The 5I’s of Virtual Technologies in Laboratory Teaching for Faculties of Higher Education in Kerala

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Abstract

In this paper, the effectiveness of training faculty in laboratory teaching (the teaching of science in a laboratory setting using experiments and similar exercises) through the use of Information and Communications Technology (ICT)—virtual technologies for faculties in institutions of higher education in the Indian state of Kerala—was evaluated and measured. The efficacy of employing ICT to train teachers in higher education is important, and we have identified 5I factors (innovative, interactive, involvement, informative, and influential) to help ascertain the effectiveness of such technology training during pandemic teaching. The laboratory learning using VL can describe the student’s engagement in the online learning process. This work more specifically identifies how ICT helps in laboratory teaching and identifies the critical pedagogical aspects of the ICT. If the technology has these 5I factors, then it will be an effective teaching method for laboratory learning. Here, we used the ICT-virtual labs in science as the technology to evaluate these five factors. The research first began by conducting an ethnicity profile of science teachers in the middle and high/secondary stages of school consisting of classes VII, IX, and X (i.e., students of ages 11 to 15). To evaluate the use of VL in the 5I framework, the faculties in science were divided into experimental and control groups (n = 101). The experimental group practiced in a virtual lab in the first stage, but the control group did not. Test I was then performed on both groups. In the second stage, both groups practiced with real lab equipment, and test II was conducted on both groups. The tests and other data from the two groups were statistically analyzed using independent t tests. There were notable differences between the experimental and control groups: in terms of time for understanding the concepts behind the experiment, time for doing the experiment, and accuracy in results, with the experimental group performing significantly better. On the other hand, there was no significant difference between the two groups in task completion accuracy. Overall, there was a beneficial transfer of training from the virtual lab exercise to the real lab, with the experimental group’s average score being higher.

Keywords Online learning · Pre-college science teachers · Virtual laboratories

Introduction

Online learning is sometimes portrayed as a less desirable choice that gives a lower-quality education than face-to-face instruction (Hodges et al., 2020), and an EDUCAUSE survey indicated similar negative sentiments toward totally online learning (Hodges et al., 2020; Pomerantz & Brooks, 2017).

Flow theory has been used to address concerns of student learning engagement, motivation, satisfaction, exploration, and performance (Auld, 2014; Santos et al., 2018). Teachers needed to assure students’ capacity and motivation to work efficiently in their new learning online environments during the COVID-19 crisis (Hew & Cheung, 2010). Students can be motivated to better collaborate with multiple dimensions of the new virtual learning systems for better learning experiences (AlShamsi, 2021). Understanding visible and unseen heuristic techniques to identify underlying concepts is regarded difficult in the case of laboratory learning, particularly in science during pandemic times. Therefore, relationships between the teacher and the teaching environment will be the factors to get positive cognitive outcomes. Having a lab with multimedia-enhanced technology boosts
As per the 2011 census, Kerala is India’s most literate state, with a literacy rate of 93.91%. Kerala’s rural population density is quite low. For rural areas in the state, a household is classified as agricultural labor, and self-employed, regular wage, or salary earning as for urban. But the distinction in case between urban and rural students is related to their learning environment, infrastructure facility, and access to various educational resources rather than their intelligence. In the past decades, urban schools have various sorts of buildings, libraries, computer and science labs, digital and smart classrooms, and Internet facilities. At present, the government of Kerala is committed to enhancing educational outcomes for both urban and rural children. There are no fees at any level in schools owned or aided by the government. For quality education, the schools enable the implementation of smart classroom programs in the state by providing high-tech computer laboratories, laptops, and free Wi-Fi. Hence, in terms of resources and learning settings, rural and urban schools are very similar. However, there are a number of factors that can influence a student’s performance. In both the rural and urban sectors, improving educational quality with online learning can have a significant impact on an individual’s ability to efficiently improve and expand different opportunities.

The government or private trusts and individuals run schools in Kerala. According to the Kerala Education Department’s figures, there are over 1600 high schools and 72% belongs to rural areas. The Indian Certificate of Secondary Education (ICSE), the Central Board for Secondary Education (CBSE), or the Kerala State Education Board is accredited with each school. Most private schools use English as the medium of teaching, whilst government schools use either English or Malayalam. Teachers have a significant impact on educational quality during pandemic situations. Though online classes are popular in educational institutions, science teachers in schools of Kerala are concerned about the difficulty of conducting practical sessions for diverse disciplines, particularly in higher classes during pandemic times. Teachers are taught how to use virtual platforms, although they are skeptical about the efficiency of such labs; they claim that due to the pandemic, they have no other choice. Their hope is that students would gain an understanding of practical learning from online lessons, notwithstanding their limitations.

The current study focuses on the science faculties of high schools who teach classes VII, IX, and X in Kerala belonging to both rural and urban areas, having experimental/practical labs in the syllabi. In Kerala, schools adhere to syllabi mandated by the National Council of Educational Research and Training (NCERT), the Central Board of Secondary Education (CBSE), and the State Board. These organizations provide curriculum, scheme of studies, academic guidelines, enrichment activities, textual material, and capacity build-up programs to schools in Kerala. The science teacher has to teach all subjects of science including physics, chemistry, and biology. The school curriculum in Kerala’s higher education is taught in accordance with a very tight schedule, which has become more difficult to adhere to during the pandemic.

According to (Kolb et al., 2001), experimental learning is a cyclic process; therefore, time consumption and accuracy in experimental outcomes for laboratory learning are essential indicators of the student’s conceptual understanding and, cognitive, and reflective skill development. Furthermore, in order to improve student achievement, today’s circumstances need instructors who are also continuing to learn, develop, and evolve. They should be aware of what they require and how they will obtain the information or skills they desire, and they should reflect on their everyday experiences to enhance their teaching and learning skills (Suryani & Widyastuti, 2015).

Research Questions

Are virtual lab-like technologies beneficial to teaching and learning laboratory science subjects in Kerala?

Does teaching with ICT-virtual labs (VL) engage and enhance student learning as evaluated by the 5I’s framework?

Ethnicity Profile of Teachers in Kerala

A science teachers’ survey was part of a wider study that included teachers of physics, chemistry, and biology. The Science Teacher Inventory of Needs (STIN) was adopted to create the survey (Baird et al., 1994). There were three parts to the STIN questionnaire. Part A included two entries that identified teachers by the subjects they teach (physics, chemistry, and biology). Part B characterized the demographics of teachers and their schools (highest professional and academic qualifications, age, gender, teaching experience, and attitude towards online teaching). Part C contained 4 sections that covered (1) field of expertise, (2) goals of teaching, (3) learning and evaluation, and (4) instructions and planning. A total of 186 STIN questionnaires were distributed through the principals of 37 schools in Kerala and 101 surveys were completed and returned.

The ethnicity profile of science teachers in a high-literacy, democratic state like Kerala is relevant to the work of creating a framework of online teaching. In state schools, the science teacher in high/secondary level has to teach all subjects of science (i.e., physics, chemistry, and biology). The
STIN survey provides all of the important attributes regarding Kerala schools’ faculty ethnicity profile. For the returned and completed STIN surveys, the alpha coefficient of reliability and Guttman split-half reliability, used to determine the survey’s reliability, were found to be 0.81 and 0.76, respectively. The majority of science teachers who responded were from rural schools (63.3%), with only 36.6% from urban locations. Almost half (41.5%) of the teachers were between the ages of 31 and 40, with teachers older than 50 accounting for only 15.8% of those who replied. The number of teachers who responded who had been teaching science subjects for 11 years or more was 59. When compared to those who taught in rural schools, a higher proportion of teachers in urban had a teaching experience of more than 21 years (Table 1).

Factors of Virtual Laboratory Teaching

Analytics of teaching is a new theoretical method that blends teaching experience, visual analytics, and design-based research to help teachers enhance their analytic pedagogical skills to use data and evidence to improve the quality of their teaching (Ndukwe & Daniel, 2020). Getting students’ attention and keeping them active during class is crucial, but it is also difficult. Teachers should pay attention to new teaching methods and tools in order to make classrooms more participatory, interesting, and educational at the same time. Science teachers and curriculum developers have successfully used the existing 5E model of Duran (2004) (engage, explore, explain, elaborate, evaluate). The model consists of the cognitive stages of learning that can be used to design a science lesson at several levels (Duran, 2004; Galyon et al., 2011). Here, we introduce new factors for measuring VL technologies, suitable tool for teachers specific to laboratory practices that are the 5I framework (innovative, interactive, involvement, informative, and influential). The VL platform created to give students in Saudi Arabian middle schools access to a secure and engaging lab setting (Aljuhani et al., 2018). Similar to any e-learning system, it also makes teaching science easier by giving teachers and students tools for collaboration and communication. Additionally, it enables teachers to conduct laboratory tests to track their students’ progress and explore new experiments to expand their students’ knowledge. It is our hope that the 5I framework of VL will help teachers do their jobs better and provide more value to their students in Kerala. If the teacher uses technology-based laboratory teaching, they should ensure that all aspects of the 5I framework are realized (Fig. 1).

### Innovative

A learner with a unique need can benefit from a piece of lab equipment or a product of technology. In this context, teachers should know how to explore new technologies and equip new skills in teaching. The teachers are in charge of creating and/or using innovations, facilitating instructions, and incorporating technologies into laboratory learning. Innovative in this sense means it is user-friendly/risk-free and provides remote access for the students.

### Interactive

The process of intellectual interaction between a learner and a piece of lab equipment or a product of technology creates

| Table 1 Participants profiles in urban and rural schools in Kerala |

| Percentage of Urban attributes | Percentage of Rural attributes |
|--------------------------------|--------------------------------|
| # Teachers                     | 36.6                           | 63.3                           |
| Gender                         |                                |                                |
| Male                           | 37.8                           | 37.5                           |
| Female                         | 62.2                           | 62.5                           |
| Age                            |                                |                                |
| 25–30 yrs                      | 5.4                            | 3.1                            |
| 31–40 yrs                      | 51.0                           | 35.9                           |
| 41–50 yrs                      | 30.1                           | 43.8                           |
| Above 50 yrs                   | 13.5                           | 17.2                           |
| *Qualification                 |                                |                                |
| PG and B.Ed                    | 24.4                           | 56.3                           |
| PG and B.Ed and SET            | 75.6                           | 43.7                           |
| Year of Experience             |                                |                                |
| 4–10 yrs                       | 40.5                           | 42.2                           |
| 11–20 yrs                      | 29.8                           | 20.4                           |
| 21–30 yrs                      | 21.6                           | 26.5                           |
| Above 30 yrs                   | 8.1                            | 10.9                           |
| Attitude                       |                                |                                |
| Positive                       | 75                             | 98                             |
| Negative                       | 25                             | 2                              |

*PG post-graduation, B.Ed bachelor of education, SET state eligibility test for teachers
a stimulating and friendly environment. Teachers should implement interactive forms of teaching techniques in order to make the teaching interesting, and educational. Multimedia content helps to vary and enhance the learning process and leads to better knowledge retention in experimental teaching. Use of media-rich platforms can help communicate with the student more easily and provide a better understanding.

**Involvement**

The actual engagement of a learner using a piece of lab equipment or a product of technology. Teachers should prepare a plan for technology-based teaching where students can actively participate and achieve the goals: what to measure, how to perform, and what to analyze in order to solve a problem. This can be enhanced by hands-on training via multimedia technologies and the good experiences that such involvement encourages.

**Informative**

The learner can acquire the necessary knowledge and skills from a piece of lab equipment or a product of technology. Teachers can use technology to increase their productivity, introduce beneficial digital tools, and enhance student’s learning opportunities.

**Influential**

Creating a sense of reality that greatly cultivates a person’s interest and motivation towards technology products or lab equipment. The technological environments help a learner to develop their experimental teaching path in a more motivated way. The teacher should understand how technologies can have a role in an individual’s motivation and academic success for laboratory practices.

**Qualitative Analysis of Virtual Laboratories**

At all levels of education, technological developments are having a large impact in society. The traditional classroom is being disrupted by online courses, computerized instructional aids, software, and other developing technologies. Understanding how technological developments affect students, teachers, and schools is crucial to establishing methods and procedures for managing and implementing technology in the laboratory environment. Therefore, evaluation of the 5I framework is important in demonstrating the relevance of technologies in laboratory teaching for school teachers. In this study, we used virtual labs (VL) developed for school curriculums under the Ministry of Electronics and Information Technology (MeitY).

**Virtual Labs**

**(a) Innovative**

In this study, we adopted virtual experimental technology as an innovative tool for laboratory learning. Innovative in this context means to make students more enthusiastic while performing experiments. A virtual lab (VL) is a laboratory that is conducted using computer software and equipment that resembles that of a real laboratory. Virtual labs are a sort of technology that can be introduced into classrooms in order to improve current teaching methods (Kennepohl, 2010). The ICT-enabled virtual labs (ICT-VL) are supplemental
teaching tools that use dynamic multimedia technologies to teach science concepts in an experimental approach, to students (Achuthan et al., 2011, Achuthan et al., 2014). The students can conduct experiments independently without guidance from the teacher. However, the teacher still has a very important role as a motivator and guide to facilitate the use of virtual labs.

According to the research, traditional classroom teaching methods do not always have a positive impact on students learning science subjects (Erdemir, 2009). Moreover cognitive skills and sensory information processing among students has been significantly influenced by learning, using multimedia-enhanced interactive environments (Achuthan et al., 2015). The innovative approach of virtual labs in different fields of education is well documented (Faour & Ayoubi, 2018; Fernández-Avilés et al., 2016; Tüysüz, 2010). All these studies reveal and underline that virtual labs are an innovative technology that enhance student/teacher’s learning, and thus, we regard virtual labs as “innovative” as defined in the 5I framework.

ICT-VL has been argued to be beneficial for reasons that include low cost, efficiency, safety, versatility, and student convenience to access experiments (Auer et al., 2003). However, others have questioned the didactic efficiency of virtual labs (Corter et al., 2004). Of course, we disagree. ICT-VL gives students a set of tools to help them generate visual representations of real-world experiments, as well as a screen design that shows animations, videos and simulations of the experiments, and graphical results. Several researches have shown that virtual environments have a positive influence on students’ self-efficacy (Wang & Zhu, 2019; Wilde & Hsu, 2019). However, for students to fully benefit from using virtual labs, teachers need to be trained on how to assess facials of their students’ use of virtual labs. Hence, training of faculties in schools throughout Kerala was conducted as part of the study that evaluated the remaining I’s (interactive, involvement, informative, and influential) of the 5I framework.

**Faculty Training in Virtual Labs**

Testing the 5I’s framework, we have consolidated all the aspects of VL technologies in teaching and identified different parameters. For this, a training program using six virtual labs in science (2 each from physics, chemistry, and biology) was conducted. A total of 101 faculty members from departments of physics, chemistry, and biology (in approximate ratios of 2:1:1) were selected based on their completed and returned STIN surveys. Data were collected from the STIN surveys and then were divided into two groups, an experimental group (EG = 52) and a control group (CG = 49). In each group, male and female teachers were in the approximate ratios of 1:1 and 1:2, respectively. Self-assessment mode was used to evaluate training among teachers.

The extent to which knowledge, abilities, and attitudes are retained and applied from the training setting to the job environment is known as the transfer of training (Kluge et al., 2010). Several researchers on skill training have discussed how evidence of the transfer of training to the real world can be measured and how the resemblance of the training environment to the work environment is a factor affecting the efficiency of the transfer (Clark & Voogel, 1985; Morrison & Hammon, 2000). In this study, the transfer of training via VL was measured as:

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\text{Transfer of VL Training} = \frac{\text{EGS} - \text{CGS}}{\text{CGS}} \times 100
\]

The average performance score of the control group is CGS, while the average performance score of the experimental group is EGS in the training program. If the experimental group’s mean score is higher than the control group’s, the equation will result in positive transfer.

**Procedure** Four tests were conducted as part of the training program:

1. Pre-lab test
2. Test I
3. Test II
4. Test III (as needed)

The training administrators for physics, chemistry, and biology were given reference books related to theory and procedure of the experiment and then passed them out to the participants before the pre-lab test. A time of 1 h was allotted for preparation prior to the pre-lab test. The pre-lab test was used to evaluate teachers’ basic knowledge of the experiment, and the modes of the tests were demo presentations of the experiments.

**Flow Chart** A maximum of 8 h was given for the teachers to perform the virtual lab/real lab without time limitations (not limited to a particular experiment). We measured the time consumption for each faculty member per experiment during the lab session. In this study, the virtual labs platform was only used by the experimental group before the real lab session (practice I). And for the control group, the complete instruction and lab manual related to the experiment was given (practice I). This was followed by the real lab session (practice II) for the two groups, and then test II was conducted. Test I was how to perform the experiment, observations, calculations, results, and accuracy of the experiment, while test II was a test of overall understanding of the experiment and its application. A detail of the procedure design is

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*(Note: The image contains a mathematical equation which is not transcribed here.)*
Selection of Virtual Labs Experiments in Physics, Chemistry, and Biology

Many VL experiments were developed by MHRD in different branches of science and technology (Krishnashree Achuthan et al., 2011; Diwakar et al., 2012; Raman et al., 2013; Wolf, 2010). This study was based on the virtual labs for school students by MeitY. Two VL experiments from physics, chemistry, and biology matched to the curriculum of the Central Board of Secondary Education (CBSE) school syllabus were chosen. Each VL experiment offers interactive animations, simulations, and videos of experiment. The user can perform, measure, and study the experiments.

The selection of the experiments was done on the basis of the difficulty level associated with the experiment. For this, a panel of five subject matter experts in each subject analyzed the level of difficulty based on time consumption, depth of theory, procedure, observations, calculations and made a final list of six VL experiments (two from each subject) for VL training.

1. Laws of reflection of sound (physics)
2. Newton’s second law (physics)
3. Boiling point of water (chemistry)
4. Saponification—the process of making soap (chemistry)
5. Importance of light in photosynthesis (biology)
6. Role of carbon dioxide during respiration (biology)

A complete description of the experiments is available on the MeitY virtual labs site and the experiments selected for the study are shown below (Fig. 3).

(b) Interactive

Interactive means how/what interactions are possible with the learner and what tools are incorporated with the technology. VL incorporates many multimedia tools like animations, video, and simulations for each experiment, but not all ICTs are as comprehensive. Because virtual labs are enriched in multimedia technologies having interactive simulations, animations, and videos related to the experiment, VL can create interactive learning environments, to support better leaning (Achuthan et al., 2014; Park et al., 2018). Visualization and creation of graphical symbols are carried out in VL using realistic scenarios and compared to the actual equipment. Various authoring tools are used to make simulations interactive, replicating and imitating a real lab setting (Achuthan et al., 2014; Aljuhani et al., 2018). In this section, we will describe how VL technology interacts with the learner (in the case of this study, the learners are the faculty members) for each of the six VL experiments (Fig. 4).

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Table 2: Details of practices as part of faculty training program

| Experiment group (with VL) | Observation I | Practice I | Observation II | Practice II | Observation III |
|---------------------------|--------------|-----------|----------------|-------------|-----------------|
| Pre-test | Pre-test | Pre-test | Pre-test | Pre-test | Pre-test |
| VL practice (3 trials) | No lab practice | Test I | Test I | Test II |
| Real lab practice (3 trials) | Instructions/lab manual given | Test I | Test I | Test II and test III as needed |

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1. www.olabs.edu.in

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Fig. 2 Flowchart of the detailed procedure in the study
Law of Reflection of Sound  The experiment explains how sound waves travel in a continuous medium and explains how sound waves are reflected. The learner who reads the content with pictures and animations will understand the two laws of reflection. A movable/rotating protractor in the simulator is used to measure the angle, which the learner can manage. To make the virtual lab even more realistic, a speaker icon indicates that the simulation involves sound that prompts the learner to use an audio device (head phone or speakers), to hear the sound, thus creating an interactive environment between the learner and the experiment.

Newton's Second Law of Physics  The experiment gives an idea about mass, force, acceleration, momentum, and finally what the second law says. In this VL experiment, the learner can change masses and distance with measurements being automatically calculated and displayed. The learner can note the time within a millisecond, using the simulator’s digital timer. A graph of distance versus time is plotted automatically. The learner can interact with the setup.

Boiling Point of Water  The experiment explains what happens when a liquid is heated and defines the process of evaporation and boiling. The boiling point of water at different
pressures can be explored. There are different sets of impurities that can be added to the water, allowing the learner to choose what they want to do in the experiment and observe the results. Physical changes can be noted via the simulation similar to that of a real experiment, which makes the VL experiment more interactive.

Saponification—The Process of Making Soap  The detailed theory clearly shows the distinction between hard soap and soft soap. The experiment also identifies the materials that are required for the preparation of soap and how common salt is used in the saponification process is clearly visible in the simulator. The reasons, for which alkalies are required for the preparation of these soaps, can be easily understood. Using VL, the learner acquires the skill to do the preparation of soap in a real lab environment. The whole procedure can be done by clicking the apparatus, where step by step the procedure is explained making it more interactive.

Importance of Light in Photosynthesis  The experiment helps to understand why light is necessary for photosynthesis, the principles of photosynthesis, and the factors affecting photosynthesis. Learners can easily visualize and imagine the real situation while performing the VL experiment. There are provisions to change the light source, change the distance from the light source, and manually filter the light source, so that the principles of photosynthesis are conveyed.

Role of Carbon Dioxide During Respiration  Learners who have no prior knowledge can learn about and understand the terms respiration, aerobic, and anaerobic respiration. The two types of respiration and the factors affecting the rate of respiration are clearly defined in animation and simulation. The selection of seed type, temperature, and the number of seeds used can be varied and the results observed and measured through the corresponding changes in the visual presentation.

Continuous Monitoring  

Interactivity is a difficult process to quantify and to measure it is an even more difficult task. Haddadnia et al. (2002) developed a new feature extraction method for the recognition of
human faces in digital images (Ndukwe & Daniel, 2020). Smit et al. (2021) observed pre-service science teachers’ emotional experiences during a semester-long laboratory science course and the effects on teacher efficacy (Smit et al., 2021). We chose the continuous monitoring of our teachers using HD video cameras. Biometrics was used to map facial recognition from a photograph or video of a teacher similar to Quan et al. (2009), who developed a novel method for representing different facial expressions from 3D facial data (Quan et al., 2009). In this study, HD web cameras were used to capture the expressive characteristic of the faces while the teachers were engaged in the training. These visual impressions of the teacher can gage their interaction with the experiment.

Mouse cursor tracking has significantly advanced many fields of science. This method has promoted methodological creativity in experimental design and analysis (David & Mounia, 2015; Schoemann et al., 2021). As part of the training program, interactivity was also evaluated based on how long the teacher spent with the VL simulator, as well as tracking the mouse pointer while the teachers were using the VL features. An example of the observed interactions is depicted in Fig. 5. Note: even with this multi-pronged approach, there are many limitations to accurately measure levels of interaction, including surrounding environmental factors and internal mental connections.

In spite of these limitations, the data strongly suggests that the interactions of teachers with VL environments exhibits a high level of interactivity from the learner. Wästberg et al. (2019) measured the level of learner motivation as the score gained after performing the experiment (Stahre Wästberg et al., 2019). In this study, the average score of the EG is greater than the CG, thereby demonstrating that the level of motivation is increased using VL platform.

(c) Involvement

This was analyzed on the basis of how well the teachers were able to perform the experiment, follow the procedures, how much time they consumed, and the accuracy of the results obtained using VL. Comparing the results of the EG versus the CG with a real lab setup, we can estimate the level of involvement with VL during the training.

Factors Affecting Involvement in VL Experiment Training

The part of the study had one independent factor: method of practice (PM), and four dependent factors:

1. Time for understanding (TU)
2. Time for doing (TD)
3. Task completion activity (TA)
4. Accuracy in results (RA)

Method of Practice (PM) PM is a discrete variable with two values: 1 for virtual labs practice and 0 for without virtual labs practice. PM variable was determined by which group the teacher was in (i.e., EG or CG).

Time for understanding (TU) TU measured the amount of time a teacher had taken to understand the concepts and procedure for doing the experiment. Time was measured in minutes.

Time for doing (TD) TD measured the amount of time taken for performing the experiment. Time was measured in minutes.

Task completion activity (TA) TA was measured as the total scores gained by the teacher from all the practices.

Accuracy in results (RA) RA was the accuracy of observational values and a final result of the experiment performed by the teacher and was calculated using the formula:

\[
\text{Accuracy} = (1 - \text{abs(error)}) \times 100
\]

Null Hypotheses

To study the “involvement” of VL in teaching, four null hypotheses were formulated based on the dependable factors in training.

1. No difference in TU for virtual lab and real lab
2. No difference in TD for virtual lab and real lab
3. No difference in TA between the teachers who practiced in virtual lab and real lab
4. No difference in RA for virtual lab and real lab

The statistical calculations were done with the SPSS 16 statistics package. A critical value of 0.05 was used to accept or reject each of the null hypotheses.

The results of the two-tailed independent t-test for TU between two groups were less than 0.002 (i.e., \( p < 0.05 \), stars to p value indicate different levels of significance and p value of 0.05 or less is denoted with a star [*]), showing that there was significant difference between the two groups with respect to the TU variable and the null hypothesis 1 was rejected.

The next factor, TD (time for doing the experiment), the two-tailed p value (0.012) was less than 0.05 that indicates that there was a significant difference in time for doing between the experimental group and control group, and null hypothesis 2 was rejected (Table 3).
Fig. 5  Tracking the mouse pointer while doing VL.
The two-tailed $p$ value (0.06) for TA was greater than 0.05, and null hypothesis 3 was accepted. Therefore, it was concluded that there was no significant difference in the means of the activity completion and significant difference observed for RA ($p$ value = 0.012 < 0.05), where null hypothesis 4 was rejected (Table 4).

From the results, there were notable differences between EG and CG in terms of time for understanding the concepts behind the experiment, time for doing the experiment, and accuracy in results with the virtual-lab group taking the lead. On the other hand, there was no significant difference between the two groups in task completion accuracy. Therefore VL can engage students actively, similar to that of real lab and they can learn to complete the task with accurate results.

(d) Informative

The expected outcomes of faculty training are knowledge transfer and skill acquisition. The knowledge transfer was calculated from using the transfer of VL training equation with the average of both (test I and test II) test scores from both groups, EG and CG. In this study, we saw an approximate gain of 73% in test scores with the EG scoring higher, thus indicating a positive knowledge transfer. Transfer of knowledge ($KT$) is a process where gained knowledge constructed in a particular content is used in a different context (Grèzes & Decety, 2000; Moon, 2013), and this study indicates the amount knowledge transfer from VL to a real environment. Skill acquisition ($SQ$) is the acquisition of actions that tends to improve performance and VL helps to understand the procedure to do the experiment. Both these factors were measured from the average scores gained from tests I and II (Achuthan et al., 2017).

The average score achieved by the experimental group (with VL) was higher than the control group (without VL), thereby indicating positive effects on $KT$ and $SQ$. After practicing in the virtual labs, teachers spent significantly less time to finish the tasks according to the statistics gathered. Furthermore, after additional training in the real lab, teachers who had prior virtual labs experience completed their tasks faster than those who had no prior VL experience. In addition, to determine the effectiveness of VL for those already familiar with the real labs, we gave the VL platform to the control group (CG) and tested them again (test III—similar to test II). The results show that there is an enhancement in scores gained after practicing VL.

After the training program, we collected checklists from each faculty member. The checklists were designed to allow the teachers to self-assess their understanding of

| Table 3 | Time for understanding (TU) and Time for doing (TD) |
|---------|-----------------------------------------------------|
|         | Group | N      | Mean  | SD    | $t$ value | $p$ value |
| TU      | EG    | 26 (physics) 13 (chemistry) 13 (biology) | 52.5 | 6.76 | 5.25 | 0.002 |
|         | CG    | 25 (physics) 12 (chemistry) 12 (biology) | 62.7 | 10.68 |
| TD      | EG    | 26 (physics) 13 (chemistry) 13 (biology) | 42.7 | 6.66 | -6.26 | 0.012 |
|         | CG    | 25 (physics) 12 (chemistry) 12 (biology) | 48.3 | 9.78 |

| Table 4 | Task completion activity (TA) and Accuracy in result (RA) |
|---------|-----------------------------------------------------------|
|         | Group | N      | Mean  | SD    | $t$ value | $p$ value |
| TA      | EG    | 26 (physics) 13 (chemistry) 13 (biology) | 22.4 | 2.7 | 0.25 | 0.06 |
|         | CG    | 25 (physics) 12 (chemistry) 12 (biology) | 21.5 | 1.6 |
| RA      | EG    | 26 (physics) 13 (chemistry) 13 (biology) | 86.8 | 6.7 | 0.16 | 0.012 |
|         | CG    | 25 (physics) 12 (chemistry) 12 (biology) | 88.1 | 5.2 |
the experiments they performed and allow us to show the whether VL is an informative technology or not. The check- lists given were specifically related to the experiments that the teachers they themselves had performed via the practi ces as described in Table 2. During the training program, the teachers had to self-cross-check if they acquired the knowledge related to the experiment given in the checklist. The maximum score from practices I, II, III are 10, 25, and 15, respectively. If the teacher obtained a percentage of the maximum score of 75% or higher, we concluded that VL was informative and the training was successful. About 82% of faculty members understood the items in their checklists and therefore have completed the training program successfully.

(e) Influential

This parameter was measured using a feedback form. VL training programs can be distinguished from other technologies by how it is utilized (Ericsson et al., 1993). Feedback can be used to inquire and explore natural or constructed environments to determine if they are influential (Hattie & Yates, 2013). In this technique, the student (teacher) guides their own investigation of a certain environment or topic by attempting various tasks and observing the results. The yes/no questionnaire we used to understand the influence of VL in teaching and the results are given below (Table 6).

From the feedback, most of the teachers showed support for using VL as a teaching tool and agreed that it is effective in learning for the students. The majority of teachers said that interactive experimental learning is a necessity of today’s laboratory teaching. There is an interesting observation for the feedback 8, the majority of them were not supportive for implementing virtual labs into the curriculum even though VL has many advantages. Significant comments for feedback item 8 are given below.

- **Comment 1**
  The dimensions of the experiment are an unknown factor if the students do not see the apparatus before. It will lead to confusing and make a false teaching.
- **Comment 2**
  You can drive a car using video game and study all the parts. Using interactive car racing, you can even win the race. But after practicing car race through these technologies many times, it will not be beneficial while handling the real car.
- **Comment 3**
  It can be only be used as a pre lab tool

Regarding comment 2, VL is interactive learning/teaching tool and engages the user in the experimental setup similar to that of real lab experiment, but it never replaces real lab experience. However, we have clearly demonstrated that if the student has no idea about the experiment, this tool is helpful in his/her learning process.

### Limitations of Virtual Labs

From the feedback response, teachers do not support for the implementation of VL into the science curriculum under universities of Kerala. This clearly indicates that there are major drawbacks of such technologies while using as a teaching aid. Here, we try to point out some reasons behind the response. According to the students, replacing traditional laboratories with virtual laboratories is not yet a comprehensive solution, but virtual laboratories can be utilized in conjunction with traditional methods to promote enhanced learning outside of lab hours. Virtual lab learning may encourage decline in teamwork and communication between tutors/students (Cecila et al., 2009). Because the experiment in the virtual lab can be repeated as many times as needed, students will become indifferent to failure and danger in the real world. Students cannot benefit from full sensory lab experience such as noise, smells, random error and so on.

The term “influential” means the technology has motivated the learner to perform experiments and has a crucial impact in student academic accomplishment (Galyon et al., 2011). According to the study, learners with strong self-efficacy showed higher levels of student engagement, greater study attempts, and better exam achievement when the technology is influential (Tomás et al., 2020).

From the feedback, the majority of teachers are more positively motivated using VL training as compared to just working with real labs. Interactive simulations are more easily engaged with by the user at any time. They may also be a more efficient use of the student’s time. We calculated the time taken by the faculty to perform the six experiments in real labs. The results show that the teachers were able to perform the virtual labs significantly faster (Fig. 6).
Conclusions

VL offers the benefits of being accessible at any time and from any location, fostering a welcoming conversation atmosphere for students, and expanding the scope of teaching and exploration. During this epidemic, these technologies in science can be used to replace traditional laboratory equipment, especially for tests that require expensive, risky, and inaccessible laboratory equipment. The “involvement” session of VL clearly measures student understanding about the experiment and get more accurate and exact results, which will help them understand the concept better.

Using virtual labs, teachers were able to discover and solve more problems than their peers who did not use any virtual labs. This study created awareness about impact of online virtual lab for laboratory teaching and a qualitative analysis of the I’s (innovative, interactive, involvement, informative, and influential) was conducted by employing VL. Our detailed study shows that VL enhances laboratory teaching and itself can be successfully used as a quantitative measure of ICT efficacy. The pandemic situation pushed teachers into a state of hysteria, creating special difficulties for imparting course material. It was particularly difficult to replace the lab experiments that are a common part of science labs. This study suggests that the use of VL is an additional tool to improve teaching and learning in science laboratories. The 5I’s show different experiences of a learner while using ICT-enabled VL environment (Fig. 7).

Regarding the practice on the real equipment, both groups (EG and CG) showed an improvement after doing VL. Prior practice in the virtual labs considerably reduced the time for understanding and performing the experiments. The improved accuracy in activity completion and results supports the claim that skills were transferred from the virtual platform to the real lab and is very useful tool during pandemic times. The virtual laboratory practices will be a breakthrough for laboratory teaching/learning. Information and Communications Technology-VL infrastructure for training is key to increased capacity for the provision of technical, vocational, and entrepreneurship skills. Appropriate and effective utilization of virtual laboratories should be promoted in all experimental practices. This work can be used to evaluate the total effectiveness while implementing VL and other new technologies in teaching.

![Fig. 6 Time taken to complete the experiment by the faculties in virtual labs and real labs](image-url)

![Fig. 7 VL in laboratory teaching](image-url)
We are planning to extend the research by performing the same kind of analysis for student-centric learning practices, with an open eye to understanding how students can best benefit from this method of teaching and how the technology can enhance student efficacy based on the 5I factors and will develop a model for laboratory teaching. This proposed study will extend research on how student efficacy is impacted when younger subjects experience the use of VLs.

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Declarations

Ethical Statement The submitted work should be original and has not been published elsewhere in any form or language to our knowledge.

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