Virtual Labs Improve Student's Performance in a Classroom

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Abstract. With the world wide acceptance of virtual educational technologies, it has been shown that they play a vital role in the scientific arena. The purpose of this paper was to analyze the role of Biotechnology virtual laboratories in integrating student's learning ability and introducing it as an effective instructional tool in biotechnology courses. A post-usage survey was conducted among the users and included questions about perceptions of virtual laboratories, its role in virtualization of sophisticated instruments. The survey suggested virtual labs usage enhanced autonomous and guided educational methods. Comparing groups on usage of virtual labs against a control (traditional lab), our studies suggest improved performance in students using virtual labs. Usage analysis and surveys indicated that biotechnology virtual labs are significant elements in adaptive learning process in blended classroom environment.

Keywords: Virtual labs · Biotechnology · Blended learning · Virtualization · Adaptive learning

1 Introduction

Information and Communication Technology (ICT)-based education is a new trend in gathering knowledge in the current educational scenario. The growth of web-based learning has massively influenced the present learning pedagogy [1]. A new model of computer-based learning was achieved by the introduction of Virtual laboratories in science education (http://vlab.co.in)] and also see MHRD Sakshat NMEICT mission document (http://www.sakshat.ac.in/PDF/Missiondocument.pdf). The virtual biotechnology laboratories focus on virtualizing wet-lab techniques has added a new dimension to the classroom education in Universities. This kind of educational technology supports an improved individualized learning that met rural and urban educational needs with high level of flexibility and reduced the concerns regarding time and space. Web tools have immensely influenced the current teaching and learning process [2]. Virtual labs offers diverse analysis of a concept through different components such as a close emulation of a real laboratory 'experience' through animations, which in turn

G. Vincenti et al. (Eds.): eLEOT 2014, LNICST 138, pp. 138–146, 2014.
DOI: 10.1007/978-3-319-13293-8_17

serves diagrammatic understanding of a concept or an experiment in an emphasized mode [3]. By simulating the key steps of an experiment, students may experience an alternative hands-on method of proceeding with the steps thereby promoting interaction with the laboratory scenario. This includes ways to reduce recurrence of mistakes as it cautions the user about the common errors one commits while handling equipment or while performing the experiment by resetting the experimental scene [4]. In current education prospect, computer-aided technologies provide special advantages for designing innovative biology course materials and developing highly interactive student-teacher relationship [5]. Modern web-based educational systems are distinct from the traditional educational models. Adapting to the web based educational systems requires certain qualities and different learning pedagogies. With this change in the education trend, many educational and research institutions widely employed such innovative technologies for teaching and learning purposes [6]. This user-friendly, interactive and problem-oriented methodology of instruction helps users to realize the concepts in a more precise manner.

Laboratory practices are fundamental in teaching and learning biotechnology courses [7]. There are lots of limitations to successfully carry out traditional labs mostly in developing countries [8]. Time constrains, shortage of equipment and reagents, insufficient laboratory protocol, issues in personal safety, inadequate technical support etc. are the most common reasons of setting up a proper laboratory condition in most Indian universities [9]. Online labs may be an asset to many universities which confront economic issues in maintaining equipment and other necessary conditions that need to be met for a good laboratory practice (Diwakar et al., submitted). Virtual labs are popularized as a visual tool that could add advantages to students and instructors towards reducing the laborious procedures in a more effective manner. Virtual labs offer diverse analysis through different components like user- interactive animations, simulations, remote-triggering of real laboratory equipment and haptic devices to employ productive online biotechnology laboratory [10]. The actual feel and visualization of a real laboratory can be delivered through graphical animations to a greater extent. Animations provide a diagrammatic understanding of the concepts of an experiment in a better way that cannot be easily conveyed through text based or passive illustrations. Visualization techniques employed in virtual labs allow the student to freely experience the virtual world to strive to make learning science fun [11]. In a traditional lab system, users may face certain problems such as limited access to laboratory facilities, equipment shortage, inadequate technical support, that may interfere with their curiosity for learning science. Virtual labs play a pivotal role in bridging the lack of lab facilities, and devising individual experience at a low cost and thus increase the chance of self-organized learning methods [12]. This ultimately imparts analytical thinking skills among the learners.

In this paper, we focus on the use of virtual biotechnology laboratory as a new pedagogy for promoting university student's learning experience. The study analyses the effect of virtual labs on student users thereby assessing the relationship between their cognitive and social presence in active learning.

2 Overview of Amrita Virtual Laboratories

To enhance University education in rural and urban areas, several national mission projects had been launched in the recent years. Sakshat Virtual Labs project (http://vlab.co.in) is a joint collaboration of several universities in India including the Indian Institutes of Technology and Amrita University amongst others. It is an initiative of

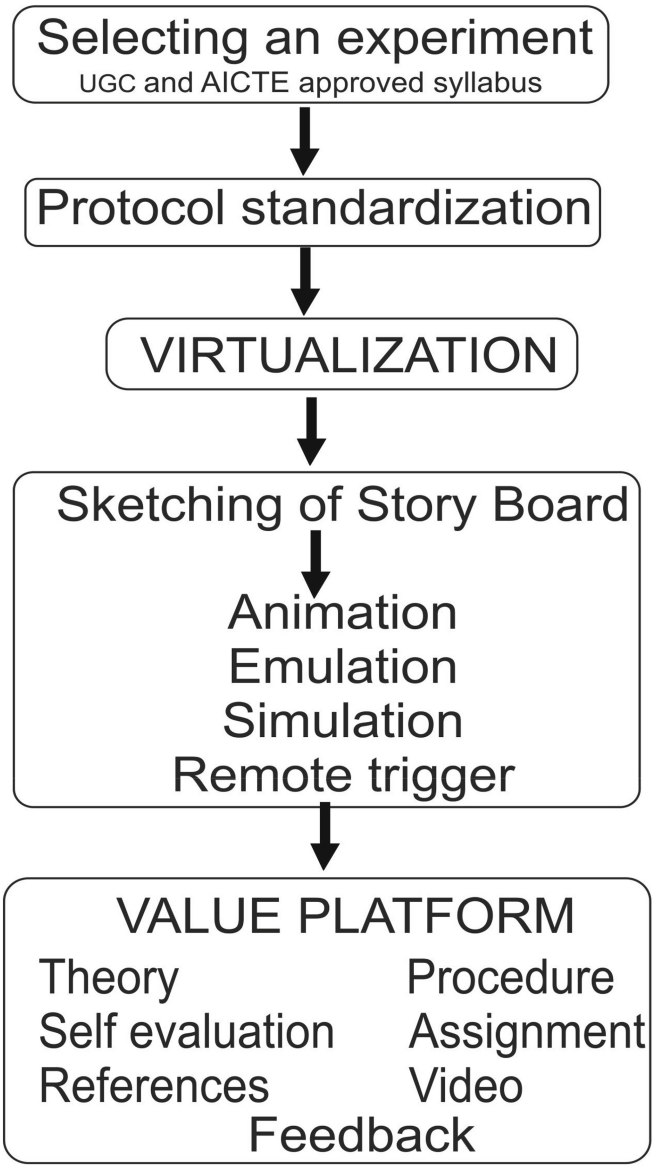

Fig. 1. Flow chart showing the basic steps behind the development of a virtual lab experiment

Ministry of Human Resource Department under National Mission on Education through ICT. The labs developed under Biotechnology and Biomedical Engineering Virtual Labs are freely available on the website http://amrita.vlab.co.in/. This covers about 23 disciplines of biotechnology course with a total of 211 experiments (8–10 experiments per lab). The experiments are virtualized after referring the syllabus (approved by the University Grants Commission (UGC) and All India Council for Technical Education (AICTE)) of different universities. The experimental protocol is first standardized by trial and error methods using different text book references and journal articles. The next step is the software development which includes a storyboard sketch, followed by animation, emulation (interactive animation) and simulation techniques. This virtualization steps helps to make the virtual laboratory with a close proximity to a traditional laboratory scenario. These classroom-based implementations as virtual laboratories were used as interactive textbooks and as tools for actual learning [13].

Apart from animation and simulation, for each experiment we added a theory section which explains the science behind the experiment, procedure which gives details of step- by step protocol performed in a real lab. The self evaluation icon helps to assess the user's knowledge on the experiment. The Assignment icon is provided with a set of questions that the user could answer as a part of laboratory examination. All additional information and reading materials for the experiment were linked in the Reference section. Recorded video of each experiments are also uploaded as an additional reference material. Feedback icon allows the users to post their comments and receive feedback on usage (See Fig. 1). It is a critical element that helps us to improve the quality of virtual lab exercises. Animation, Simulation and remote triggered experiments are accessible to the users through free registration using Google's Gmail id or an open-id. The id details are used only to keep track the number of users. All other components are openly available without any usage restrictions.

The remote-triggered laboratories are now adding a new venture to laboratory education. These labs are an excellent tool to provide access to costly lab equipment for users in places without such facilities. The advantage of using remote laboratory is that the user can effectively use the equipments such as light microscope and conduct experiments without being onsite [14]. VLCOP [15] in its full functionality was used as a platform for virtual labs. The animated or simulated experiments include the use of 2D Adobe Flash (AS3) which can run faster and reduces most server issues [16].

3 Methods

The evaluation of biotechnology virtual labs was performed via surveys to analyze whether virtual labs can bring a significant change in the learning process [14]. In order to evaluate the effect of virtual labs as an educational tool, we conducted a qualitative and quantitative analysis on students. The demonstration and hands on session were followed with a set of questionnaires to evaluate the students' adaptability in using virtual labs in their learning curriculum. The feedback survey included the following questions (See Table 1) with Likert-scale ratings (1- Poor, 2- Average, 3- Good, 4- Very

Table 1. Analysis on the adaptability of virtual labs in classroom learning

Sl No.	Questions for analysis
Q1	How do you rate the online performance of the experiment?
Q2	To what extent did you have control over the interactions?
Q3	To what degree was the actual lab environment simulated?
Q4	The measurement and analysis of data was found to be easy?
Q5	The manuals were found to be helpful?
Q6	The links provided were consistent with the objectives of the experiment?
Q7	Were the results of the experiment easily interpretable?
Q8	A clear understanding of the experiment and related topics was gained?

Table 2. Analysis on the overall performance of students when using virtual labs as a laboratory material

Sl No.	Questions for analysis
1	Name the primary stain used in the Gram staining procedure
2	Name the chamber in which Microbiology experiments are carried out
3	Name equipment used to transfer microorganism from a broth/agar to a slide
4	Name the critical step involved in the gram stain process
5	Specify the color of secondary stain used in the gram stain procedure
6	Specify the basic principle of gram staining
7	Name the instrument used to observe the gram stained organism
8	Name the counter stain used for gram stain
9	Identify the nature of *Staphylococcus aureus* under gram stain
10	Shape of *Escherichia coli* after gram stain

Good, 5- Excellent). The responses given by each user is then converted into corresponding percentage scales and plotted.

The effect of virtual labs on enhancing user perception and learning ability was the focus of this microbiology laboratory course-based case-study. The protocol followed includes survey-based analysis and assessment of student's theoretical and practical information on laboratory content. A total of 100 students, who were not previously introduced with concepts of microbiology laboratory practices were selected for this study. As a prior step, the 100 students were subjected for a questionnaire based pre-test having 10 questions regarding basics of gram staining. They were then allowed to perform the Gram stain experiment virtually to familiarize the basic laboratory concepts. After the virtual lab experience, a post-test was conducted with the same set of questions as in the pre-test. The performance level of students in each test was noted for further analysis. Virtual lab users were asked to respond to a pre and post-exercise survey (See Table 2).

4 Results

4.1 Student-Feedback Based Analysis Shows Easy Adaptation to Usage of Virtual Labs

The feedback data collected from the study participants of biotechnology virtual labs were used to determine the easy adoption to usage of the virtual labs in their learning process. About 45−50 % of the participants rated virtual labs as an excellent learning platform which compliments their laboratory education. User responses indicate that virtual labs are easily adaptable tools for students to improve their laboratory skills and thereby reduced common errors occurred while performing the experiment in the wet labs (see Fig. 2). Student users rate self-grading questions (Q1−Q4) with a lower mean value than information related questions (Q5−Q8) in the feedback.

The data was then analyzed by calculating the overall performance of the users based on the marks obtained from the examination and these were then converted to Percentage scale. The number of users scoring the respective percentage of marks was calculated and represented in a Pie chart (see Fig. 2).

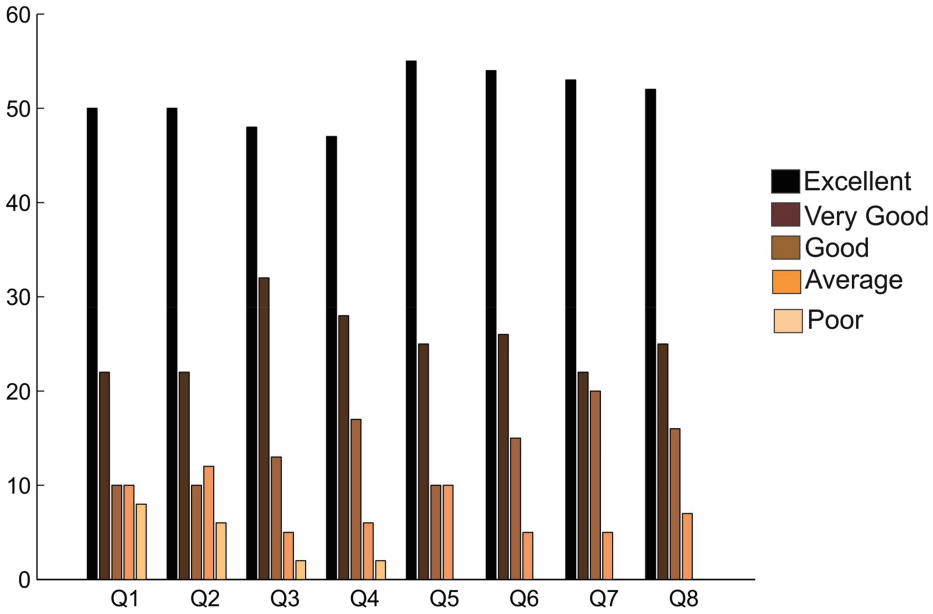

Fig. 2. Feedback of users. Each question was scored between 0−5 points on a Likert-scale. Questions for analysis on X-axis and percentage of users on Y-axis. Some values indicate information provided in virtual labs as easily readable ex. questions Q5−Q8 have a higher percentage (excellent) than other usage-related questions.

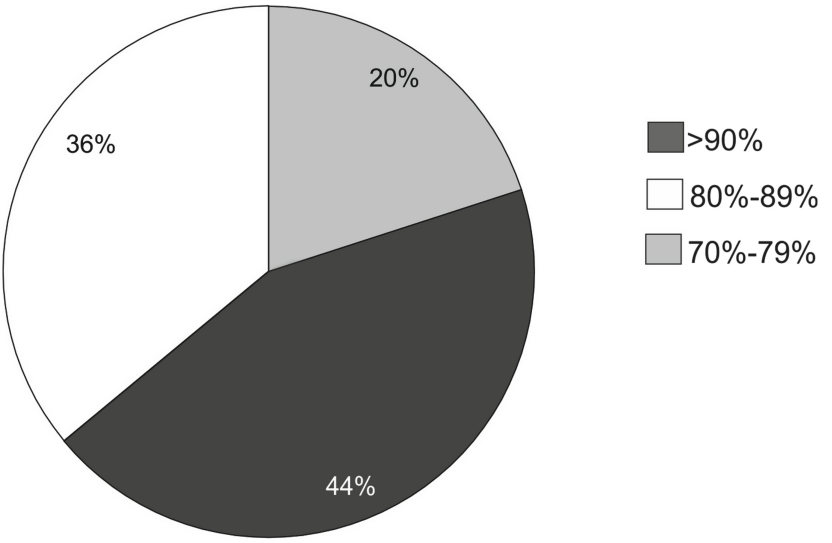

Fig. 3. Virtual labs improved student's performance rate (Post-test). The user performance was distributed according to the percentage scores from the examination. 44 % of the users scored above 90 % marks, 36 % of the users scored in the range of 80−89 and 20 % users scored above average scores in the range of 70−79 %.

4.2 Virtual Labs Augment Student's Performance in Classroom

The statistics shows 44 % of the users were able to score above 90 % marks in the post-test. The same users did not score as much in their pre-test evaluations. All participants scored above 70 % in the post-test, improving the class average from the pre-test scenario (see Fig. 3 and Table 3). This suggests the role of virtual labs as an augmented reality textbook for effective education.

Table 3. User performance rate in examination. Most students perform after using virtual labs as an interactive textbook (post-test) compared to traditional classroom learning (pre-test) and feedback shows improved performance post-test.

Percentage of marks	Pre-test evaluation (# or % users)	Post-test evaluation (# or % users)
>90	0	44
80−89	8	36
70−79	4	20
<70	88	0

5 Discussions

In this study, the effect of virtual biotechnology labs as an educational tool in supporting students to increase their active learning process was analyzed. The content-rich learning materials provided by the virtual laboratories help the users to understand the concepts of the experiments. The survey conducted amongst the students suggests virtual labs as a more effective learning material and usage ensured a better performance during evaluations. A student commented: "Since, most of the biology experiments are time consuming and requires high cost equipment it will limit individual practical experience. By getting experience from virtual laboratory, we students can avoid common mistakes such as improper handling of equipment in the traditional laboratory. Virtual laboratory experiments are direct to use, and also helpful in allowing students to gain the biological concepts, principles and procedure thoroughly". Studies on the incorporation of virtual labs in curriculum suggest that it has a greater impact in education due to its supplementary components. The study showed that students who has used virtual labs as an additional learning material understood the concepts of experiments even in the absence of an instructor.

The results of the study indicate virtual labs improve student's performance when virtual labs are used as a learning tool or as a textbook reference. From the preliminary studies on student performance, it was evident that virtual laboratory experiments are very effective when (a) the reagents and equipment are expensive (b) time requirement does not fit into the class room schedule (c) ethical concerns (d) Difficulty in result interpretation (e) handling of sophisticated instruments (f) Use of hazardous materials (data from student comments, not shown). Our study strongly supported that virtual labs serve as an alternative solution for some of the problems related to classroom laboratory environments, and thereby was effective in improving student performance in the classroom education. Although these initial results suggest virtual labs to be effective, the study is being extended to understand the interaction of social, cognitive and teaching presences in a virtual scene and within traditional blended learning environments.

Acknowledgements. This work derives direction and ideas from the Chancellor of Amrita University, Sri Mata Amritanandamayi Devi. Authors would like to thank Prof. Prema Nedungadi and Prof. Raghu Raman, Dr. Sanjay Pal, Dr. Nandhita Misra, Dr. Sobha V. Nair, Ms. Vidhya Prakash, Mr. Ajith Madhavan, Ms. Nijin Nizar and the whole of CREATE team of Amrita University for their contributions and support in developing this work. The work is supported by the Sakshat project of National Mission on Education through ICT, Department of Higher Education, Ministry of Human Resource Department and Government of India.

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