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Evaluating improvements in students' learning outcome with virtual laboratory tool: a Case Study in Engineering Chemistry

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Abstract— Students can comprehend the conceptual contents of any subject in general, by three methods: by involving in experimental activities in physical lab, by simulating the experimentation through Virtual Laboratory (now on, VL) and simply by visualization. But the visualization method is relatively difficult as it demands a lot of attention and subject expertise and hence will only help in the later stages of learning process. Physical lab set up inherently has certain obvious constraints like accessibility, time, cost etc. The VL is the buzz word in the current scenario of booming e- learning and online classes. VLs are computer simulations that make real life conditions. Research studies in the past have demonstrated the utility of integrating VL tools with traditional teaching methods in enhancing students understanding, thinking and creativity. The present case study deals with evaluating student's engineering chemistry learning outcomes in terms of scores secured in internal assessment test. The study also aimed at identifying and analyzing the data collected through robust feedback system, about the effectiveness of VL tools in increasing students' understanding, active participation in classes and performance.

Keywords— Virtual Laboratory, Amrita Lab, Engineering Chemistry, Learning Outcomes

I. INTRODUCTION

Concept of VLs in India is an initiative of Ministry of Human Resource Development (MHRD), Government of India under the aegis of National Mission on Education through Information and Communication Technology (NMEICT). It aims to provide remote-access to simulation-based labs in various disciplines of Science and Engineering. National Education Policy, 2020 emphasizes upon adopting student-centric teaching-learning activities and experimental learning. But accessibility and affordability of physical or hands-on laboratories poses a huge challenge in this regard. However, a new mode of laboratory known as the VLs are gaining more and more attention and becoming a low-cost alternative solution of Real Labs (now on RL) particularly in the engineering education field.

Basically, these are web-based technological platforms designed to mimic real operations of experimental processes in a safe, interactive and self-assisted environment to students. VLs have immense potential in educational fields as they provide opportunity to students for enhancing and improving learning and teachers to explain the complicated concepts easily. VLs do not require any additional equipment for conducting experiments; remotely available via internet, easy to use and generate data, takes less time than its real counterpart. Therefore, VLs are rightly said to encompass three aspects learning process: infotainment, edutainment and enrichment (Lavanya Rajendran, 2010; Darrah, Finstein, and Simon, 2014). Most important advantage of these tools is that students by trial-and-error methods get to explore a variety of hypothetical experimental scenarios by just changing the input and observing the effect on the output by simple drag and drop features. Most of the virtual research and educational facilities accessible online today are free. Laboratory experiments can be well studied by using VLs as they create real life environments (Harry and Edward, 2005). It can likewise be utilized for theory sessions also as to make teaching-learning process intelligent, more engaging and enjoyable. This paper presents impact of use of VLs on students' performance in engineering chemistry. Chemistry is one of the fundamental sciences. It is identified with investigation of structure and composition of matter. Most ideal approach to understand this science is through investigations and laboratory experiments. It is one of testing subjects for understanding (Ayas,1997). Furthermore, it is difficult to carry lab facility to the classrooms as it requires space, instruments, dish sets and glassware's and lot of investment as well. Thus, for better comprehension of subjects like Chemistry, hypothetical learning ought to be given through these virtual platform facilities in classrooms.

II. METHODOLOGY

In this research both qualitative and quantitative evaluation approaches were carried out. The purpose of this case study was to observe the impact of VL on students learning outcomes. The research methods adopted in the study are integration of VL facility with the traditional laboratory set up in blended mode (combination of real and virtual learning) and feedback survey in order to evaluate the improvement in student's performance and learning outcomes. The qualitative evaluation approach was based on students' performance in term of marks obtained by them in unit tests.

This was quantified by statistical analyses of data obtained based on two practice tests. The engineering chemistry course topic 'Analytical Techniques' was considered for evaluation, before and after integration of VL in our regular pedagogy. Sample size considered for this study is 60, i.e., students from Computer Science Information and Technology (CSIT) branch studying first semester 1st year B. Tech. program in Rajarambapu Institute of Technology (RIT), Sangli, Maharashtra.

In this pilot study, students were facilitated and encouraged to perform Virtual Laboratory experimentation on various topics like Spectrophotometry, Flame photometry and Chromatography etc. They were provided with opportunities to investigate a problem, search for possible solutions with repeated experiment using drag and drop features, make observations, ask questions, test out ideas, think creatively and use their intuition. VLs were also used to train and familiarize students before they conducted real experiments in physical labs as this would avoid inadvertent damage that could be caused due to mishandling of chemicals and equipment, adverse output etc. For quantitative evaluation of the effectiveness of using VL and to measure its differences compared to RLs, the survey- based feedback approach was adopted. As a part of this, extensive questionnaire was designed and distributed to students through google forms. The close ended questionnaire was framed after extensive survey of literature and consultation with peers and students so as to gauge students' attitude and approach towards this innovative and reformative ICT tool like VL in their learning process. The responses were collected in the form of Yes/No options and rating basis on the scale of 1-5. The list of questions asked in our feedback survey is presented below.

Table 1. Feedback analyses questionnaire

Q. No.	Feedback questions
1.	Have you ever used virtual lab in your academics previously?
2.	How would you rate your experience of using VL for chemistry experimentation?
3.	Do you feel using VL has helped you in understanding chemistry concepts and improve your performance in exams?
4.	How do you rate your ease and comfortable level while using VL compared to RL (Real lab)?
5.	How do you rate to what extent the VL are interactive and effective in arousing curiosity and interest in you towards the subject?
6.	Would you like to emulate your experience of using VL in chemistry to other courses?
7.	Based on your experience of using both RL as well as VL till today, pick your preference of mode for your higher semester courses.

We extensively utilized VL technique for Instrumental strategies in chemical science. For this we utilized "Amrita Lab", which is accessible online as an open source. It has the functionality to simulate the experimental processes, and obtain the corresponding experimental output. We simply need to enroll to use it. A few snapshots of experimental interface on Amrita Lab platform are shown below.

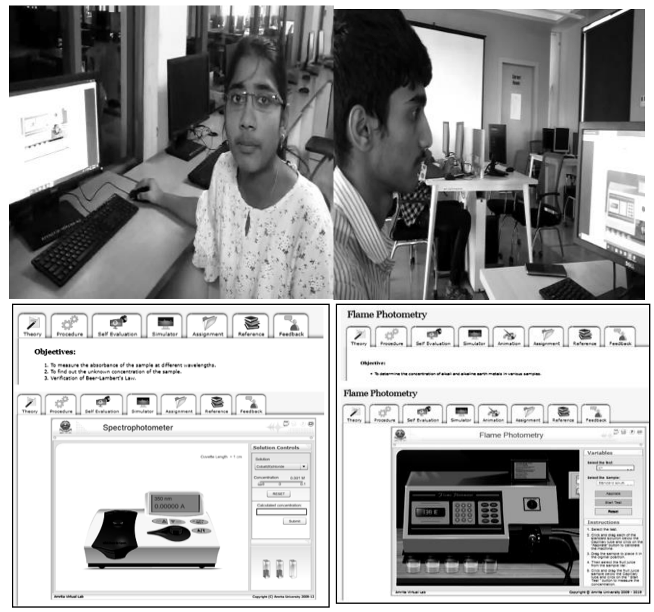


PHOTO1. STUDENTS WITH VIRTUAL LAB

(Source: https://vlab.amrita.edu)

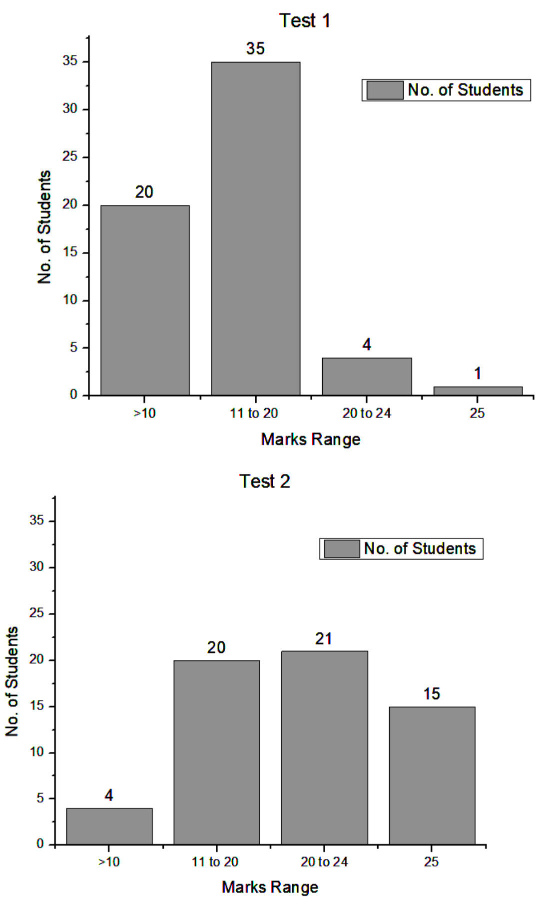
III. RESULTS AND DISCUSSION

To see the impact of integration of VL in pedagogy on students' conceptual understanding, we compared students' early ability and final ability and improvement. The initial ability was obtained before introduction of VL tool from the marks of first unit test conducted as a part of regular in-semester assessment while the final ability is obtained after introduction of VL tool, from the marks of unit test. The improvement in students' performance was quantified by calculating the corresponding scores in two practice tests. Fig. 1 shows the result of two unit tests conducted. It can be observed from the bar chart that there is a remarkable progress in the range of marks obtained by students who are exposed to VL tools. Number of students scoring marks under excellent category (25 marks) for the same topic after using VL was found to be much higher when compared to before using VL.

As already mentioned, quantitative evaluation of VL on the students' learning outcome was done with survey-based feedback system. Total sample size in our study was 61 (number of students considered for the study). All the participants responded to the feedback questions through google form. The analyses of feedback data received provided valuable insights regarding effectiveness of VL in students' learning outcome.

The summery of the survey findings are listed below.

1. 87% of the respondents have previously used VL in their academics.
2. 36% students opined that VL is excellent as an effective and interactive learning platform.
3. 38% students felt their VL experience in chemistry was excellent..

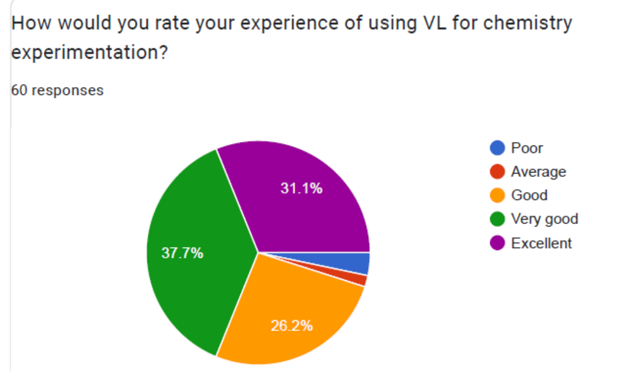


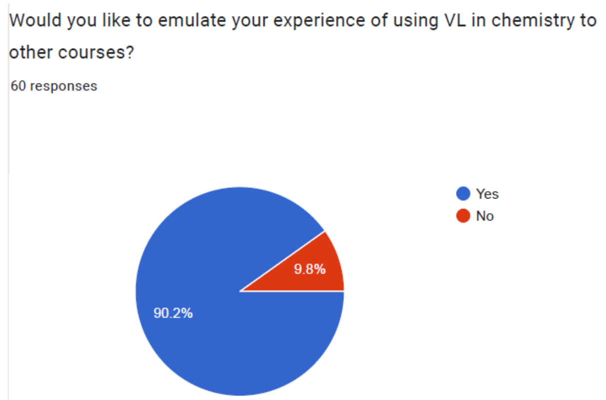
Fig, 1 Marks scored by students before and after use of VL

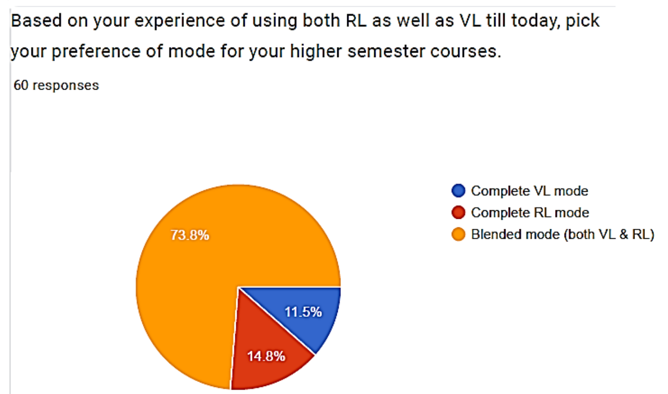
4. 40% students gave excellent rating as to their improved performance in exam after using VL and only around

3% students felt VL to be difficult and not comfortable for use.

5. 90% of the respondents showed interest to emulate their experience of using VL in chemistry to other courses also.
6. 74% of the students preferred blended mode as against complete VL (12%) and complete RL (15%) mode.







We have noticed the pronounced improvement in students' involvement during teaching sessions as is reflected in the summery of the above evaluation processes. The improvement in students' involvement and longer attention span can be attributed to the self-assisted and interactive environment that the platform offers. For instance, in spectrophotometry experiment to determine the unknown concentration of the given solution, the VL interface offers simulator tab from where a student gets drag and drop prompt to select blank and standard samples of known and unknown concentrations. As soon as samples are put into the sample holder inside the spectrophotometer, the display gives the absorbance for a preset wavelength. Since the absorbance of the sample is obtained in no time for different concentration and wavelength, a student can verify and conceptually understand Beer-Lambert's law very quickly. Thus, the VL platform incites students' curiosity and improves learning aptitude.

Similar findings were also observed in few other studies

(Hofstein, 2004; Zacharia, 2003; Tatli, 2013; Herga, 2016) that the use of VL has resulted in positive impact and demonstrated the benefit of VL in achieving better students learning outcomes.

Interestingly, even though 87% of the students were known about VL and used it in some way previously in their academics and found it beneficial, only 12% opted their preference for complete VL mode of learning. Remarkable 74% of students have shown their interest for blended mode of learning. Certainly, there is a limitation of entirely relying on VL as it cannot ensure psychomotor and affective skill development. Hence, we recommend that VLs should only be used as supplementary aids but not as the substitute to traditional physical labs. One such study (Tatli, 2013) conducted in the past at the university of Hong-Kong, has pointed out that engineering students had slight preference for traditional physical laboratory and blended lab mode as against complete VL mode. The study had highlighted that VLs may not facilitate in acquiring the skills such as team- work and communication skills which are often encouraged in traditional physical laboratories. Most of the students (90%) responded that they would like to emulate their experience of using VL in chemistry in future for other courses. This indicates the student's aptitude and enthusiasm in using VL. They felt by using these VL tools, they could learn through activity and fun..

IV. CONCLUSION

Initially VLs were used for practical sessions only, but later on same approach were extended intermittently for classroom theory sessions also to improve students' participation in the class. Gradually moving from RLs to VLs in our day-to-day teaching-learning process could bring paradigm shift in our pedagogy. Moreover, this could also reduce the costs and enhance teaching efficiency. The study has clearly shown that the proper inclusion of VL tools for theory and practical sessions has resulted in a drastic shift in students' attitude towards chemistry learning and improving their curiosity, attention span and learning outcomes..

V. ACKNOWLEDGMENTS

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