RESEARCH ARTICLE

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A Comparative Study on the Use of Physical and E-labs: A Case Study at University of Delhi, India

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Abstract

With COVID-19 pandemic, the world has shifted from traditional classroom teaching to digital platforms and 'screen based' education. The use of labs for the practical component has raised multiple questions about the effectiveness in bringing precise learning outcomes. The present work comprehends the experience of more than 500 undergraduate science students at the University of Delhi about the use of virtual labs. It analyzes their inclination towards the online education system as compared to the physical mode system in reference to practical work. The input from students has been gauged via an online questionnaire. A majority (65%) of survey respondents show their preference for the physical mode of practical education than the virtual mode. It is concluded that the blended mode of teaching and learning promises to benefit students more, rather than shifting the education system entirely to an online mode.

Keywords: e-Labs, Online education, University of Delhi.

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Introduction

The curriculum of undergraduate science courses (particularly Physics, Chemistry, Botany, Zoology, and Mathematics) comprises theory classes and hands-on laboratory sessions, both of which equally strengthen the learning outcomes and deepen the conceptual understanding in students.[1] Whereas theoretical knowledge equips students with the theorems, logic, and principles that they need to know, parallel lab sessions enable them to put the theoretical knowledge garnered in the classrooms into their real lives. They get to visualize things from classroom lessons in a much more convincing and compelling way. The practical component in natural science (broadly comprising of life sciences and physical sciences) disciplines is an essential element that enables the students to understand and master the theoretical concepts they learn. Besides this, it also inculcates important qualities in students, like teamwork, leadership, problem-solving, designing, etc.[2]

With the COVID pandemic disruption across the world, the traditional teaching-learning process in physical mode had to shift to online mode completely.[3] Teachers are using different virtual meet platforms like MS Teams, Google Meet, Zoom, WebEx, etc. to ensure that the theoretical learning process keeps moving with essentially the same momentum as earlier. Under such settings, the hands-on laboratory sessions in physical mode are not feasible. The most that can be done in this situation can be the presentation of videos demonstrating these laboratory experiments during the online lectures that students have. However, the essence remains that the 'actual' practical illustration before students is still a far-fetched idea.

To sustain the learning outcomes of the practical component of the science curriculum, the teachers started making use of virtual labs. The virtual labs are complemented with pre-laboratory activities such as videos, simulations, quizzes, interactive animations, and post-laboratory assignments to meet the learning objectives.[4] Various researchers have reported that these virtual labs can work as temporary substitutes for the traditionally used practical hands-on sessions in delivering practical knowledge effectively.[5-7] An advantage of exercising virtual labs is that a student can repeat an experiment number of times from any location.[2] Also, there exist reports that stress on virtual lab learning not being at par with the practical hands-on sessions in physical mode.[8] With the pandemic crisis and consequent halt in the physical education system, the online

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education system has taken the front seat.[9,10] This has piloted the concerned authorities to investigate the efficacy and legitimacy of a completely online education system, thus preparing the system for black swan events like the COVID pandemic.[11,12] The shift to an online platform is an entirely different learning experience from a science student's perspective.[11,13-16]

In the present study, the authors attempt to capture the perception of undergraduate science students regarding the efficacy of virtual labs. A valid online questionnaire was designed and circulated among students pursuing different undergraduate science courses at the University of Delhi for the desired study. More than 500 students responded to the survey, and the outcomes reflect the need for integration of online practices rather than complete replacement of the standard physical education model. These results can be instrumental in framing education policies aiming towards optimized benefit for science students in terms of learning and associated pedagogy at the undergraduate level.

Literature Review

Natural Science is an empirical subject that demands students to conduct practical sessions in laboratories. This helps in developing various essential skills like the methodical ability to plan and do a range of scientific experiments, understand the data obtained, and bring out the results.[17] Quite naturally, the knowledge of subjects like Physics, Botany, Zoology, Chemistry, and Mathematics remain incomplete unless they are complemented with the much-needed hands-on training and visualization. A well-equipped laboratory amplifies students' motivation to learn and boosts the teaching process.[18] The effective use of new available technological tools in education helps bring change in teaching and learning methods.[19] Using these tools, the knowledge and information to be delivered to the students can be presented efficiently and explained enjoyably. One of the upcoming technological means that employs virtual technology to provide tools and visualizations for motivating students to participate and learn the practical component of science subject effectively are virtual laboratories.[20] A virtual laboratory or e-lab can be defined as a setting where investigations are steered or controlled partially or solely with computer operation, replication, and/or animation either in the vicinity or distantly via the internet.[1] In a computer animation kind of virtual laboratory, the experimentation is typically a graphical model of the actual experiment. This type of virtual laboratory does not consist of physical components but allows the user to visualize the process and the result through the animation.[1] Various virtual labs like Amrita lab, IITB lab, etc., are available for performing laboratory work remotely. The use of virtual laboratories in imparting practical knowledge has been researched earlier by many researchers.[21-26] These studies have suggested that the use of virtual labs provides ample flexibility to facilitate the user in repeating the tasks or re-watch instructions number of times, subsequently helping in building a deeper insight into the subject.[27-29] The other benefits of using virtual labs are location independence, motivation, and easier access.[21-26] However, there are certain concerns in the students' attitude about using virtual labs in place of physical labs.[30] Students lack the seriousness, responsibility, and carefulness leading to the production of low-quality work compared to hands-on laboratories.[3,30]

The outbreak of the COVID-19 pandemic has switched the mode of education entirely to an online system using widely used platforms like MS Teams; Google meets, CISCO WebEx, and Zoom.[3] The students of science courses are now dependent on virtual labs for learning the practical component in their curriculum. Since there are varying outlooks regarding the use of the virtual lab for teaching-learning practical components, some researchers believe it comes with the same level of effectiveness as traditional hands on physical lab, and others argue that it does not. However, various reviews emphasize it to be an efficient medium for imparting practical knowledge.[31] All these studies motivated the authors to explore the perception of major stakeholders (i.e., students) about the paradigm shift to online mode to gain knowledge about the implications of changes in the higher education sector during these unprecedented times. This may help in unmasking various hurdles in flexibly carrying out the scientific experiments with limited resources and within the given time frame. The output of the present study may be instrumental in making practical education of science in the higher education system more understandable and enjoyable, hence facilitating the learners in enhancing their learning experience.

Understanding the Research Issue

To effectively comprehend the research problem, data was collected from an aimed sample. An online questionnaire was used to collect the facts from the target group, which includes science students of different disciplines in various colleges of the University of Delhi, India. The purpose of the questionnaire was to understand the students' experience of doing experiments on virtual laboratories due to the sudden shift towards online education in the University of Delhi and gauge their futuristic preference of using virtual labs as an alternative to hands on physical laboratories. Descriptive statistical methods were exercised to analyze the data in the present work to acquire information related to conventional physical and virtual laboratories.

Research Design

To gauge the student's stance on the use of virtual laboratories, the science undergraduate students from various streams viz Physics, Chemistry, Electronics, Mathematics, Zoology, Botany, etc. studying at the University of Delhi expressed their views on the practicals mentioned in their curriculum via virtual lab, which they had done in the real physical lab before the onset of COVID pandemic, and share their

experience by answering the online questionnaire. Figure 1 explains the stepwise procedure followed in the present study to capture the same.

An online questionnaire was prepared using Google Forms. The questionnaire consisted of fourteen questions to capture the students' perception about their experience and viewpoint on the use of conventional physical, practical labs vs virtual labs. Five-point Likert scale was used to calibrate the levels of agreement or disagreement with the statements, and for data analysis, the following values were assigned to different levels:

Strongly Agree - 5, Agree - 4, Neutral - 3, Disagree - 2, Strongly Disagree - 1.

The questionnaire in the survey comprised of basic profile questions (such as age, gender, course and class) along with 14 questions for evaluating the perception of physical lab and virtual lab. The questions, along with the response data collected through this survey are presented in Table 1.

The questionnaire used in the present study was first examined for its accuracy and validity to carry out the intended research. The accuracy or precision of a measuring instrument is defined in terms of reliability that measures the level of consistency or dependability of the measure of a construct.[32] Amongst the numerous gauges, internal consistency is the typically used measure for assessing scale reliability. Internal consistency measures whether many items that imply to determine the same construct yield similar scores. The internal consistency of the questionnaire has been evaluated using Cronbach's Alpha. Whitley (2002) stated that Cronbach's alpha score greater than 0.70 indicates a strong item co-variance.[33] The Cronbach's alpha scores of different items presented in Table 2 indicate that the instrument can be presumed to be reliable.

Validity is the degree to which data collection methods correctly measure what they were aimed to measure. The authors have used face validity in the present study. Accordingly, the questionnaire has been validated by the two key stakeholders: the students and the professors. Before collecting data, feedback concerning the validity was taken from professors and students from the different science

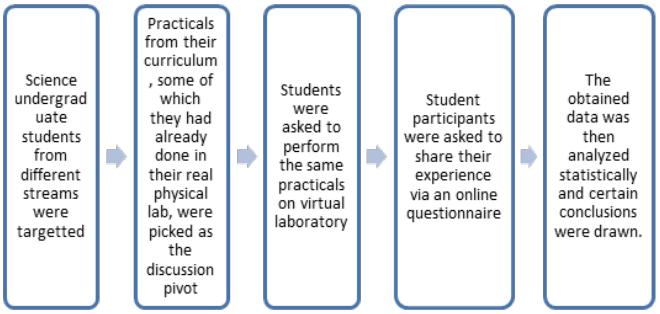

Figure 1: Research flowchart of the present study

Table 1: Data findings and analysis

S. No.	*Statement*	*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*
1	I found the physical practical laboratory easy to operate	36%	35%	20%	5%	4%
2	I found the physical, practical laboratory easy to understand	37%	35%	20%	5%	3%
3	I found the physical practical laboratory interesting, cost-saving, and flexible to use in relation to time and place	14%	5%	26%	27%	28%
4	I found the physical, practical laboratory stimulating	29%	36%	27%	5%	3%
5	I found the physical, practical laboratory satisfying	34%	37%	19%	7%	3%
6	I found the virtual, practical laboratory easy to operate	14%	28%	23%	19%	16%
7	I found the virtual, practical laboratory easy to understand	12%	24%	26%	19%	18%
8	I found the virtual, practical laboratory interesting, cost-saving, and flexible to use in relation to time and place	21%	33%	20%	13%	14%
9	I found the virtual practical laboratory stimulating	9%	20%	31%	23%	17%
10	I found the virtual practical laboratory satisfying	10%	21%	28%	21%	21%
11	The Virtual practical laboratory is more suitable for senior students (2nd year and above)	11%	18%	28%	23%	20%
12	Learning and understanding is better in Virtual practical laboratory than physical Laboratory	28%	11%	23%	8%	29%
13	Virtual labs are available for all types of practicals listed in the science undergraduate syllabus	8%	25%	30%	24%	12%
14	If I have an opportunity to choose the platform to do experimental work, I (will/will not) use the virtual practical lab over physical practical lab.	Will 35%			Will Not 65%	

fields, viz. Physics, Electronics, Botany, Zoology, Chemistry, and Mathematics.

More than 500 students studying at the University of Delhi participated in the survey. Students pursuing various courses like Physics, Botany, Mathematics, Zoology, Life Sciences, Electronics, and Chemistry responded. The course-wise and year-wise distribution of students participating in the survey is summarized in Figure 2.

Results

The opinion on complete adoption of virtual labs over physical labs was sought, and year-wise responses were obtained. The responses show heterogeneity, with senior students showing a little more positivity and readiness with respect to virtual lab settings. This positive attitude may be attributed to the prior familiarity of senior students with the software and equipment in use; longer and older connect with the mentor and better understand the whole system of work.[34] The descriptive statistical analysis tabulated in Tables 3 and 4 was carried out to derive further conclusions. It can be seen from Table 3 that the whole data is moderately skewed, with around 35% of respondents expressing their preference for virtual labs over physical labs. In contrast, the comparative analysis shown in Table 4 shows that the data restricted to third-year students is negatively skewed with median and mode both as unity, indicating more positivity towards virtual labs. More than half of the respondents from third-year prefer virtual labs over physical labs. As pointed out earlier, this deviation in responses may be attributed to third-year students being pre-acquainted with the work system.

When asked about ease of operation, most respondents answered in favor of physical labs being easier to operate compared to virtual labs. The same is depicted in Figure 3.

The data from the Likert-type questions indicate that virtual labs are well perceived by some students owing to flexibility in terms of time and place. Still, at the same time, stimulation and satisfaction of learning experience through the virtual labs is considered to be way behind that of the physical practical laboratory. The associated negatives of virtual labs are reduction in teamwork, communication between teachers and students, and plagiarism in assessment.[1,13]

It can be inferred from Figure 4 that there is heterogeneity in terms of responses on the complete adoption of virtual labs over physical labs. Virtual labs, undoubtedly, served as a savior to continue with laboratory work in these unprecedented times,[35-37] but complete substitution of the conventional physical laboratory with the virtual laboratory is not a solution from students' perspective. One can continue to use virtual labs as an enhancer in visualizing the concept and fetching a more profound learning experience outside the physical, practical laboratory hours.

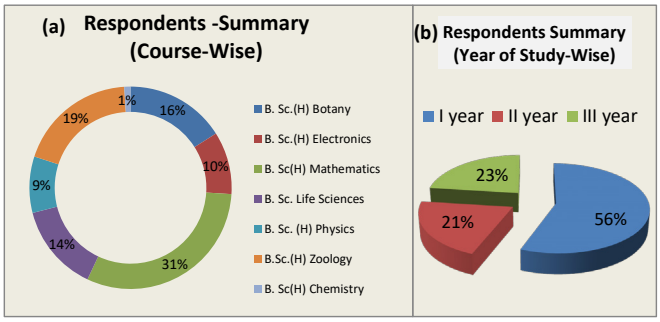

Figure 2: (a) Course wise summary of respondents (b) Year of study wise summary of respondents

Table 2: Cronbach's Alpha score for Reliability test

Test of Reliability: Cronbach's Alpha	
Measurement Statements	Cronbach's Alpha Values
Statements for Physical Lab	0.936328535
Statements for Virtual Labs	0.936664761
Virtual Vs. Physical	0.850028727

Discussion

Table 1 and Figure 4 summarize the results obtained in the present study on student perception regarding the use of virtual laboratories vs. physical laboratories. It was found that about 70% of the respondents considered the traditional hands-on lab as more stimulating and satisfying while lacking flexibility with respect to time and space. On the other hand,

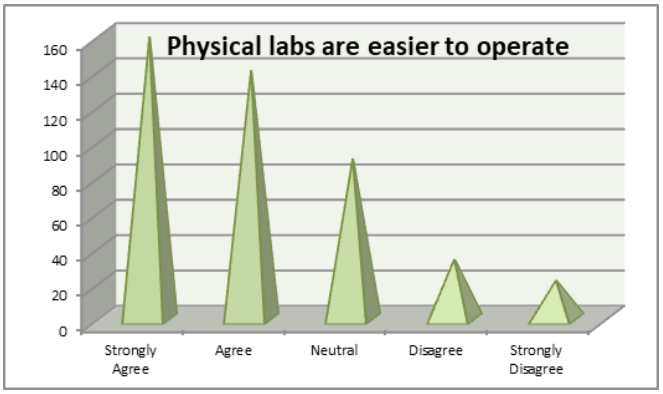

Figure 3: Opinion on ease of operation of physical labs as compared to virtual labs

Table 3: Statistical analysis for preference of virtual laboratories for whole data

Preference for virtual labs (Whole data)	
Mean	0.35980
Standard error	0.02322
Median	0
Mode	0
Standard deviation	0.48051
Sample variance	0.23088
Kurtosis	-1.66413
Skewness	0.58624

Table 4: Statistical analysis: Comparison for preference towards virtual laboratories between third-year students and first-year students

Preference of virtual labs (Third-year students)		*Preference of virtual labs (First-year students)*	
Mean	0.55208	Mean	0.29114
Standard error	0.05102	Standard error	0.036256
Median	1	Median	0
Mode	1	Mode	0
Standard deviation	0.49989	Standard deviation	0.45573
Sample variance	0.24989	Sample variance	0.20769
Kurtosis	-1.99676	Kurtosis	-1.15293
Skewness	-0.21281	Skewness	0.92835

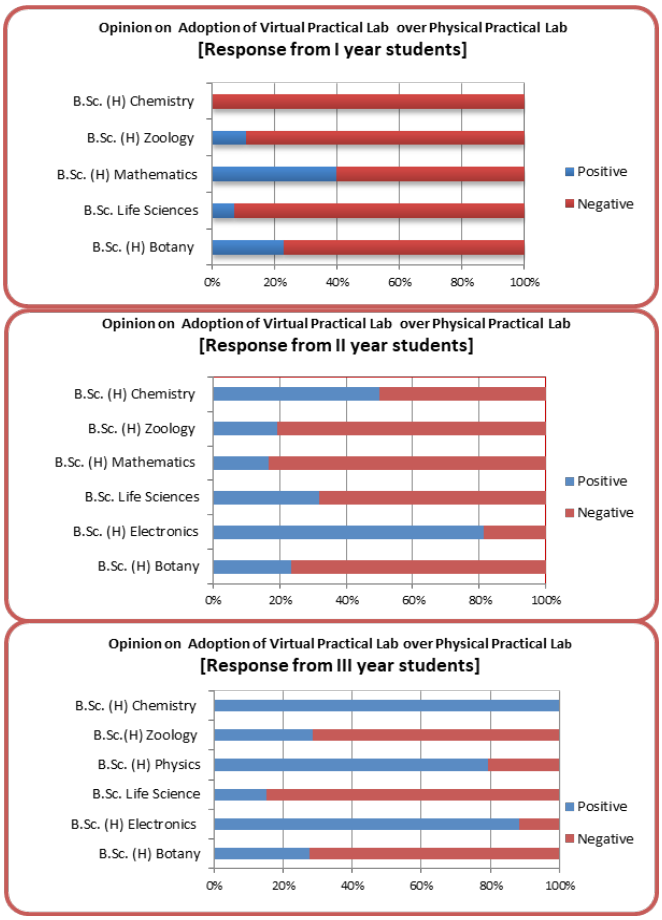

Figure 4: Year-wise opinion on adoption of the virtual practical lab over physical practical lab

most of the students found the use of simulations to be interesting as it provides flexibility concerning time and place. The students can perform an experiment remotely with ease and comfort. Moreover, they may repeat an experiment on a virtual lab any number of times irrespective of the concern of resources and time limitation. Students' stance is in line with the earlier reported results by many researchers.[21-26] As discussed by Babateen (2011), almost 60% of respondents of the present survey also agreed to the use of virtual laboratories in improving the knowledge and learning the principle behind science experiments.[20] Contrary to the earlier reported results Babateen[20] that virtual labs are easier to operate, trigger stimulation, and are satisfying, a majority of responses in the present study were inconsistent. This may be attributed to the fact that the present study is conducted during pandemic times when the respondents do not have an option to access the hands-on physical laboratory. Since they are not able to reproduce the results in a physical practical laboratory, they lack the desired stimulation and satisfaction.

Moreover, in pure remote education, it is difficult to have one-to-one interaction with the instructor/mentor, which probably has made carrying out practicals on virtual lab strenuous, especially for the first-year students. The survey results show that the students do not want hands on physical labs to be replaced by virtual labs. This is in contrast with the earlier reported results by.[29,38] Although they agree that the aim of science education is to impart technical knowledge during the circumstances when one does not have access to actual resources, have certainly been saved with the use of virtual environment.[35-37] but complete replacement of conventional hands on physical laboratory with the virtual laboratory is not a way out from students' perspective. The virtual labs are inventive tools that strengthen the knowledge and boost the confidence of students to prepare them for practical classes. It has been previously reported that virtual labs in conjunction with actual hands on physical labs enhance the teaching-learning of practical component of the subject.[28-29,38-39] Therefore the authors propose that virtual laboratories are more useful for acquaintance and preparation but not a complete alternative to hands on physical labs.

A probable limitation of the present study is that the responses recorded through the survey came only from inspired students involved in the task of simulations through a fixed set of questions. Although the authors believe that in-depth opinions from students could be gauged through focused group interviews, the present research still features the significance of the problem under study. It provides an outlook to be appraised further in future studies.

Conclusion

This investigative case study intended to examine student perceptions of their experiences of using a real and physical lab for conducting practicals in their curriculum. The use of virtual laboratories has gained momentum during this unprecedented pandemic time to continue the teaching-learning process. Virtual laboratories are an evolving vogue for science undergraduate students. The survey respondents show agreement to the fact that online platforms provide more flexibility in terms of carrying out practicals remotely, there is no time restriction, and things work out decently well, yet it is not satisfying and stimulating in the real sense when compared to physical mode sessions. As per the results of the conducted survey, a majority (65%) of undergraduate student- participants prefer the physical mode of practical education to the virtual mode. Lack of teamwork, group discussions, and direct connection with the mentor are considerable shortcomings in the virtual mode. Gauging the students response and considering the positives (the flexibility, the comfort that it brings to students, self and manageable-paced learning and the cost savings) of using virtual laboratories that cannot be disregarded or passed over, it is recommended to consider the use of virtual laboratories in harmony with the physical hands-on laboratories. This has been sensed already by the authorities, and the practical classes in physical mode have been revived on a rotation basis for third-year students and is planned to be revived in phases for other years too. This blended mode of teaching and learning will benefit its stakeholders, initiate critical thinking, and lead to the holistic development of students. It is hoped that the lessons learned in this difficult phase will go along with us and keep us at a better position in case of any future emergency.

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