and 10th November 2020	India	Uttarakhand Open University	62
2	17th and 18th December 2020	India	Open Universities in India	71
3	1st to 3rd February 2021	Maldives	National Institute of Education, Ministry of Education, Maldives	194
4	5th and 6th April 2021	Malaysia	HELP University	43
5	23rd to 25th August 2021	Bangladesh	Chittagong University	98

Training Methodology and Modalities

The workshops were conducted through virtual platforms such as Zoom and MS Teams. The methodology consisted of a live demonstration of virtual lab experiments from the Amrita University website (vlab.amrita.edu) and the main virtual lab website (vlab.co.in) followed by hands-on activities by participants based on in-session assignments provided by the resource persons. The organizing team shared a WhatsApp group to facilitate asynchronous interaction among the resource persons and the participants (Figure 11). This forum was provided for sharing information, answering queries, and submitting feedback. Practice assignments based on the workshop were provided at the end of each session to encourage the participants to explore the Virtual Lab Platform and to apply the learning from the workshop.

During the workshops, the presentation and demonstration of experiments was interspersed with hands-on activities for the participants. Around 10 minutes were provided to complete each task and submit the answers through polls (Figure 9). Participants who could not submit the correct answers were encouraged to repeat the experiments at their own pace as part of the assignment after the online session. Table 2 represents the percentage of correct answers submitted by the participants during the online workshops.

Table 2: Responses to hands-on activities during a workshop's live session

Hands-on task	Per cent of correct responses
Magnetic field around the circular coil, Number of turns: 20, Radius of the coil: 7cm, Compass box position: 14 cm, Current: 1A. Identify the deflection shown in the compass box.	62 per cent
Identify the voltage of the cell if the cathode electrode as Gold (Concentration: 4M) and anode electrode as Copper (concentration: 1.19M) at 10 degree Celsius temperature	71 per cent
What is the pH value of lake water?	70 per cent
Identify the organic compound-13 by using its boiling point in the experiment Boiling point of an organic compound	100 per cent
Determine the time taken to flow the Nitrobenzene from point 'C' to 'D' in the experiment- Determination of Viscosity of Organic Solvents	63 per cent

Figure 9: Screenshot of a poll question posted for the participants during a workshop

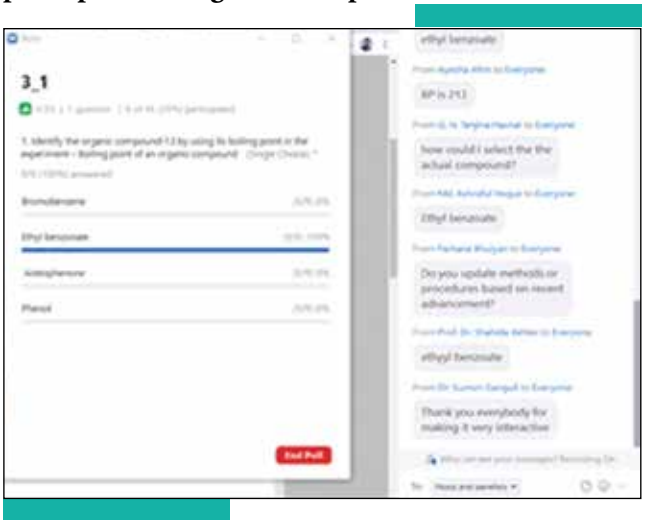


Figure 10: Screenshot of an interactive session during a workshop

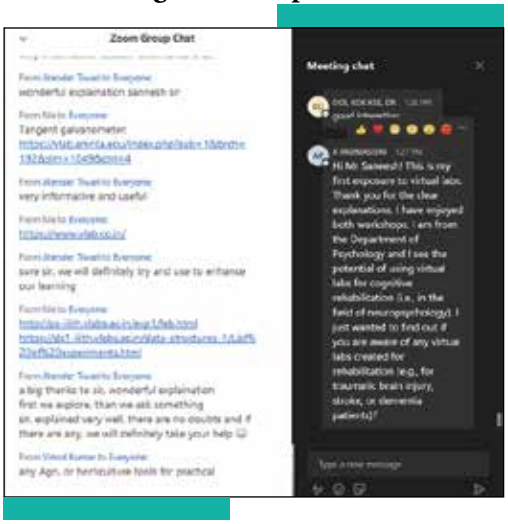
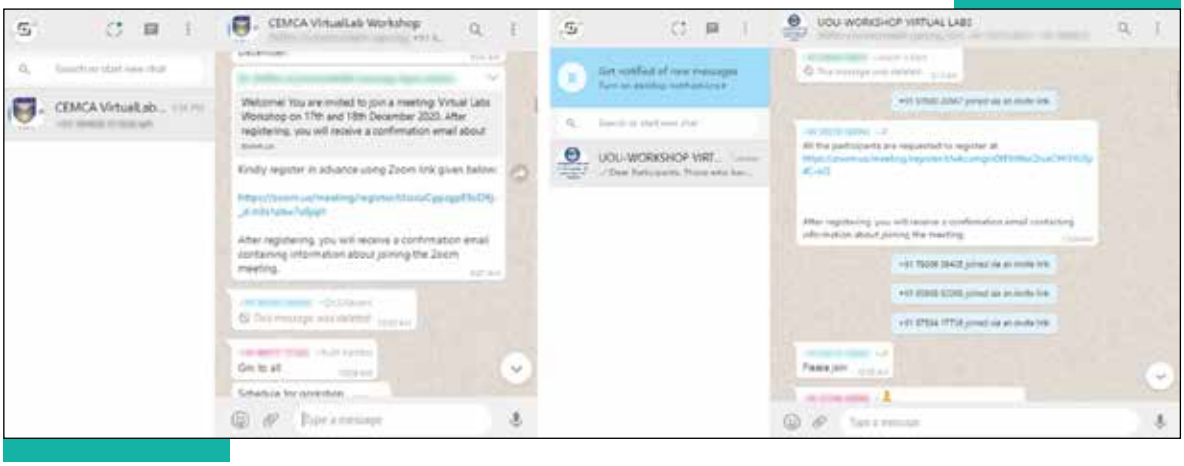


Figure 11: Screenshot of a WhatsApp group chat for asynchronous communication all figures need to be mentioned in text



Workshop Schedule

The live online sessions of the training programmes ranged from a minimum of 1 hour 30 minutes to a maximum of 3-hour sessions per day for two to three days. A typical workshop schedule is provided in Table 3. There were some variations across workshops, for example, the Uttarakhand Open University and HELP University workshops were held for two hours per day, while workshops for faculty members of the Maldives, Malaysia, and open universities in India were held for one and a half hours each day. Asynchronous learning activities continued to be facilitated after the live online sessions.

Table 3: Workshop schedule

Time (in minutes)	Activity	Session details
Day 1		
15	Inaugural session	
30	Introduction to virtual labs (Presentation and video)	Participants gain an overall understanding of virtual labs; the concept and overview; virtual lab related activities

Time (in minutes)	Activity	Session details
60	Demonstration of virtual lab experiments from Physics, Chemistry, Biology, and related disciplines. Hands-on activity	Participants learn how to perform experiments through virtual labs
15	Q&A session	Queries shared and answered Practice assignments explained
Day 2		
10	Opening session	Recapitulation and overview of virtual labs
10	Impact of virtual labs	Significant research findings on virtual labs presented
60	Demonstration of virtual lab experiments	Participants learn how to perform experiments using virtual labs
20	Hands-on activity	
10	Virtual Lab Learning Management System (LMS Module)	Participants learn to use the LMS module of virtual labs
10	Q&A session	Queries and observations shared
	Closing session	Conclusion and way forward

Participants' Profiles

Participants were requested to fill up the post-workshop feedback form designed using Google Form. The feedback link was shared via a WhatsApp group and the Zoom chat box at the end of the session. 366 responses were received from 468 participants. Figure 12 represents the demography of the participants (53.27 per cent male and 46.73 per cent female) (Figure 12A). 23.13 per cent of the participants had less than five years of work experience, 31.83 per cent had 6 to 10 years of work experience, 17.98 per cent had 11 – 15 years of work experience, 13.95 per cent had 16 years to 20 years of work experience, and 13.12 per cent had over 20 years of experience (Figure 12B). One per cent of the participants were below 20 years of age; 30.5 per cent were in the age category 21 to 30 years; 34 per cent were in the 31 to 40 years age category; 11.5 per cent were in the 41 to 50 years age category; and 23 per cent were above 50 years of age (Figure 12C). 23 per cent of the participants were from physical science departments, 19.6 per cent were from mathematics departments, 16.25 per cent from chemistry departments, 14 per cent from biology departments, 5 per cent from computer sciences, 5 per cent from commerce, 4.16 per cent from botany, 2 per cent from zoology, and 9 per cent from education, geography, defence studies, library, and social work departments (Figure 13).

Figure 12: Demographic profile of participants

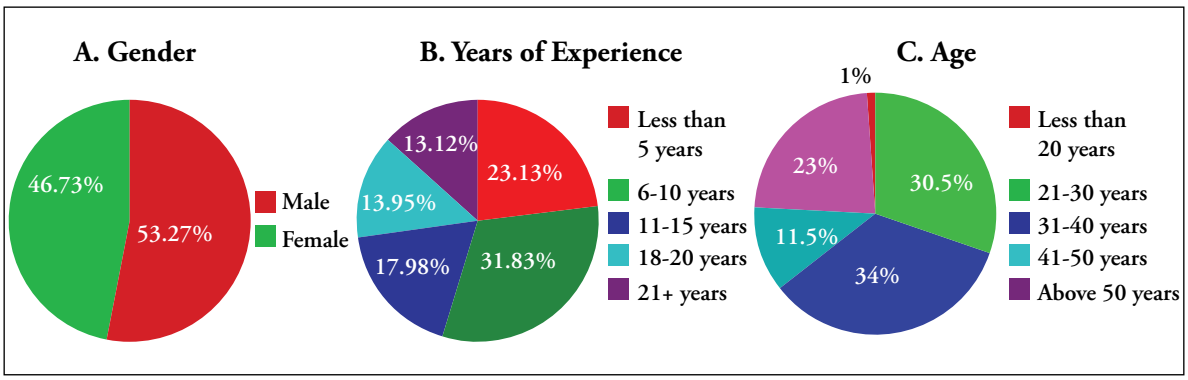
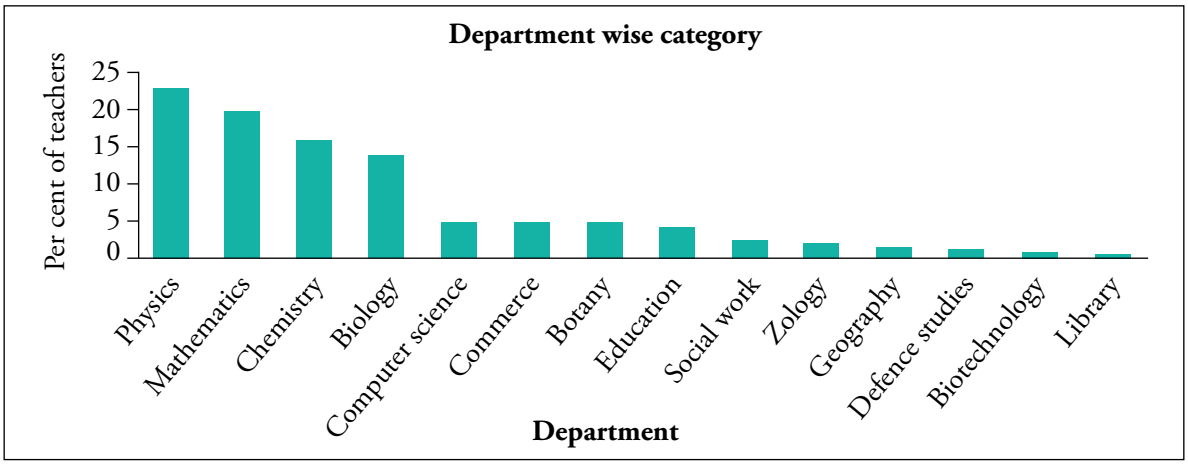
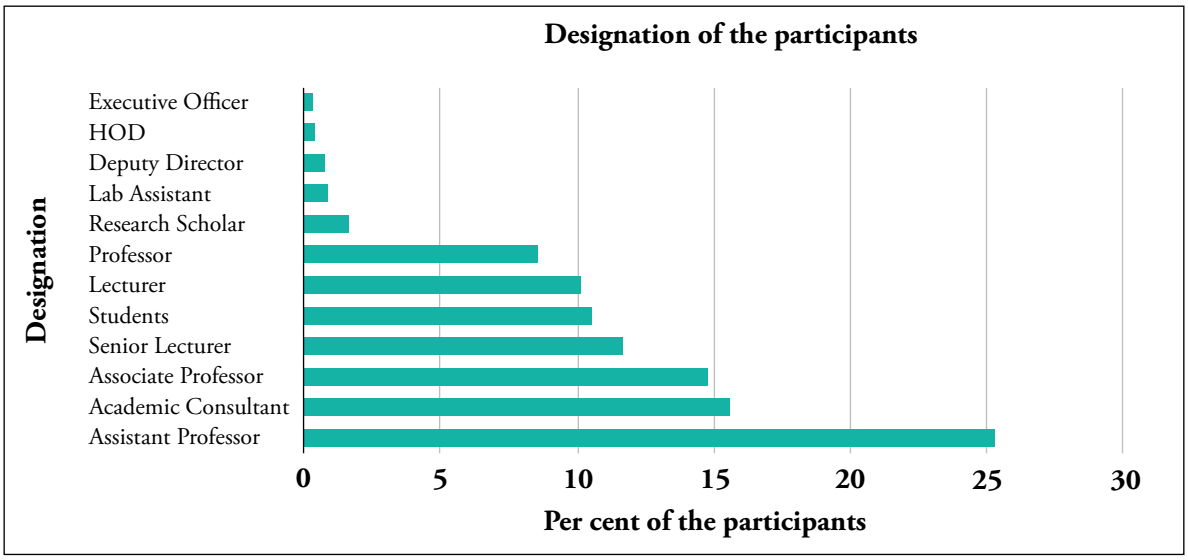


Figure 13: Department-wise categorization of the participants



Participants were categorized based on their designation. As shown in Figure 14, 25.19 per cent of the participants were assistant professors, 15.50 per cent were academic consultants, 14.72 per cent were associate professors, 11.62 per cent were senior lecturers, 10.42 per cent were students, 10.08 per cent were lecturers, 8.52 per cent were professors, 1.55 per cent were research scholars, and 0.77 per cent were lab assistants. The participants also included deputy directors, HODs, and executive officers.

Figure 14: Designations of the participants



A Sample of Experiments Demonstrated

Selected experiments from science and engineering disciplines including biotechnology, physical sciences, chemical sciences, environmental engineering, and computer sciences were demonstrated during the workshops. Experiments demonstrated from biotechnology include Blood grouping, Light microscope, and Gram stain technique. Chemical science experiments such as Spectrophotometry, Determination of viscosity of organic solvents, and EMF Measurement were demonstrated. Physical science experiments demonstrated include Parallel LCR Circuit, Tangent Galvanometer, Magnetic Field Along The Axis of A Circular Coil Carrying Current). The Problem Solving Lab in computer sciences and an experiment on Determination of TS, TDS, and TSS from the Environmental Engineering lab were some of the experiments demonstrated during the workshops (Figure 15).

Figure 15: Sample experiments demonstrated during the online workshops

Virtual Lab Experiment demonstration

Blood grouping

Spectrophotometer

Determination of viscosity of organic solvents

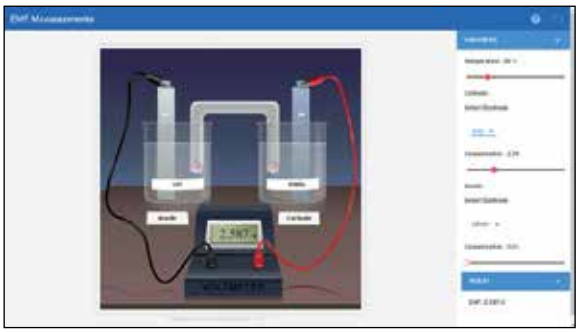
Parallel LCR Circuit

Tangent Galvanometer

Problem solving lab

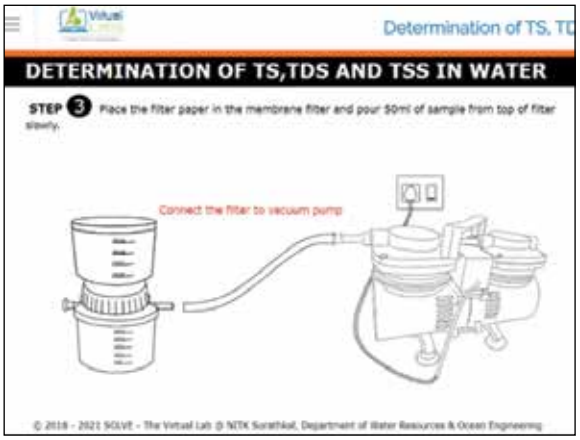
Light Microscope - Biotechnology

Gram Stain Technique – Biotechnology

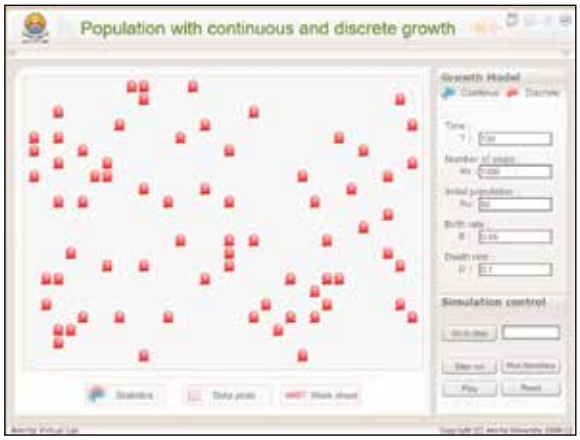


Chemistry: EMF Measurement

Magnetic Field Along the Axis of A Circular Coil Carrying Current – Physics



Environmental Engineering Lab: Determination of TS, TDS and TSS



Population with Continuous and Discrete Growth

Assignment Questions

To encourage familiarization with virtual labs, participants were given assignments based on experiments demonstrated in the workshops. Some sample assignment questions are presented below.

Physical Sciences

Problem 1: Study of Variation of Specific Heat of Cardboard with Temperature
Link: *http://vlab.amrita.edu/index.php?sub=1&brch=194&sim=353&cnt=1*

Problem 2: Determination of Stefan- Boltzmann constant σ
Link: *http://vlab.amrita.edu/index.php?sub=1&brch=194&sim=548&cnt=1*

Problem 3: Ultrasonic Velocity in Liquids Ultrasonic / Interferometer Method
Link: *http://vlab.amrita.edu/index.php?sub=1&brch=201&sim=803&cnt=1*

Problem 4: Determination of Numerical Aperture
Link: *http://vlab.amrita.edu/index.php?sub=1&brch=189&sim=343&cnt=1*

Problem 5: For a circular coil of 30 turns and diameter 10cm, find the magnetic field at the centre of the coil, if 1A current flows through it. Also obtain the fields at different points on the axial line and verify the Gaussian distribution of magnetic fields).
Link: *https://vlab.amrita.edu/index.php?sub=1&brch=192&sim=972&cnt=1*

Problem 6: What should be the minimum applied potential for complete stoppage of photocurrent in an experiment if the target material is zinc, area of the plate 0.2cm2, intensity of light 15w/m2 and wavelength of light 120nm?
Link: *https://vlab.amrita.edu/index.php?sub=1&brch=195&sim=840&cnt=4*

Chemical Sciences

Problem 1: Find out the unknown concentration of the sample – Rose Bengal.
Link: *http://vlab.amrita.edu/index.php?sub=2&brch=190&sim=338&cnt=1*

Problem 2: Determine the absolute viscosity of organic liquids.
Link: *http://vlab.amrita.edu/index.php?sub=2&brch=190&sim=339&cnt=1*

Problem 3: Determine chemical parameters such as hardness, alkalinity, and chemical oxygen demand COD) of water samples.
Link: *http://vlab.amrita.edu/index.php?sub=2&brch=193&sim=1548&cnt=1*

Problem 4: Identify unknown concentration of the 'Rose Bengal.'
Hint: Spectrophotometry

Problem 5: What is the absolute viscosity of Nitrobenzene?
Hint: Determination of Viscosity of Organic Solvents

Problem 6: Which of the following is a weak base?
Hint: Acid Base Titration

1. KOH
2. HF
3. NaOH
4. K_2CO_3

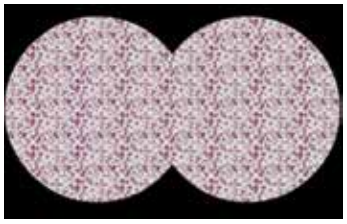
Biotechnology and Biomedical Engineering

Problem 1: Differentiate between the two major categories of bacteria: Gram positive and Gram negative.
Link: *http://vlab.amrita.edu/index.php?sub=3&brch=73&sim=208&cnt=1*

Problem 2: What are the requirements for establishing a tissue culture laboratory?
Link: *http://vlab.amrita.edu/index.php?sub=3&brch=187&sim=1100&cnt=1*

Problem 3: Two parents with blood types A and O have a child who has type O blood. What is the probability that their next child will be type A?
Link: *http://vlab.amrita.edu/index.php?sub=3&brch=69&sim=192&cnt=1*

Problem 4: Identify the sample
Hint: Gram Stain Technique



Problem 5: How much voltage is applied across the electrode of the electrophoretic chamber?
Hint: Agarose Gel Electrophoresis

Evaluation Methodology

End-of-Workshop Evaluation

An online survey was conducted at the end of each virtual lab workshop to obtain feedback from the participants about the workshop and their perceived effectiveness of virtual labs. The survey questionnaire consisted of the following sections:

Programme Design, Content, and Results

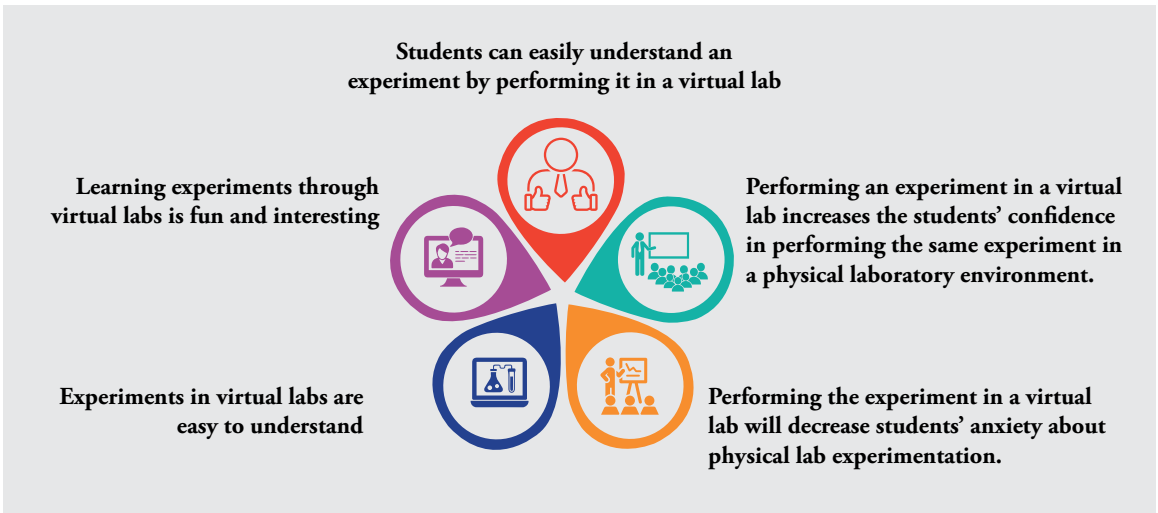
To understand the participants' views about attainment of the workshop's objectives and how they will use the knowledge gained during the workshop, nine questions were included in the feedback form. These included three questions each on programme design, programme content, and programme results.

Workshop Rating

Feedback on the overall quality of the workshop is crucial to inform modifications for improving programmes in the future. The participants were requested to rate the overall quality of the workshop on a scale of 1 to 5 where 1 was very poor and 5 excellent.

Perceived Effectiveness of Virtual Labs

The participants were requested to respond to five statements based on the effectiveness of virtual labs. The statements were:



Suggestions from the Participants

As part of the workshop feedback, the participants were requested to share their suggestions for modifying and improving the workshops in the future.

Follow-up Evaluation

Participants' Profiles

116 teachers from four countries submitted their responses to an online survey questionnaire which was distributed to 366 participants. Survey respondents (n = 116) were 38.06 years old on average (standard deviation = 7.95; range = 26 to 62).

Table 4 represents the demographic profile of the respondents. 66 (56.9 per cent) of the respondents were male while 50 (43.1 per cent) were female, 56.9 per cent of the responses were received from the Maldives, 25 per cent from India, followed by Bangladesh (12.07 per cent) and Malaysia (6.03 per cent). The highest number of participants (42.24 per cent) were in the 36 – 45 years age group, 37.07 per cent were in the age group 26 – 45 years, and 14.66 per cent in the age group 46 – 55 years. 3.45 per cent of the participants were above 55 years while 2.59 per cent were in the age group 18 – 25 years. With reference to years of experience, 36.21 per cent of the participants had 6-10 years of teaching experience and 30.17 per cent had 11-15 years of experience in teaching. The distribution of the participants with 1-5 years of experience and experience above 15 years is 14.66 per cent and 18.97 per cent respectively. Most of the participants were from biological sciences (31.03 per cent), education (22.41 per cent), chemical sciences (14.66 per cent), and physical sciences (13.79 per cent). The remaining were from engineering and technology (7.76 per cent), mathematics (6.03 per cent), oceanography (1.72 per cent), social sciences (1.72 per cent), and journalism and mass communication (0.86 per cent).

Table 4: Demography

Particular	Category	Responses	Percentage
Gender	M	66	56.90
	F	50	43.10
Age group	18 – 25	3	2.59
	26 – 35	43	37.07
	36 – 45	49	42.24
	46 – 55	17	14.66
	Above 55	4	3.45
Years of experience	1 - 5 years	17	14.66
	6 - 10 years	42	36.21
	11 - 15 years	35	30.17
	Above 15 years	22	18.97
Major discipline area	Biological Sciences	36	31.03
	Education	26	22.41
	Chemical Sciences	17	14.66
	Physical Sciences	16	13.79

Particular	Category	Responses	Percentage
Major discipline area	Engineering and Technology	9	7.76
	Mathematics	7	6.03
	Oceanography	2	1.72
	Social Sciences and Humanities	2	1.72
	Journalism and mass Communication	1	0.86
Country	India	29	25.00
	Bangladesh	14	12.07
	Malaysia	7	6.03
	Maldives	66	56.90

Data Collection

Data was collected with the help of two tools designed for the study - a survey questionnaire and an interview schedule.

Questionnaire

A survey questionnaire was created to assess individual experiences and perceptions about the use and implementation of virtual labs. Selected items were based on a questionnaire constructed and used by Mtebe and Raisamo (2014), appropriate modifications were made wherever necessary. The Likert scale was used to seek responses on items based on perceptions or opinions. In addition, open-ended and multiple-choice questions were incorporated in the questionnaire to seek feedback on different aspects regarding the use and implementation of virtual labs. The online questionnaire was created using Google Forms and administered to participants through email. The participants were requested to fill the responses online. The questionnaire with the accompanying email are given in Appendix A.

Teachers' perceptions about students' use of virtual labs, virtual lab adoption and implementation, and benefits of virtual labs were measured on a 5-point Likert scale ranging from Strongly Agree to Strongly Disagree. The extent of teacher use of virtual labs for teaching and learning was measured on a 5-point Likert scale (1 – Not at all, 2 – Only to a little extent, 3 – To some extent, 4 - To a great extent, and 5 – To a very great extent). Teachers' perceptions about the challenges faced in the use of virtual labs was measured on a 5-point Likert scale from 1 - Most important to 5 - Least important. The subset-wise distribution of the items in the questionnaire is presented in Table 5. The Cronbach's alpha value of the survey instrument was calculated to ensure the internal consistency of the items (Table 6).

Table 5: Distribution of the items in the questionnaire

S. No.	Particulars	No. of items
1	Personal information	11
2	Teachers use of virtual labs	8
3	Teachers' perceptions about students' use of virtual labs	5
4	Virtual lab adoption and implementation	8
5	Use of virtual labs for teaching and learning	12

S. No.	Particulars	No. of items
6	Teachers' perception about the benefits of virtual labs	13
7	Teachers' perceptions about the challenges faced in using virtual labs	11
8	Suggestions	8
	Total	**76**

Table 6: Cronbach's alpha score

S. No.	Particulars	Cronbach's alpha
1	Teachers use of virtual labs	0.78
2	Teachers' perception about students' use of virtual labs	0.82
3	Virtual lab adoption and implementation	0.88
4	Use of virtual labs for teaching and learning	0.76
5	Teachers' perception about the benefits of virtual labs	0.81
6	Teachers' perception about the challenges faced in using virtual labs	0.89
	Total	**0.79**

Interview schedule

The interview schedule (Appendix B) was designed for an understanding of the responses received from the survey. Interviews were conducted after the survey data collection. Online platforms such as Zoom and Google Meet were used for the interviews. Interviews were recorded and their transcripts prepared for analysis.

Data Analysis

The survey data responses were received from 116 of the 366 teachers who participated in virtual lab workshops organized by CEMCA. Data collected through the online survey questionnaire was coded and transferred to the SPSS software package for further analysis. MS-Excel was used for tabulating the data and performing statistical calculations. The objective of the study guided the analysis and interpretation of the data. In Likert scale items, the overall mean score was taken to represent the inclination of the participants towards one end of the scale and the level of agreement or disagreement towards a particular statement. One-way ANOVA was performed to analyse the significant differences between different categories of participants. Personal interviews of the participants were conducted and audio recorded for transcription purposes. The transcriptions were later used for supporting the findings of the survey data analysis.

Teachers' use of virtual labs

the dimension teachers' use of virtual labs contained eight items. Two of the items used Yes/No choices while six were multiple choice questions for analysing the use of virtual labs. To identify virtual lab access, participants were asked whether they had used virtual labs. A follow-up question was asked about how many experiments were done by the participants in their teaching and learning practices. The participants were asked to state the device used for accessing virtual labs. The choices included

laptops, desktops, mobile phones, or tablets. To understand the frequency of accessing virtual labs a question was included on 'how often do you use virtual labs in your teaching activity?' The participants were categorized into five groups based on their level of proficiency in virtual lab usage: 'no experience with virtual labs,' 'attempted to use virtual labs but still require help on a regular basis,' 'able to perform basic functions in a limited number of virtual lab experiments,' 'very proficient in using a wide variety of virtual labs,' and 'have the ability to competently use virtual labs.'

Teachers' perceptions about students' use of virtual labs (PSVL)

As per existing studies, the challenges faced by teachers in a science class include facilitating learning for diverse learners, giving individual feedback, and facilitating student engagement and motivation (Lynch, 2017). In this regard, teachers' perceptions about students' use of virtual labs (PSVL) was studied. PSVL contained five items where each item was measured using a 5-point Likert scale ranging from Strongly agree (5 points) to Strongly disagree (1 point). The Cronbach alpha depicting the internal consistency of the sub-scale was measured at 0.82 which was taken as acceptable (Cronbach, 1951). A mean value above 3 represents positive inclination of the participants' perceptions.

Virtual lab adoption and implementation (VLAI)

Eight items were used for analysing the extent of virtual lab adoption and implementation in the teaching and learning process. Each item was measured using a 5-point Likert scale ranging from Strongly agree (5 points) to Strongly disagree (1 point). Cronbach alpha for VLAI was calculated at 0.88 which was taken as acceptable.

Use of virtual labs for teaching and learning (VLTL)

The dimension use of virtual labs for teaching and learning contained 12 items. Each item was measured using a 5-point Likert scale ranging from 'Not at all' (1 point) to 'To a very great extent' (5 points). The Cronbach alpha score was calculated at 0.76. The questions included whether participants used theory, procedure, assignment questions, simulation, animation, assignment questions, and references from the Virtual Lab Platform. Questions also focused on whether the participants were able to locate experiments of their interest and engage students in online activities using virtual labs.

Teachers' perceptions about the benefits of virtual labs (TPVL)

Previous studies show that virtual labs can be applied as an effective teaching aid for conducting laboratory sessions or as pre-or post-lab material for various laboratory courses (Nair, 2012). This study analysed teachers' perceptions about the benefits of virtual labs. Thirteen items were used for measuring the sub-scale of teachers' perceptions about the benefits of virtual labs. The Cronbach alpha score was calculated at 0.81, which shows that the items were reliable. The scale ranged from Strongly agree (5 points) to Strongly disagree (1 point).

Teachers' perceptions about the challenges faced in using virtual labs (TPCVL)

The dimension teachers' perceptions about the challenges faced in using virtual labs contained 11 items. Each item was measured using a 5-point Likert scale ranging from Most important (1 point) to Least important (5 points). The Cronbach alpha score was calculated at 0.89 which shows internal consistency

among the items. Questions related to limited knowledge about using virtual labs, excessive workload, lack of training in virtual labs, and institutional support; these were also analysed. A higher mean score represented challenges perceived while a lower score represented perceived ease in adopting and implementing virtual labs.

An Analysis of the interviews

A semi-structured interview was used for capturing teachers' knowledge and perceptions about virtual labs. Three experienced science teachers participated in the interviews. The objective was analysing and elaborating on teachers' perceptions regarding adoption, implementation, and promotion of virtual labs.

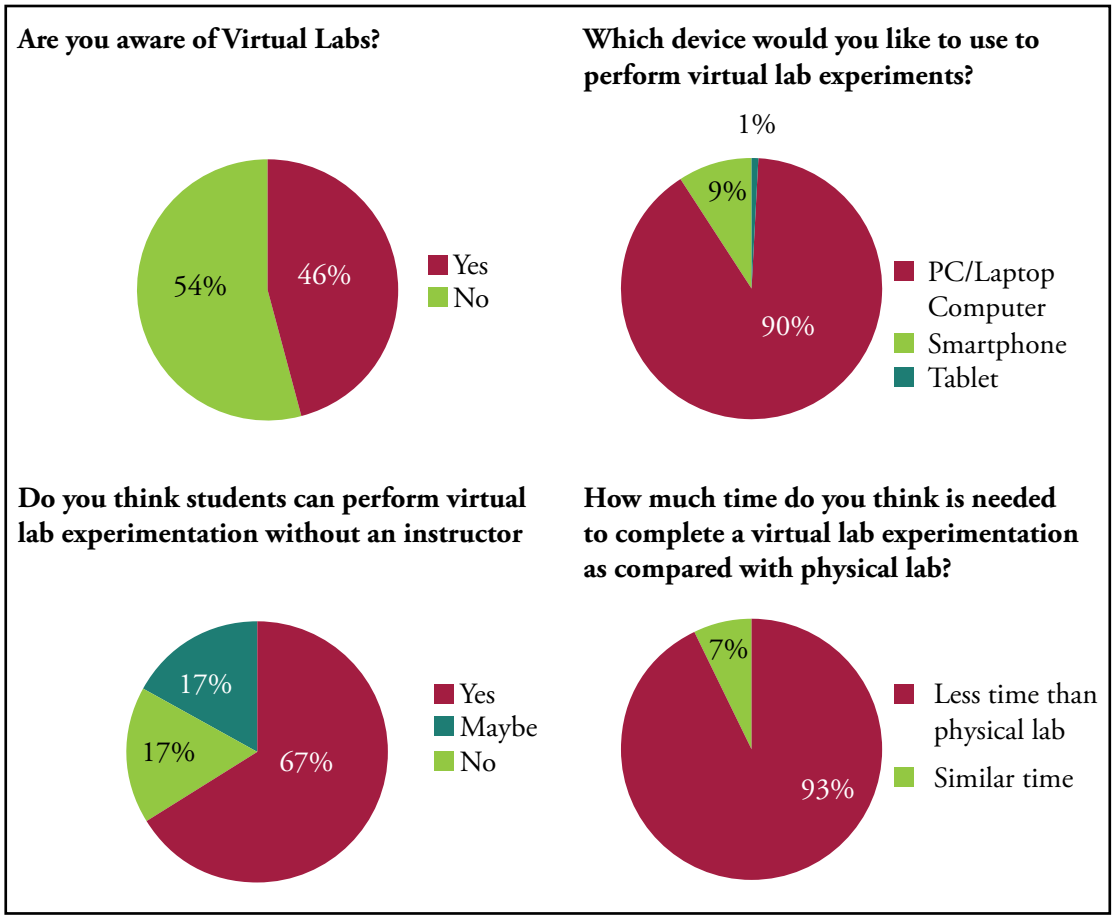
Findings and Discussion

Feedback was collected from the participants at the end of each workshop with the aim of getting an insight into their perceptions about virtual labs and the training programmes. This section gives the consolidated results from the end-of-workshop survey conducted for each of the five workshops. In addition to the end-of workshop survey, poll questions were asked during the workshop sessions to engage the participants and understand their views about virtual labs. Responses to the poll question are presented now followed by feedback from the end-of -workshop survey.

Poll Question Responses

Figure 16 represents the average poll responses by the participants during the workshop. The question 'Are you aware of virtual labs?' was asked at the beginning of the workshop.

Figure 16: Summary of the poll responses received during the workshop



End-of-workshop Survey Responses

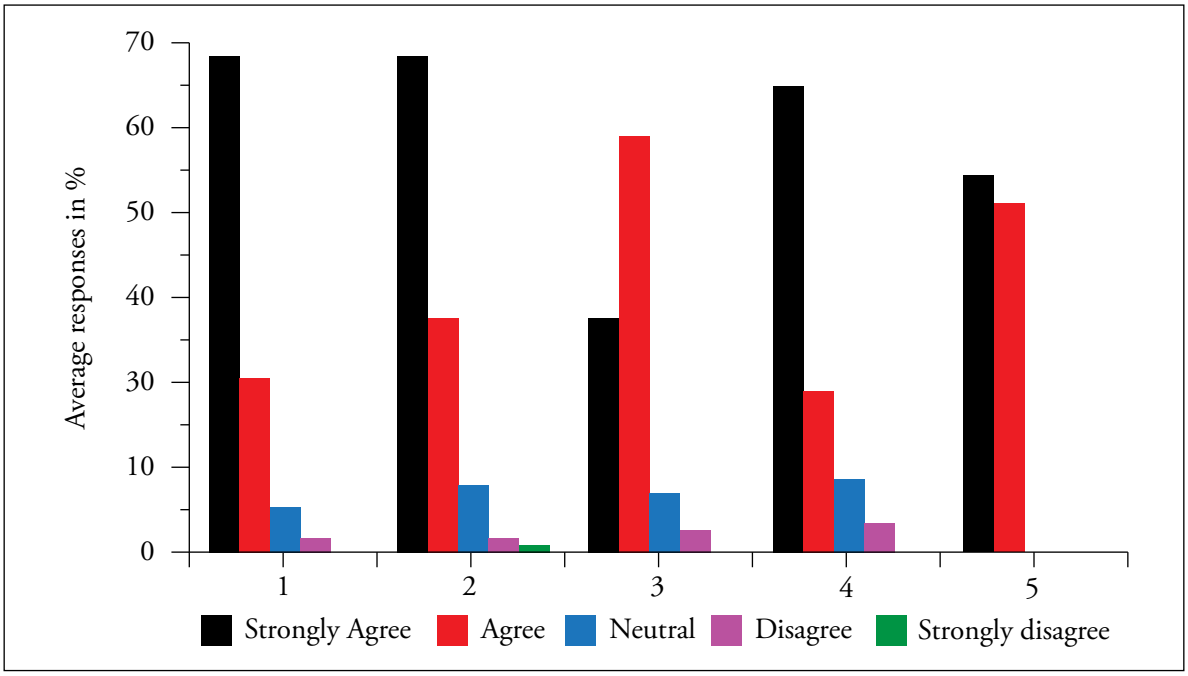
Perceived Effectiveness of Virtual Labs

The participants' responses corresponding to five statements based on the effectiveness of virtual labs are reported in Figure 17. The statements were:

1. Students can easily understand an experiment by performing it in a virtual lab.
2. Performing an experiment in a virtual lab increases the students' confidence in performing the same experiment in a physical laboratory environment.
3. Performing the experiment in a virtual lab will decrease students' anxiety about physical lab experimentation.
4. Experiments in virtual labs are easy to understand.
5. Learning experiments through virtual labs is fun and interesting.

As observed in Figure 17, most of the teachers either Strongly agreed or Agreed that virtual labs were effective in teaching and learning laboratory experiments. A few responses to the fourth statement neither agreed/disagreed that virtual lab experiments were easy to understand. This feedback will be useful for further modifications in the training on virtual labs.

Figure 17: Survey responses on the effectiveness of virtual labs

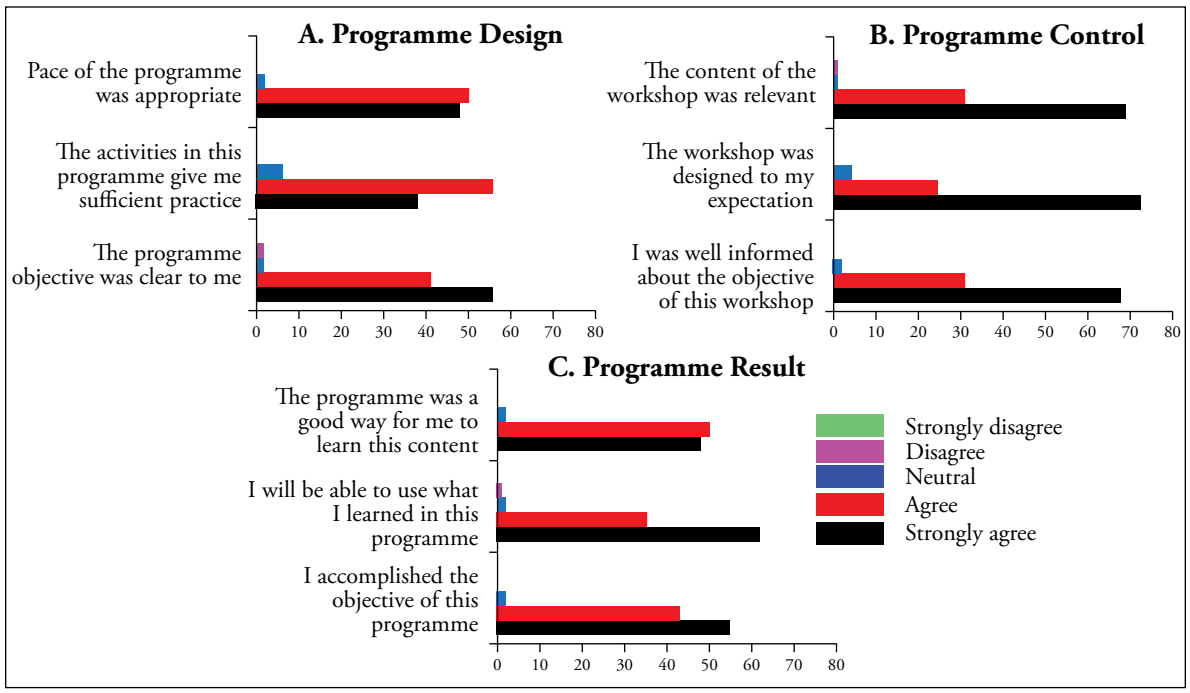


Programme Design, Content, and Results

To understand the effectiveness of the workshops in terms of programme design, content, and results, nine questions were asked. The participants' responses are given in Figure 18 which shows participant feedback regarding the programme objectives, practice sessions, and pace of teaching and learning activities. Most of the participants replied in the affirmative. (Figure 18A). Two of the faculty members expressed their disagreement which should be explored to strengthen the workshop further. 90 per cent of the participants felt that they were informed about the objectives of the workshops and they found the content relevant

and designed as per their expectations (Figure 18B). It is important to know what the participants thought about attaining the objectives and how they will use the knowledge gained during the workshops. Figure 18C shows that most of the participants were satisfied with respect to these points. Two faculty members disagreed about the clarity of the programme objective and the ability to use what they had learnt during the workshops. Further investigation revealed that these faculty members were from disciplines for which there are no virtual experiments available on the platform, for example, oceanography. This feedback helped identify experiments for future development of virtual labs.

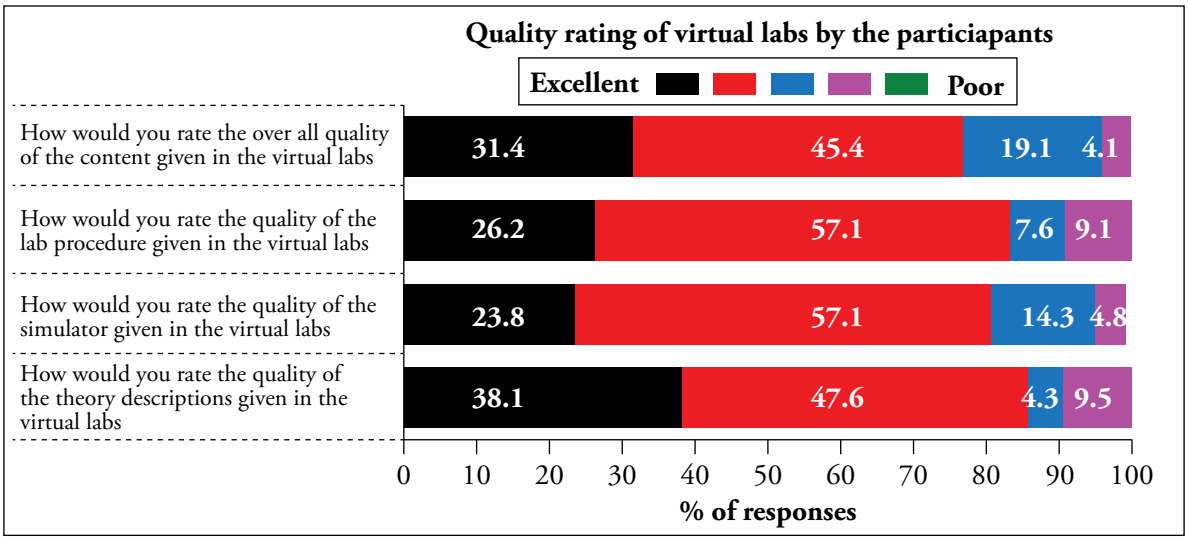
Figure 18: Feedback from the participants on Programme Design, Content, and Results



Quality Rating of Virtual Labs

Participant feedback on the quality of the virtual labs was also assessed as part of the workshops (Figure 19). As evident from the analysis, most of the participants rated virtual labs as excellent or very good in terms of quality of content, lab procedures, simulators, and theory description.

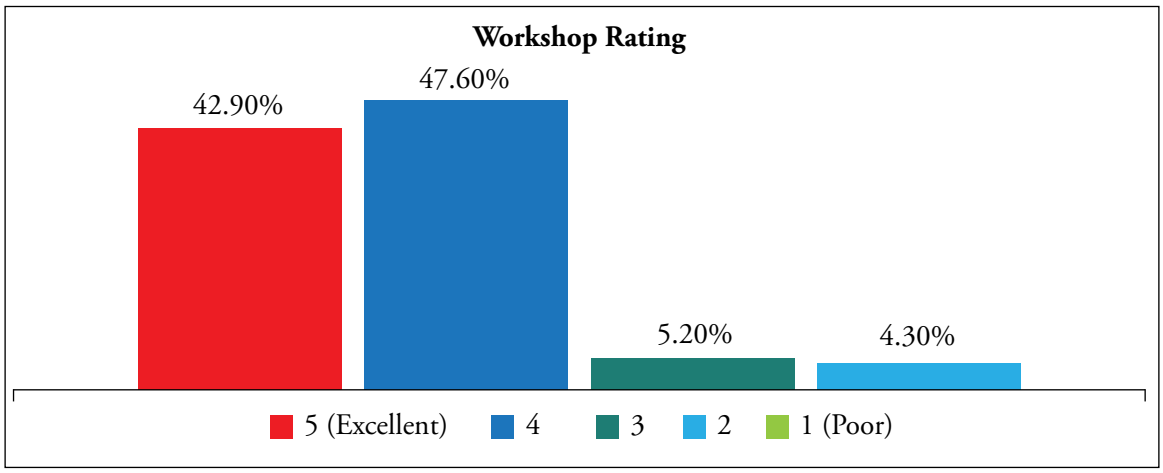
Figure 19: Quality rating of virtual labs in the end-of -workshop survey. Black represents 'Excellent' and green represents 'Poor'



Overall Workshop Rating

The participants rated the overall quality of the workshop on a scale of 1-5 (where 1 represents Poor and 5 represents Excellent). As shown in Figure 20, most of the participants rated the workshop at 5 out of 5 (42.90 per cent) or 4 out of 5(47.60 per cent). 4.3 per cent of the participants gave it 2 out of 5 while 5.2 per cent gave it 3 out of 5.

Figure 20: Overall rating of the virtual lab online workshops



Suggestions from the Participants

As part of the workshop feedback, participants were encouraged to share their suggestions for modifying future workshops. They shared the following suggestions:

- Many participants **(56.45 per cent)** requested for more training sessions for each discipline.
- **165 (45.12 per cent)** of the participants reported that they required more time to practice in virtual labs.
- **141 (38.66 per cent)** of the participants suggested including more experiments based on their syllabus.
- **27 per cent** of the participants suggested that subject area topics and simulations could be provided through apps.
- **24 per cent** of the participants, primarily from the Maldives, suggested that online labs for primary grades should also be included.
- **61 participants (16.78 per cent)** expressed the need for more activities on how to use virtual labs.

An Analysis of Follow-up Survey Findings

Descriptive statistics for the different attributes (PSVL, VLAI, VLTL, TPVL, and TPCVL) used in the analysis of the follow-up workshop survey responses are given in Table 7. The highest average score was obtained for Teachers' Perception about the benefits of Virtual Labs (TPVL) (M = 82.14, SD = 18.32), followed by Virtual Lab Adoption and Implementation (VLAI, M = 72.89, SD = 13.02), use of Virtual Labs for Teaching and Learning (VLTL, M = 63.79, SD = 18.55), Teachers' Perceptions about the Challenges faced in using Virtual Labs (TPCVL, M = 53.28, SD = 18.32), and Teachers' Perceptions about Students' use of Virtual Labs (PSVL, M = 53.22, SD = 14.63).

Table 7: Descriptive statistics of the questionnaire categories

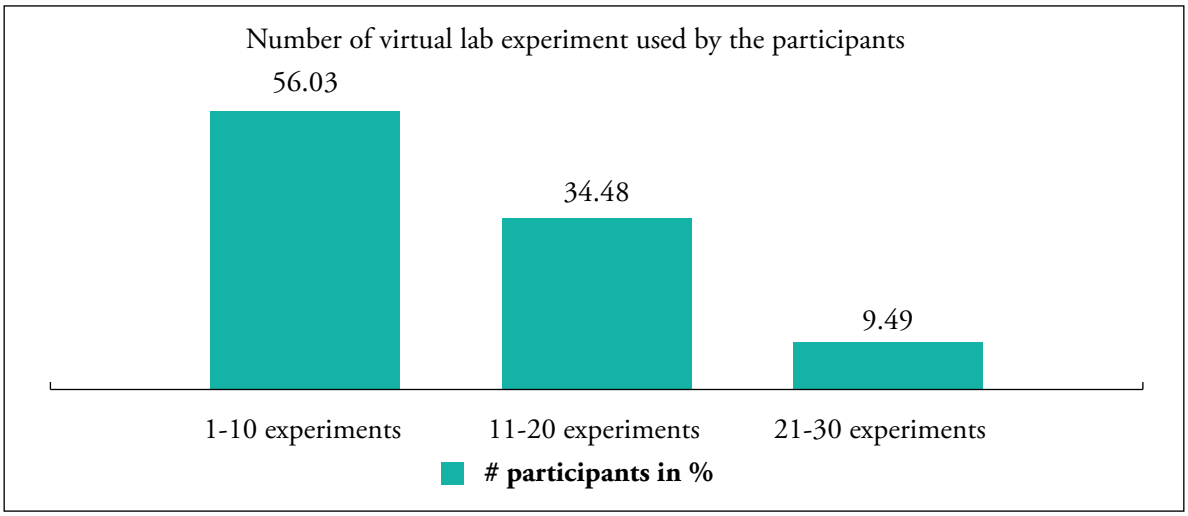
Category	Mean score in per cent	N	SD
PSVL	53.22	108	14.63
VLAI	72.89	108	13.02
VLTL	63.79	108	18.55
TPVL	82.14	109	12.27
TPCVL	53.28	108	18.32

Teachers' use of Virtual Labs

87.75 per cent of the participants had used virtual labs. Most of them (85 per cent) had used Amrita virtual labs, while 13 per cent had used PhET simulations and 2 per cent had used other online labs. The report also analysed how many experiments were used by the participants for their teaching and learning purposes (Figure 21). 56.03 per cent had used 1-10 virtual lab experiments, 34.48 per cent had used 11 – 20 virtual lab experiments, and 9.49 per cent had used 21 – 30 virtual lab experiments. 68.96 per cent of the participants accessed virtual labs using laptops, 20.68 per cent used mobile phones, and 10.34 per cent used tablets. On the question 'how often do you use virtual labs in your teaching activities' many of the participants said that they used virtual labs either occasionally (41 per cent) or rarely (36 per cent) in their teaching activities. Participants were categorized into five groups based on their perceived level of

proficiency in using virtual labs: 'no experience with virtual labs' (9 per cent), 'attempted to use virtual labs but still require help on a regular basis (21 per cent), 'able to perform basic functions in a limited number of virtual lab experiments' (41 per cent), 'very proficient in using a wide variety of virtual labs' (1 per cent), and 'have the ability to completely use virtual labs' (28 per cent).

Figure 21: Number of experiments used by the participants



Teachers' Perceptions about Students' use of Virtual Labs (PSVL)

Teachers' perceptions about students' use of virtual labs was were measured using five items. The Cronbach alpha was calculated at 0.82 which was taken as acceptable (Cronbach, 1951). The 5-point Likert scale ranged from Strongly agree (5 points) to Strongly disagree (1 point). The mean score of the items ranged from 3.32 to 3.98, which indicates that the participants were inclined towards agreeing with statements reflecting students' use of virtual labs. The highest mean score (3.98) was obtained for the statement 'Students have access to the devices and internet connectivity needed for virtual labs.' This indicates teachers' perceptions about the availability of devices and internet connectivity for students to access virtual labs. Similarly, 46.54 per cent of the participants strongly agreed/agreed that 'Students used virtual labs for activities related to their course.' The descriptive statistics for the items are presented in Table 8.

Table 8: Teachers' perceptions about students' use of virtual labs

Statement	Frequency / per cent	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Std. deviation
Students have access to the devices and internet connectivity as needed for virtual labs	Freq.	36	41	21	7	1	3.98	0.94
	per cent	31.03	35.34	18.10	6.03	0.86		
Students are aware of how to access and use virtual labs	Freq.	12	38	36	16	5	3.33	1.01
	per cent	10.34	32.75	31.03	13.79	4.31		
Students use virtual labs for self-learning	Freq.	13	37	33	20	4	3.32	1.03
	per cent	11.20	31.89	28.44	17.24	3.44		

Students use different virtual labs in addition to the Virtual Labs initiative of the Ministry of Education, Government of India for enriching their learning	Freq.	10	39	36	18	3	3.33	0.96
	per cent	8.62	33.62	31.03	15.51	2.58		
Students use virtual labs for activities related to their courses	Freq.	13	41	39	11	3	3.46	0.93
	per cent	11.20	35.34	33.62	9.48	2.58		

Virtual Lab Adoption and Implementation (VLAI)

Eight items were included with respect to virtual lab adoption and implementation in the teaching and learning process. The highest mean score (3.96) was obtained for the item 'There is a positive overall effect of adoption of virtual labs in my teaching.' This indicates the positive impact of virtual labs on faculty members' teaching activities. Participants reported that they used virtual labs for self-learning (M = 3.87), and fulfilment of academic requirements for students (M = 3.74). Support from the institution played an important role in the adoption and implementation of virtual labs. 62.06 per cent of the participants strongly agreed/ agreed that their institution valued the use of virtual labs for teaching and learning (M = 3.81). Table 9 gives the statistics for the items used in the survey.

Table 9: Teachers' perceptions about virtual lab adoption and implementation

Statement	Frequency / per cent	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Std. deviation
I adopt virtual labs for my teaching as they fulfil the academic requirements of my students	Freq.	18	54	27	8	1	3.74	0.85
	per cent	15.51	46.55	23.27	6.89	0.86		
My institution values the use of virtual labs for teaching and learning	Freq.	18	54	33	1	1	3.81	0.75
	per cent	15.51	46.55	28.44	0.86	0.86		
There is adequate infrastructural and technical support at my institution for using virtual labs	Freq.	16	42	34	12	3	3.52	0.97
	per cent	13.79	36.20	29.31	10.34	2.58		
I use virtual labs as a pre-lab session	Freq.	12	49	33	11	2	3.54	0.89
	per cent	10.34	42.24	28.44	9.48	1.72		
I use virtual labs as a post-lab session	Freq.	8	42	38	13	5	3.33	0.95
	per cent	6.89	36.20	32.75	11.20	4.31		
I use virtual labs for assignments to promote active learning	Freq.	15	49	33	9	1	3.63	0.86
	per cent	12.93	42.24	28.44	7.75	0.86		
I use virtual labs for self-learning	Freq.	23	55	23	5	1	3.87	0.83
	per cent	19.82	47.41	19.82	4.31	0.86		
There is a positive overall effect of adopting virtual labs in my teaching	Freq.	26	55	22	4	0	3.96	0.77
	per cent	22.41	47.41	18.96	3.44	0		

Use of Virtual Labs for Teaching and Learning (VLTL)

The dimension measuring the use of different features of virtual labs for teaching and learning contained 12 items. The Cronbach alpha score was calculated at 0.76. The scale points ranged from 'To a very great extent' (5 points) to 'Not at all (1 point). The mean score ranged from 3 to 3.44, which indicates that different features of virtual labs had been incorporated to some extent in teaching and learning. The highest mean score (3.44) was for the item 'I use simulations from virtual labs for teaching.' 51.71 per cent of the participants reported that they used virtual lab simulations for their teaching purposes to a great/very great extent. The mean score for 'Use of animation in teaching' (3.42) shows that most of the participants used animations from the Virtual Lab Platform. The least score (3.00) was obtained for 'Use of assignment questions from virtual labs.' Table 10 gives the corresponding statistics.

Table 10: Use of virtual labs for teaching and learning

Statement	Frequency / per cent	To a Very Great Extent	To a Great Extent	To Some Extent	Only to a Little Extent	Not At All	Mean	Std. deviation
I use theoretical notes from virtual labs for my teaching	Freq.	10	23	47	12	15	3.01	1.12
	per cent	8.62	19.82	40.51	10.34	12.93		
I use procedural notes from virtual labs for teaching	Freq.	10	31	39	16	12	3.10	1.12
	per cent	8.62	26.72	33.62	13.79	10.34		
I use assessment questionnaires from virtual labs to assess students	Freq.	11	27	39	18	13	3.05	1.14
	per cent	9.48	23.27	33.62	15.51	11.20		
I use simulations from virtual labs for teaching	Freq.	19	41	26	11	10	3.44	1.17
	per cent	16.37	35.34	22.41	9.48	8.62		
I use assignments based on virtual labs to assess students	Freq.	8	29	36	25	10	3.00	1.08
	per cent	6.89	25	31.03	21.55	8.62		
I use references provided in virtual labs	Freq.	13	35	29	18	12	3.17	1.18
	per cent	11.20	30.17	25	15.51	10.34		
I use animations from virtual labs for teaching experiments	Freq.	18	38	32	9	10	3.42	1.14
	per cent	15.51	32.75	27.58	7.75	8.62		
I use data tables/sheets from virtual labs for calculations	Freq.	13	28	38	16	13	3.11	1.17
	per cent	11.20	24.13	32.75	13.79	11.21		
I use video lectures from virtual labs for teaching	Freq.	18	36	30	14	10	3.35	1.17
	per cent	15.51	31.03	25.86	12.06	8.62		
I am able to find virtual labs on the web as per my requirements	Freq.	16	31	43	11	6	3.37	1.04
	per cent	13.79	26.72	37.06	9.48	5.17		
I try to engage students with the help of online activities like assignments and quizzes using virtual labs	Freq.	14	39	34	13	7	3.37	1.06
	per cent	12.06	33.62	29.31	11.20	6.03		
I use the virtual lab LMS module for online assessments	Freq.	8	30	43	15	10	3.10	1.05
	per cent	6.89	25.86	37.06	12.93	8.62		

Teachers' Perceptions about the Benefits of Virtual Labs (TPVL)

Thirteen items were included to measure teachers' perceptions about the benefits of virtual labs. The Cronbach alpha score was calculated at 0.81, which shows that the items were internally consistent. The scale points ranged from 'Strongly agree' (5 points) to 'Strongly disagree' (1 point). The average score for all the items except negative questions had a score of 4.13, which shows that the teachers were inclined towards agreeing with the statements regarding benefits of virtual labs. The highest mean score (4.39) was obtained for the statement 'Training workshops on virtual labs increased my awareness about virtual labs.' This shows the importance of the training programme in increasing awareness about virtual labs. The participants also affirmed that virtual labs will improve students' laboratory performance if used as a pre-laboratory session. A negatively worded statement was introduced: 'Use of virtual labs is not an effective way to promote student engagement and motivation.' The mean score for this question (2.83) shows that most of the participants did not agree with the statement. Table 11 gives the statistics of teachers' perceptions about the benefits of virtual labs.

Table 11: Teachers' perceptions about the benefits of virtual labs

Statement	Frequency / per cent	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Mean	Std. deviation
The training workshops on virtual labs increased my awareness amount virtual labs	Freq.	54	46	8	0	1	4.39	0.71
	per cent	46.55	39.66	6.90	0.00	0.86		
After participating in the training workshops on virtual labs, there has been a positive change in my experience and insights about virtual labs	Freq.	46	46	14	2	1	4.23	0.81
	per cent	39.66	39.66	12.07	1.72	0.86		
Use of virtual labs is a valuable instructional tool	Freq.	40	58	9	0	1	4.26	0.69
	per cent	34.48	50.00	7.76	0.00	0.86		
Virtual labs can help improve students' understanding of critical concepts and ideas	Freq.	41	57	9	1	1	4.25	0.72
	per cent	35.34	49.14	7.76	0.86	0.86		
Use of virtual labs enables teachers to explore different teaching methods	Freq.	42	58	8	0	1	4.28	0.68
	per cent	36.21	50.00	6.90	0.00	0.86		
Use of virtual labs helps enhance my professional development	Freq.	42	53	11	2	1	4.22	0.77
	per cent	36.21	45.69	9.48	1.72	0.86		
Virtual labs help students improve their laboratory performance once the students use the virtual labs as a pre-lab session	Freq.	44	54	7	2	1	4.28	0.75
	per cent	37.93	46.55	6.03	1.72	0.86		
Use of virtual labs helps in improving students' academic performance	Freq.	37	54	16	0	1	4.17	0.74
	per cent	31.90	46.55	13.79	0.00	0.86		

Use of virtual labs is not an effective way of promoting student engagement and motivation	Freq.	11	13	55	0	26	2.83	1.23
	per cent	9.48	11.21	47.41	0	22.41		
Virtual lab-based activities promote interpersonal skills among students such as the ability to relate or work with others in a team	Freq.	32	53	18	4	0	4.06	0.79
	per cent	27.59	45.69	15.52	3.45	0.00		
Adopting virtual labs eases the pressure on me as a teacher	Freq.	30	48	24	5	1	3.94	0.88
	per cent	25.86	41.38	20.69	4.31	0.86		
Using virtual labs makes teachers feel more competent as educators	Freq.	30	58	18	3	0	4.06	0.74
	per cent	25.86	50.00	15.52	2.59	0.00		
Virtual labs can accommodate diversities in students' preferred learning styles	Freq.	34	54	17	4	0	4.08	0.78
	per cent	29.31	46.55	14.66	3.45	0.00		

Teachers' Perceptions about the Challenges Faced in using Virtual Labs (TPCVL)

Teachers' perceptions about the challenges faced in using virtual labs was measured through 11 items. The Cronbach alpha score was calculated at 0.89 showing internal consistency among the items. The scale points ranged from 'Least important' (1 point) to 'Most important (5 points). The mean score of the items ranged from 2.73 to 2.91. The highest mean score (2.91) was obtained for the item 'Cannot find existing virtual labs on topics of my interest.' This result is aligned with the feedback from the participants that they could not find virtual lab experiments related to specific disciplines such as oceanography. Some participants said that experiments which were a part of their curriculum were not available on the Virtual Lab Platform. The Virtual Lab Platform offers experiments commonly taught by universities in India. One of the participants observed: 'Biology O level syllabus experiments are not there.' The second highest mean score (2.82) was obtained for the statement 'Limited training and capacity building opportunities in virtual labs.' Many teachers reported that they required more training on how to use virtual labs. Due to time constraints, the workshops did not cover all the virtual lab experiments. An examination of the end-of-workshop feedback corroborates this finding. Participants reported that they required additional training to explore and learn more experiments from virtual labs. The statistics for each item are given in Table 12.

Table 12: Teachers' perceptions about the challenges faced in using virtual labs

Statement	Frequency / per cent	5 (most important)	4	3	2	1 (least important)	Mean (Std. deviation)	Ranking
Limited knowledge about using virtual labs in my teaching and learning activities	Freq.	7	14	43	29	12	2.76 (1.04)	6
	per cent	6.03	12.06	37.06	25	10.34		
Inadequate technical support for resolving day-to-day issues in the use of virtual labs	Freq.	9	17	35	30	13	2.79 (1.12)	4
	per cent	7.75	14.65	30.17	25.86	11.21		

Virtual labs are not available for some disciplines	Freq.	12	13	36	28	16	2.78 (1.19)	5
	per cent	10.34	11.20	31.03	24.13	13.79		
Cannot find existing virtual labs on topics of my interest	Freq.	15	13	31	36	8	2.91 (1.17)	1
	per cent	12.93	11.21	26.72	31.03	6.89		
It is difficult to use virtual labs due to lack of ICT skills	Freq.	7	10	36	36	16	2.58 (1.07)	11
	per cent	6.03	8.62	31.03	31.03	13.79		
Lack of interest among teachers to engage in virtual lab activities	Freq.	9	12	39	34	11	2.75 (1.07)	7
	per cent	7.75	10.34	33.62	29.31	9.48		
Excessive workload for teachers	Freq.	10	8	37	32	18	2.61 (1.14)	10
	per cent	8.62	6.89	31.89	27.58	15.51		
Lack of incentives and recognition for teachers who engage in virtual lab-related activities	Freq.	11	9	37	37	11	2.73 (1.10)	8
	per cent	9.48	7.75	31.89	31.89	9.48		
More time and effort is needed to plan learning activities using virtual labs	Freq.	9	11	38	37	10	2.73 (1.05)	9
	per cent	7.75	9.48	32.75	31.89	8.62		
Limited training and capacity building opportunities in virtual labs	Freq.	10	12	37	40	5	2.82 (1.02)	2
	per cent	8.62	10.34	31.89	34.48	4.31		
Limited institutional support for virtual lab adoption	Freq.	9	13	37	37	7	2.80 (1.03)	3
	per cent	7.75	11.20	31.89	31.89	6.03		

Effect of Age, Gender, and Years of Experience in Perceptions about Virtual Labs

Effect of age, gender, and teaching experience on PSVL, VLAI, VLTL, TPVL, and TPCVL was analysed using one way ANOVA. Table 13 gives the ANOVA analysis of age category, while Tables 14 and 15 give the ANOVA analysis of gender and teaching experience respectively. From the analysis, it is evident that there is no statistically significant difference in teachers' perceptions with respect to age, gender, or years of teaching experience.

Table 13: One way ANOVA on age category

		Sum of Squares	df	Mean Square	F	Sig.
PSVL	Between Groups	613.715	4	153.429	.711	.586
	Within Groups	22013.574	102	215.819		
	Total	22627.290	106			
VLAI	Between Groups	284.513	4	71.128	.409	.802
	Within Groups	17758.478	102	174.103		
	Total	18042.991	106			

VLTL	Between Groups	576.938	4	144.234	.409	.802
	Within Groups	36007.123	102	353.011		
	Total	36584.060	106			
TPVL	Between Groups	861.922	4	215.480	1.488	.211
	Within Groups	14768.184	102	144.786		
	Total	15630.106	106			
TPCVL	Between Groups	216.026	4	54.007	.154	.961
	Within Groups	35681.958	102	349.823		
	Total	35897.984	106			

Table 14: One way ANOVA on gender category

		Sum of Squares	df	Mean Square	F	Sig.
PSVL	Between Groups	360.244	1	360.244	1.692	.196
	Within Groups	22566.423	106	212.891		
	Total	22926.667	107			
VLAI	Between Groups	291.940	1	291.940	1.733	.191
	Within Groups	17860.085	106	168.491		
	Total	18152.025	107			
VLTL	Between Groups	720.740	1	720.740	2.115	.149
	Within Groups	36128.334	106	340.833		
	Total	36849.074	107			
TPVL	Between Groups	97.760	1	97.760	.661	.418
	Within Groups	15667.723	106	147.809		
	Total	15765.483	107			
TPCVL	Between Groups	140.279	1	140.279	.415	.521
	Within Groups	35803.247	106	337.766		
	Total	35943.526	107			

Table 15: One way ANOVA on years of teaching experience

		Sum of Squares	df	Mean Square	F	Sig.
PSVL	Between Groups	359.448	3	119.816	.552	.648
	Within Groups	22567.219	104	216.992		
	Total	22926.667	107			
VLAI	Between Groups	289.370	3	96.457	.562	.642
	Within Groups	17862.656	104	171.756		
	Total	18152.025	107			
VLTL	Between Groups	829.897	3	276.632	.799	.497
	Within Groups	36019.177	104	346.338		
	Total	36849.074	107			

TPVL	Between Groups	245.779	3	81.926	.549	.650
	Within Groups	15519.704	104	149.228		
	Total	15765.483	107			
TPCVL	Between Groups	1940.271	3	646.757	1.978	.122
	Within Groups	34003.255	104	326.954		
	Total	35943.526	107			

Interview Responses

Many research studies have focused on identifying teachers' knowledge and beliefs and on understanding how they affect their teaching actions (Kang & Wallace, 2005; Munby et al., 2001) Teachers' knowledge and beliefs about virtual labs are critical for adopting and implementing virtual labs. A semi-structured interview provided insight into teachers' knowledge and perceptions about virtual labs. The goal of the interview was analysing teachers' perceptions about adopting and implementing virtual labs as also challenges and issues related to the use of virtual labs. Three experienced science teachers were interviewed for this. The interviewees appreciated CEMCA's role in supporting their institutions by organizing online workshops on virtual labs. Table 16 gives a summary of the interviews with the teachers.

Table 16: Interview responses

	Interview Comments
Teacher 1	*I didn't use virtual labs before the online workshops organized by CEMCA. It was a very good opportunity to learn about virtual labs. Students also provided positive responses while we were taking classes using virtual labs.* *Our students do not have a proper school lab facility, they have a lot of ideas, but we have some limitations to show YouTube videos. When we introduced virtual labs to the students, they felt these were real labs, they explained to the others that they had performed virtual lab experiments, which motivated other students.* *It is a very good initiative by the Ministry of Education, Government of India for developing virtual labs and I appreciate CEMCA for organizing the online workshops on virtual labs. So many teachers didn't use virtual labs before the awareness programme. During the workshops, we got more information about virtual labs which helped us understand different aspects of virtual labs. We need more workshops on virtual labs and only then will teachers become aware of them.* *Once students use virtual labs, it will help increase their confidence levels and they will become self-learners.* *The only drawbacks are the infrastructure at our institute, low internet connection, and fewer computer facilities.*
Teacher 2	*I had not heard about virtual labs before the workshops organized by CEMCA. Virtual labs are very interesting and motivate students to do practical laboratory work.* *There are some difficulties in the effective implementation of virtual labs. Students have tablets but are not able to access most of the websites. Also, slow internet affects the implementation of virtual labs. Most of the teachers are not aware of virtual labs.* *Only a few schools have physical lab facilities. Even though the lab is available, chemicals are not available for individual practice. In such a case, virtual labs are really helpful as students can perform experiments like in a real laboratory.* *CEMCA in collaboration with Amrita University provided wonderful workshops on virtual labs. CEMCA's initiative was very helpful in understanding virtual labs and their benefits.* *Most of the teachers working here are not aware of virtual labs. It will be good to provide a virtual lab awareness programme at the beginning of every semester.*

Teacher 3	*My colleagues participated in this workshops and I took their opinion and feedback. They said the programme was very helpful. So, I too used virtual labs and I am satisfied with the features provided on the platform. In this COVID-19 situation, I am not going to school. Instead, I am teaching lab courses from home.* *Most of the experiments included in my course were there, though a few experiments needed to be added. Virtual labs are really helpful for me because in the physical laboratory, most of the equipment is not working properly. But in virtual labs students find it very interesting and they can repeat the experiments any number of times.* *I have used virtual labs for inorganic chemistry. Students are very satisfied. Once they go through it and they enjoy virtual lab experimentation.* *In my opinion, only a few teachers are aware of virtual labs, more training sessions are needed for promoting virtual labs among all the faculty members.* *One suggestion for the Virtual Lab Platform, give more references in each lab that will be helpful and save time in finding references from the library or from Google.*

Suggestions for Promoting the use of Virtual Labs

The study analysed suggestions by the participants for increasing the use of virtual labs. Most of the participants (75 per cent) suggested providing more training programmes on virtual labs to use and integrate virtual labs as part of teaching and learning. 54.31 per cent of the respondents reported that ongoing technical support related to experiments should be provided. None of the participants reported providing incentives/credit for the use of virtual labs. 61.21 per cent of the participants suggested that virtual labs should be integrated in the curriculum, while 43.10 per cent proposed that a mechanism should be developed for monitoring virtual lab activities for teaching purposes. 50.86 per cent of the participants suggested developing new virtual labs for disciplines not yet covered in the existing virtual labs, while 55.17 per cent suggested strengthening quality assurance for virtual labs. This includes modifying the theory and procedure sections of virtual labs. Table 17 gives the frequency and percentage of responses for each of the suggestions.

Table 17: Suggestions for promoting the use of virtual labs

Suggestions	Frequency	per cent of responses
Provide ongoing technical support	63	54.31
Provide more training opportunities for teachers on use and integration of virtual labs	87	75.00
Provide incentives/credit/recognition to teachers engaged in the use of virtual labs	0	0.00
Virtual labs should be integrated in the curriculum	71	61.21
Develop a mechanism for monitoring virtual labs' activities	50	43.10
Develop new virtual labs for disciplines not covered in existing virtual labs	59	50.86
Strengthen quality assurance for virtual labs	64	55.17

Conclusion

Virtual laboratories are computer-based, interactive environments that allow a user to perform a set of tasks that would normally be performed in a laboratory, through an interface that supports simulation, animation, and in some cases remote control of real laboratory hardware. Such laboratories are seen as a solution to educational challenges where there is lack of infrastructure to provide good laboratory facilities to students. Virtual labs can be used for complementing physical labs. As media-rich online platforms for performing experiments remotely, virtual or online labs enable students to learn at their own pace and enthuse them to conduct experiments. Virtual labs also provide a complete Learning Management System where the students can avail of various tools for learning, including additional web resources, video lectures, animated demonstrations, and self-evaluation.

This study evaluated the virtual lab workshops organized by CEMCA. It analysed participant feedback from an end-of-workshop survey and a follow-up evaluation. Using a mixed-methods approach, the study focused on six dimensions - teachers' use of virtual labs, teachers' perceptions about students' use of virtual labs, virtual lab adoption and implementation by teachers, use of virtual labs for teaching and learning, teachers' perception about the benefits of virtual labs, and teachers' perceptions about the challenges faced in using virtual labs. The results show that the participants were positively inclined towards the use, adoption, implementation, and promotion of virtual labs. It is interesting to note that there was no significant difference observed in teachers' perceptions with respect to age, gender, and years of teaching experience. The findings from this report highlight the role of virtual labs in providing quality opportunities for laboratory-based education.

Laboratory education plays an important role in STEM disciplines. Virtual labs offer a practical solution to the challenges faced by traditional labs as reflected in the responses given by the teachers who took part in the study. The results of this survey provide a useful indication of teachers' perceptions about virtual labs and what they value the most. Virtual labs can be a solution for institutions which lack sufficient facilities to provide quality education. This can supplement existing teaching-learning practices and promote flexible opportunities for laboratory-based learning.

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Appendix

Appendix A: Survey Questionnaire

Dear Participants,

As part of a post-workshop initiative, we are conducting a survey among faculty members who attended the online workshops on virtual labs organised by the Commonwealth Educational Media Centre for Asia (CEMCA).

The aim of this survey is to understand how virtual labs are being used in teaching and learning, and the related benefits and challenges. We request for about 10-15 minutes of your time to respond to this survey.

There are no anticipated risks to your participation. Your participation is completely voluntary. Please feel free to skip a question in case you choose not to respond to it.

All the responses will be kept confidential, and results will be presented at an aggregate level. We look forward to your support as this will help us to improve the virtual labs and upcoming training programmes.

If you have any concerns, please feel free to contact us. We thank you for your support.

Best regards,

Part A: General information

Full Name:

Email ID:

Gender:	M		F		Others	

Your age in years:	18-25		26-35		36-45		46-55		56 or older	

How many years of professional experience do you have?

1-5 years		6-10 years		11-15 years		16 years or more	

Your Designation:

Your Major Discipline area:

a. Physical Sciences

b. Chemical Sciences

c. Biological Sciences

d. Medical and Health Sciences

e. Engineering and Technology

f. Agriculture

g. Management and Commerce

h. Education

i. Social Sciences and Humanities

j. Others (please specify).....

Name of Institution:.....

Country:.....

The average class size that you teach

A. Less than 25 students

B. 25-50 students

C. More than 50 students

Preferred teaching methodology

A. Largely teacher-directed (e.g., teacher-led discussion, lecture)

B. More teacher-directed than student-centred

C. Balance between teacher-directed and student-centred activities

D. More student-centred than teacher-directed

E. Largely student-centred (e.g., cooperative learning, discovery learning)

Part B: Teacher use of virtual lab

1. Have you accessed any virtual labs?

   a. Yes

   b. No

2. If yes, please name the virtual lab website/platform(s) you have accessed.

   .....

3. Have you performed any virtual lab experiments?

   a. Yes

   b. No

   c.

4. If yes, how many experiments have you performed?

   a. 1-10 experiments

   b. 11-20 experiments

   c. 21-30 experiments

   d. 31 or more

5. List the names of the experiments that you have used in virtual labs.

   .....

6. Which of the following devices do you use for virtual labs?

   a. A laptop/desktop computer

   b. A tablet

   c. A smartphone

7. Please indicate how often you use virtual labs in your teaching activities.

   a. Not at all

   b. Rarely

   c. Occasionally

   d. Frequently

   e. All the time

8. Select the level that you think best describes your proficiency as a user in relation to virtual labs.

   a. I have no experience with virtual labs.

   b. I have attempted to use virtual labs, but I still require help on a regular basis.

   c. I am able to perform basic functions in a limited number of virtual lab experiments.

   d. I have the ability to competently use virtual labs

   e. I am very proficient in using a wide variety of virtual labs

Student use of virtual labs

For each of the following statements, please select the option that best shows your perception (SA = Strongly Agree, A =Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree).

Statement	SA	A	N	D	SD
Students have access to the devices and internet connectivity as needed for virtual labs					
Students are aware of how to access and use virtual labs					
Students use virtual labs for self-learning					
Students use different virtual labs in addition to the Virtual Labs initiative of the Ministry of Education, Govt.of India for enriching their learning					
Students use virtual labs for activities related to my course					

Virtual lab adoption and implementation

Please tick the following statements on the basis of your perception (SA = Strongly Agree, A =Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree)

Statement	SA	A	N	D	SD
I adopt virtual labs for my teaching as they fulfil the academic requirements of my students					
My institution values the use of virtual labs for teaching and learning					
There is adequate infrastructural and technical support at my institution for use of virtual labs					
I adopt virtual labs as a pre-lab session					
I adopt virtual labs as a post-lab session					
I adopt virtual labs for assignments to promote active learning					
I use virtual labs for self-learning					
There is a positive overall effect of adoption of virtual labs in my teaching					

Use of virtual labs for teaching and learning

Please tick the following statements on the basis of your perception (VGE = To a Very Great Extent, GE = To a Great Extent, SE = To Some Extent, OLE = Only to a Little Extent, NA = Not At All)

Statement	VGE	GE	SE	OLE	NA
I use theoretical notes from the virtual labs for my teaching					
I use procedural notes from the virtual labs for teaching					
I use assessment questionnaires from the virtual labs to assess students.					
I use simulations from the virtual labs for teaching.					
I use assignments based on virtual labs to assess students					
I use references provided in the virtual labs					
I use animations from the virtual labs for teaching experiments.					
I use data tables/sheets from the virtual labs for the calculations					
I use video lectures from the virtual labs for teaching					
I am able to find virtual labs on the web as per my requirement					
I try to engage the students with the help of online activities like assignments and quizzes, using virtual labs					
I use the virtual Lab LMS module for online assessment					

Teachers' perception towards benefits of virtual labs

For each of the following statements, please select the option that best shows your perception (SA = Strongly Agree, A =Agree, N = Neutral, D = Disagree, and SD = Strongly Disagree).

Statement	SA	A	N	D	SD
The training workshops on virtual labs increased my awareness of virtual labs					

After participating in the training workshops on virtual labs, there has been a positive change in my experience and insights about virtual labs					
Use of virtual labs is a valuable instructional tool					
Virtual labs can help to improve students' understanding of critical concepts and ideas					
Use of virtual labs enables teachers to explore different teaching methods					
Use of virtual labs helps to enhance my professional development					
Virtual labs help students to improve their laboratory performance once the students use the virtual lab as a pre-lab session					
Use of virtual labs helps in improving the academic performance of students					
Use of virtual labs **is not an** effective way to promote student engagement and motivation					
Virtual lab-based activities promote the interpersonal skills of students such as the ability to relate or work with others in a team					
Adopting virtual labs eases the pressure on me as a teacher					
Using virtual labs makes teachers feel more competent as educators					
Virtual labs can accommodate diversities in students' preferred learning styles					

Teachers' perception towards challenges in use of virtual labs

In your opinion, what are the issues or challenges that are important for the use and promotion of virtual labs? Please rank each of the issues listed below in order of priority with **1** as **most important** and **5** as **least important**. If you think that some issues have the same ranking, please assign accordingly. In case you feel there are important challenges other than the ones listed here, please specify and rank them.

	1 (most important)	2	3	4	5 (least important)
Limited knowledge for using virtual labs in my teaching and learning activities					
Inadequate technical support to resolve day-to-day issues in the use of virtual labs					
Virtual labs are not available for some disciplines					
Cannot find existing virtual labs on topics of my interest					
It is difficult to use virtual labs due to lack of ICT skills					
Lack of interest among teachers to engage in virtual lab activities					
Excessive workload of teachers					
Lack of incentives and recognition for teachers who engage in virtual lab-related activities					
More time and effort is needed to plan learning activities using virtual labs					
Limited training and capacity building opportunities in virtual labs					
Limited institutional support for virtual lab adoption					
Others (Please specify) _____					

Suggestions

Please share your suggestions for promoting the use of virtual labs. Please tick all the suggestions you think are relevant and add any further suggestions:

- Provide ongoing technical support.
- Provide more training opportunities for teachers on use and integration of virtual labs.
- Provide incentives/credit/recognition to teachers engaged in use of virtual labs.
- Virtual labs should be integrated in the curriculum.
- Develop a mechanism for monitoring virtual lab activities.
- Develop new virtual labs for disciplines not covered in existing virtual labs.
- Strengthen quality assurance for virtual labs.
- Others (please specify) _____

Appendix B: Interview schedule

Dear Participants,

Thank you for your kind cooperation in sharing your feedback about virtual labs. We would like to conduct a short online interview (10 - 15 Minutes) with you regarding the use of virtual labs and your reflection on the training program on virtual labs. Kindly share your convenient date and time for the short online interview.

Interview questions

Q. 1 Have you used virtual labs for teaching and learning?

- If yes, please describe your experiences in using virtual labs.
- If not, what are the reasons for not using virtual labs in teaching and learning?

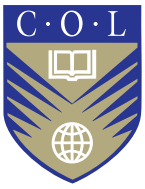
Q. 2 In your opinion, what is the impact of virtual labs on the learning experiences of students?

- How are the students getting benefitted?
- In case of your university, how many students are likely to be benefitted?
- If not benefitted, what could be the possible reasons?

Q.3 What are your reflections on initiatives taken by CEMCA for awareness creation and capacity building in use of virtual labs? Have the initiatives of CEMCA helped in understanding different aspects of virtual labs? If yes, please elaborate. If not, what are the reasons?

Q.4 What is your opinion on the promotion, development, and use of virtual labs?

Q.5 What changes do you visualise after adoption of virtual labs in your institution?



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