REVIEW ARTICLE

Virtual Labs: Greener and economic approach for learning the Pharma-Lab

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Abstract

At present, a demand of greener methodologies is increased to protect the environment by reducing the waste. At graduation level, a vast hazardous chemical and pollutants are used in wet-labs causing the various health issues as well as pollution. Several rules and regulations are forced by regulatory bodies to control the pollution but are less effective. Recent technology made it easier with the help of a computer to adopt the green approach as a virtual lab to substitute the wet-lab in learning and understanding the experimental pharmaceutical sciences. Here we compiled and discussed the importance of relevant virtual labs which are helpful for pharmacy students.

Key words: Computer, green approach, pharmaceutical sciences, virtual lab

INTRODUCTION

Virtual labs use the power of computerized models and simulations and various other instructional technologies to understand laboratory experiments by taking help of interesting animation. These are frequently used in the pharmaceutical and engineering field.[1] The Government of India also started an initiated to promote virtual lab under the Ministry of Human Resource Development.[2,3]

An example of a virtual lab is a collection of digital simulations supported by discussion forums, video demonstrations, organized in a World Wide Web format produced by an authoring language such as Author ware or Director.[4]

Virtual labs mainly aim to provide access to Laboratories of various fields of science and engineering for students to enhance their knowledge of their respective field in an interesting way with the help of a computer [Figure 1]. It also develops a complete Learning Management System where the students can see the working of various tools, information about different web resources, video lectures, and animated demonstrations.

PROS AND CONS OF VIRTUAL LAB

Pros of Virtual Labs

1. We can perform a virtual lab on a topic before a real-world lab; it allows students to make mistakes without fear of not getting the experiment done right. Furthermore, virtual labs can present ideas in such a way that may not be easily viewed. For example, when learning about gas laws it may be hard to visualize what is actually happening at the microscopic level, but with the use of a simulation the interactions it can be made visible and interesting.
2. Virtual labs are helpful for those students who are not physically able to be in the classroom so with the help of virtual lab they can study their topics.
3. Some topics are there in the syllabus which may be easy for a teacher to understand but may be beyond the capability of students in the classroom, so virtual lab plays a crucial role at this point.

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4. The virtual lab is quite helpful in distance learning program.
5. In pharmacology, we have to perform experiments on animal, these experiments are already performed by scientists so there is no point to kill that animal and do that experiment again to teach student so keeping in mind the strict law of animal cruelty we can take help of software and virtual lab to learn and study those experiments which are already performed on animal.
6. Virtual labs provide a medium for teachers to present demonstrations and conduct labs that they might not have been able to afford practically. In addition, they can help present ideas which are hard to visualize or explain.
7. The experiments given in virtual lab are usually quick and time-saving; for example, if a beaker takes 20 min to heat up to 100°C then the virtual lab will take <2 min to show this process.

Cons of Virtual Labs

1. The biggest disadvantage of virtual labs is that they are removed from the reality of the lab the quality of experience from virtual labs does not have the immediate and embodied impact of handling specimens and live organisms. Even prepared microscope slides engage the student in the interpretation of structure in ways that photographs, movies, and animations can never do.
2. All virtual exercises lack the immediacy of the supervision and contact with experienced teachers.
3. Virtual labs need a computer and the internet. They rely on servers that are not always in service.

VIRTUAL LABS

Virtual labs are very useful for the learning in the various field of sciences; herein we discussed the important virtual labs can be used in pharmaceutical science. We classified them base on the subject of interest:

1. Biotechnology virtual labs.
2. Biochemistry virtual lab.
3. Pharmacology virtual labs.
4. Pharmacognosy virtual lab.
5. Pharmaceutics virtual lab.
6. Pharmaceutical spectroscopy virtual lab.
7. Pharmaceutical chemistry virtual labs.

Biotechnology Virtual Labs

Virtual lab on DNA extraction[5]

There are various reasons for extracting DNA from human cells. It can be used to check for genetic disease in a newborn if any, analyze for forensic evidence to solve criminal cases, etc. It is also helpful to find out the genes involved in cancer. In this virtual lab [Figure 2], one can learn various applications of DNA extraction. DNA extraction lab can be accessed from the link "Learn.genetics.utah.edu/content/labs/extraction/."

Gel electrophoresis to separate DNA fragments[6]

This virtual lab explains about gel electrophoresis technique for separation and analysis of macromolecules such as DNA, RNA, and proteins and their fragments by their charge to mass ratio. This technique used in forensics, genetics, molecular biology, and biochemistry. The results can be analyzed quantitatively by visualizing the gel with ultraviolet (UV) light. Various apparatus used during this process are mentioned to understand this process in an easy and effective way. It is a technique in which DNA, RNA, and proteins are separated according to their molecular weight. This virtual lab can be accessed from the link: Learn.genetics.utah.edu/content/labs/gel.

Virtual lab to learn the technique of latex agglutination[7]

Latex agglutination is observed when a sample containing the specific antigen (or antibody) is mixed with an antibody (or antigen) which is coated on the surface of latex particles. This virtual lab helps to understand the technique and the protocol. It can be accessed from the link: http://vlab.amrita.edu/index.php?sub=3&brch=69&sim=195&cnt=1.

Enzyme-linked immunosorbent assay (ELISA) test[8]

ELISA test is used to detect the presence of an antigen in a sample and also as a diagnostic tool in medicine. This can also be used to detect food allergens and in toxicological studies for certain classes of drugs. ELISA test also used to diagnose various diseases such as AIDS, hepatitis, and sexually transmitted diseases by checking the presence of antigen or antibody in the serum sample. This virtual lab helps to understand the assay to quantitate soluble antigens or antibodies. It can be accessed at http://vlab.amrita.edu/index.php?sub=3&brch=69&sim=696&cnt=1.

Figure 1: Virtual lab on computer

Figure 2: (a) DNA extraction; (b) Gel electrophoresis

Miscellaneous

Various other virtual lab is also useful like extraction of IgG from immunized hen egg.[9], demonstration of the purification protocols of antibodies for use in research and diagnostics,[10] preparation of the fragments of IgG using pepsin digestion,[11] point mutation, and frameshift mutation impact genetic sequences,[12] how can Punnett squares help predict the traits of offspring?[13] Gene splicing technique (how gene transfer from one organism to another),[14] identification of bacteria by observing appearance stainability, guanine, and cytosine base ratio content of its DNA,[15] how can a sex-linked trait are identified?[16] etc.

Biochemistry Virtual Labs

Estimation of blood glucose by glucose oxidase method[17]

Glucose is a simple sugar which is a permanent and immediate primary source of energy to all of the cells in our body. The glucose in the blood is obtained from the food that you eat. The estimation is very useful to diagnose diabetes. It can be accessed from the link "http://vlab.amrita.edu/index.php?sub=3&brch=63&sim=1343&cnt=1." This virtual lab is simple to understand and helpful to find out glucose by glucose oxidase method.

Isolation of β –amylase enzyme using sweet potato as a source[18]

Amylases are the enzymes which hydrolyze starch. The enzyme β-amylase catalyzes the hydrolysis of α-1, 4 glycoside linkages from the non-reducing end of the polysaccharides to yield maltose units. The isolation method can be easily learned by this virtual lab available at http://vlab.amrita.edu/index.php?sub=3&brch=64&sim=730&cnt=1.

Analyze the proteolytic activity in cell extracts[19]

Zymography is a technique to assess the enzymatic activity of proteins either *in situ* or by separating them with electrophoresis. The enzyme converts the substrate into a product which is detected by different staining methods. This lab explains how to analyze the proteolytic activity in cell extract by accessing it at http://vlab.amrita.edu/index.php?sub=3&brch=64&sim=700&cnt=1.

Analyze the effect of substrate concentration on the activity of enzymes[20]

This virtual lab can be accessed from the link http://vlab.amrita.edu/index.php?sub=3&brch=64&sim=1090&cnt=1. In this virtual lab, one can learn about the effect of substrate concentration on the activity of enzymes. Initially, the activity of enzymes increases with increase in substrate concentration, but at one point all enzymes become saturated, and a further increase in reaction velocity is not possible that is called maximum velocity at saturation point. These types of experiments are performed for studying the mechanism of an enzyme-catalyzed reaction and the effect of substrate concentration, enzyme concentration, pH, temperature, etc., on these reactions. The activity of enzymes increases as substrate concentration increase, but after a limit it becomes constant.

To understand the various techniques applied to process a blood sample and obtain serum[21]

Blood and serum are most frequently used in biochemistry lab to diagnose the various diseases. Serum includes antibodies, antigens, electrolytes, hormones, and proteins expect that used in blood clotting. It can be accessed at http://vlab.amrita.edu/index.php?sub=3&brch=69&sim=196&cnt=1.

Miscellaneous

Various other important virtual lab in biochemistry are: To determine effect of temperature on the reaction rate of amylase enzyme,[22] hydrolysis of ester using orange peel esterase,[23] to construct a standard curve to determine the specific activity of the beta amylase enzyme,[24] to understand the basic concept of Blood Grouping,[25] to isolate the lymphocyte from whole blood by density gradient centrifugation method,[26] etc.

Pharmacology Virtual Labs

Dissection of earthworm and to study its internal structure[27]

In pharmacology, dissection is very important to find out the anatomy and organ system which are affected by diseases as well as during drug treatment. To perform an experiment on animal its dissection has to be done and it is done carefully. Different euthanasia techniques are there to kill the animal before dissection. Anatomy and organ system of earthworm help us to understand the anatomy of a more complex organism. Earthworms are hermaphrodites and commonly used so this virtual lab help to understand anatomy without sacrificing the earthworm. The virtual lab can be accessed at http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/labs/BL_17/index.html [Figure 3].

To learn how to do frog dissection[28]

Similar to an earthworm, a frog is also used in the undergraduate program for dissection to understand its anatomy. It can be accessed at http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/labs/BL_16/index.html.

In this virtual lab, all important things are explained like why we do dissection, what is the history behind that and what are the dissection tools used and how it can be used. This makes the whole concept simple and understandable without sacrificing the animals.

To familiarize the user with the common anesthesia techniques applied in laboratories on rodents[29]

Anesthetic agents are used in laboratory animals to prevent pain due to an experimental procedure. This virtual lab explains how to handle the animal and make them unconscious this lab is accessed at http://vlab.amrita.edu/index.php?sub=3&brch=70&sim=198&cnt=1.

To understand how to perform parenteral injections in experimental animals[30]

It describes the use of rodents how to handle them, manually restrain them, and how to inject in experimental animals. It can be accessed at Link: http://vlab.amrita.edu/index.php?sub=3&brch=70&sim=203&cnt=1 [Figure 4].

To perform laboratory experiments of different drugs in animal[31]

This virtual lab helps us to understand the effects of different drugs in the animals. It plays an important role to understand the action of a drug without sacrificing animals. The experiments are already performed by scientists, so demonstration of this virtual lab is efficient enough for students. The simulator software can be used to teach students how to dissect animals and how to perform drug experiments at "animalsimulator.com." In this software, it has been told how to perform laboratory experiment in an animal like how to do dissection? How to perform different drug experiment?

Miscellaneous

Various other virtual lab are also useful like: To study the behavior of membrane potential,[32] how to prepare brain slice preparation,[33] study of single or multiple ion channels in cells,[34] to study transmission of a signal from one nerve cell to its neighboring cell,[35] study of importance of ion channels in neuronal signal propagation,[36] to understand the role of selective blocking and complete blocking on action potential generation,[37] etc.

Pharmacognosy Virtual Lab

To extract caffeine from tea powder[38]

Tea powder is extracted from tea leaves which contain tannins, a number of colored compounds and an important stimulant called caffeine. This lab explains how caffeine can be extracted by using polar or nonpolar solvent extraction technique. It can be accessed from http://vlab.amrita.edu/index.php?sub=3&brch=64&sim=169&cnt=1 [Figure 5].

Nutritional value of various types of food[39]

This virtual lab discusses the importance of nutritional label facts and daily calorie charts in detail and interesting way. We need the energy to work, and we get it from food, so it is necessary to have knowledge about different nutritional values of food as a different person need different calorie based on their age, size, and gender. It can be accessed from the link "http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/labs/BL_15/index.html."

Miscellaneous

Various another pharmacognosy related virtual labs are: Transpiration rate for different plant species under the varying environmental condition,[40] how is Arabidopsis used as a model plant?[41] etc.

Pharmaceutics Virtual Labs

Preparation of sols[42]

Sols are those colloidal systems where a solid is dispersed in a liquid. Sols have also been classified as lyophobic colloids. These are very useful in pharmaceutics and this virtual lab help in learning that how one can prepare sols. It can be accessed at http://csc-iiith.vlabs.ac.in/exp1/index.html.

Preparation of gels[43]

A gel may be defined as a colloidal system in which a liquid is dispersed within a solid, solid is the continuous phase, and

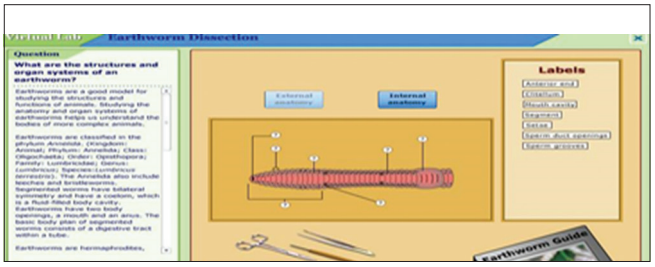

Figure 3: Dissection of an earthworm

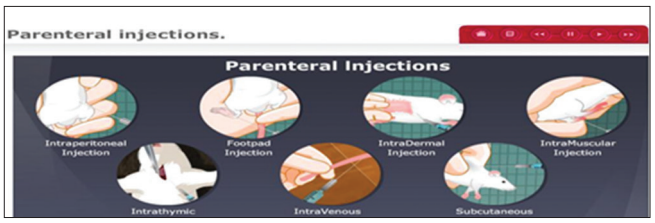

Figure 4: Parenteral injections in experimental animals

Figure 5: Extraction of caffeine from tea powder

the liquid is the discontinuous phase. The preparation of gel is well explained in this virtual lab by accessing at http://csc-iiith.vlabs.ac.in/exp2/index.html.

Demonstration of the preparation and use of association colloids (micelles)[43]

Micelles are an aggregate molecule of surfactant. Soaps and detergents are known as surface-active agents also called as surfactants. Examples of detergents are sodium dodecyl sulfate or sodium lauryl sulfate. It can be accessed at http://csc-iiith.vlabs.ac.in/exp3/index.html.

Demonstration of critical micelle concentration of surfactant[44]

When the concentration of a surfactant molecule in an aqueous solution is increased, above a particular concentration then micelles begin to form. This concentration is known as the critical micelle concentration. This lab demonstrates the determination of critical micelle concentration of surfactant [Figure 6]. It can be accessed at http://csc-iiith.vlabs.ac.in/exp14/index.html.

Miscellaneous

Other virtual labs are demonstration of a surface effect on chemical properties of finely divided powder,[45] to demonstrate the principle of Zeta Potential,[46] etc.

Pharmaceutical Spectroscopy

Demonstration of gel electrophoresis[47]

Electrophoresis phenomenon provides an analytical technique for the separation of charged particles/molecules by applying an electric field. This virtual lab shows a basic technique that how gel electrophoresis is performed. It can be performed at http://csc-iiith.vlabs.ac.in/exp7/index.html.

Instrumentation and working principles of Infrared spectroscopy using salt plates[48]

Infrared (IR) spectroscopy or vibrational spectroscopy involves the interaction of IR radiation with matter. It covers a range of techniques, mostly based on absorption spectroscopy. It can be used to identify and study the chemicals. This virtual lab gives a very clear idea about working of IR spectroscopy using salt plates for spectral analysis of the sample. In this virtual lab, we learn about preparation of the sample for IR spectroscopy. This also tells us about the basic principle of IR instrumentation functioning [Figure 7]. It can be performed at http://ccnsb06-iiith.vlabs.ac.in/exp6/index.php?section=Theory. The other part of the virtual lab explains about the methodology and spectra identifications at http://ccnsb06-iiith.vlabs.ac.in/exp7/index.php.

Instrumentation and working principles of mass spectroscopy[49]

Mass spectroscopy is the most accurate analytical tool to weigh the molar masses of a given molecule. The principle consists of ionizing the sample in the gas phase to formed positively charged ion or radical ions and then measure the mass to charge ratio of all ions. The instrumentation and principle are very well understood by this virtual lab at http://ccnsb06-iiith.vlabs.ac.in/exp8/index.php.

Determination of molar mass of simple compound using mass spectroscopy[50]

Mass spectroscopy is the most powerful technique to weigh the molar masses of a given molecule. It is useful in identifying unknown compounds and studying their molecular structure. This can be run at http://ccnsb06-iiith.vlabs.ac.in/exp9/index.php [Figure 8].

Nuclear magnetic resonance (NMR) spectroscopy and evaluation of simple 1H-NMR spectra of selected organic compound[51]

Proton NMR is the technique in which the hydrogen nucleus of a compound is studied to determine the structure of the compound. http://ccnsb06-iiith.vlabs.ac.in/exp5/index.php [Figure 9].

Identification of unknown component using spectroscopic technique[52]

In this virtual lab, we can learn about identification of unknown compounds through various spectroscopic methods

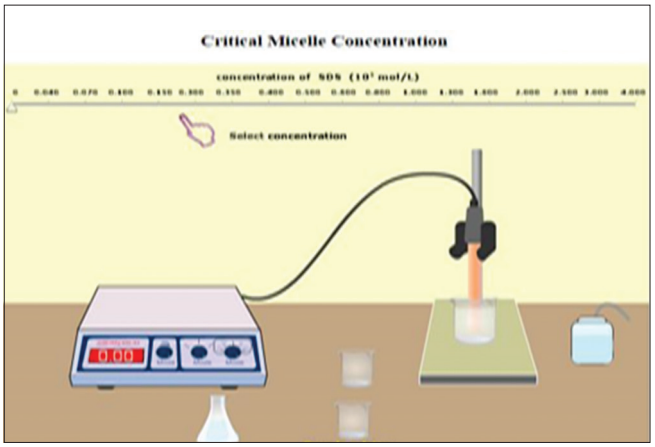

Figure 6: Critical micelle concentration

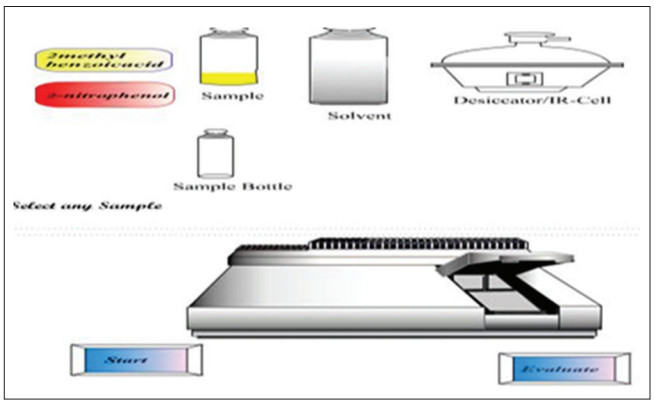

Figure 7: Infrared spectroscopy

such as IR spectroscopy, NMR, and mass spectroscopy. This lab gives a clear understanding of principle and concept of these spectroscopy techniques through a combination of instrumentation, sampling, and graph of the sample under investigation. Identification of a compound can be done using IR spectroscopy, mass spectroscopy, or NMR by clicking at http://ccnsb06-iiith.vlabs.ac.in/exp10/index.php.

Familiarization with UV-visible absorption spectroscopy[53]

UV-visible absorption spectroscopy provides useful qualitative and quantitative information regarding solid, liquid, and gaseous samples and many physical and chemical processes that occur in these samples [Figure 10]. It can be accessed at http://ccnsb03-iiith.virtual-labs.ac.in/exp1/index.html.

This virtual lab confirms the Beer-Lambert law by taking different concentrations of sample and measuring their absorbance at a fixed wavelength. As per Beer-Lambert law absorbance increase as the concentration of sample increases. Finally, we can verify the Beer-Lambert Law by observing whether absorbance and transmittance values have a linear correlation with concentration or not.

According to Beer-Lambert law: Log $(I_0/I_t) = A = \varepsilon c l$

Where I_o and I_t are the incident and transmitted intensities, A is absorbance and ε are molar absorptivity, c is a concentration of the solution, l is the length of solution through which light passes.

To determine the specific rotation of sugar using polarimeter[54]

Chemicals which can rotate a beam of polarized light passing through the solution are called an optically active compound. The instrument which measures this optical rotation is called polarimeter [Figure 11]. In this virtual lab, we will be able to understand that a plane polarized light is rotated by the chiral compound. It can be accessed at http://ccnsb05-iiith.virtual-labs.ac.in/exp1/index.html.

Miscellaneous

Various other labs are an introduction to fluorescence spectroscopy principle,[55] demonstration of a solvent effect on fluorescence spectra of fluorophore,[56] the effect of excimer and exciplex formation on fluorescence emission,[57] etc.

Pharmaceutical Chemistry Virtual Labs

Demonstration of surface tension lowering of water[58]

The surfaces of water and other liquids behave like elastic membranes. The intermolecular forces of attraction in the surface liquid molecules give rise to this property of surface tension. This phenomenon easily explained in this virtual lab (http://csc-iiith.vlabs.ac.in/exp4/index.html).

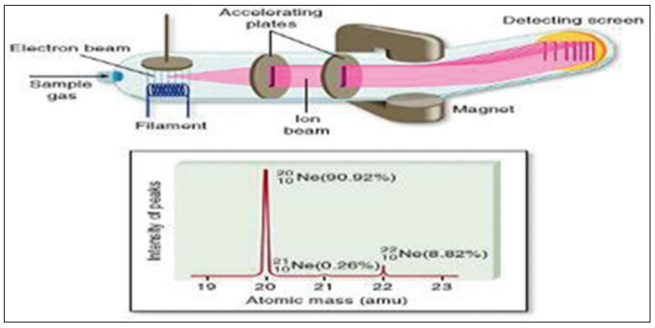

Figure 8: Mass spectroscopy

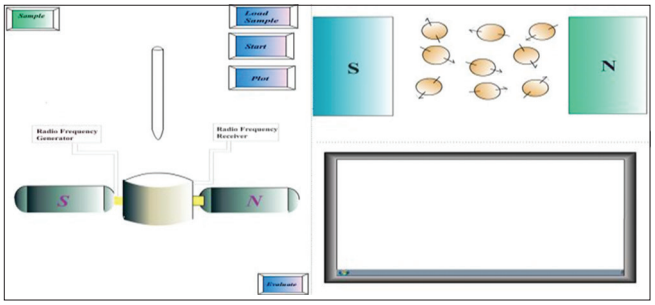

Figure 9: Nuclear magnetic resonance spectroscopy

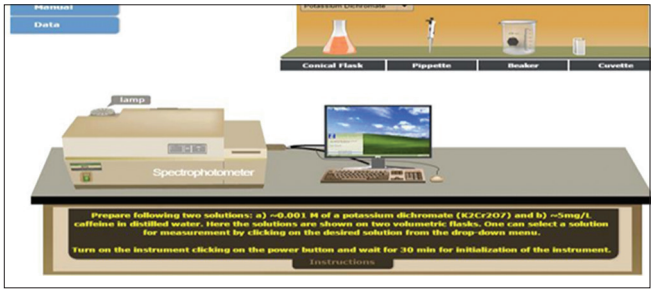

Figure 10: Ultraviolet spectroscopy

Demonstration of Tyndall effect or Tyndall scattering in colloidal system[59]

Tyndall effect may be defined as a scattering of light by fine particles dispersed in a light-transmitting medium. Tyndall effect is observed when light falls on particles of size range 40–900 nm suspended in a transparent medium (http://csc-iiith.vlabs.ac.in/exp5/index.html).

To perform molecular docking to predict the interaction energy between molecules[60]

Molecular docking studies are used to determine the interaction of two molecules and to find the best orientation of ligand which would form a complex with overall minimum energy [Figure 12]. It helps in design and identification of potent molecules (http://pe-iitb.vlabs.ac.in/exp16/index.html#).

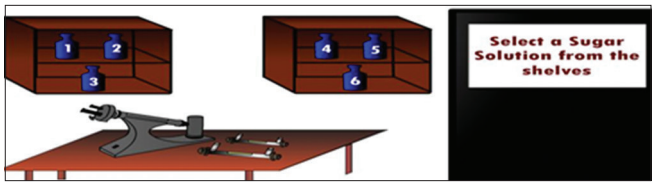

Figure 11: Polarimeter

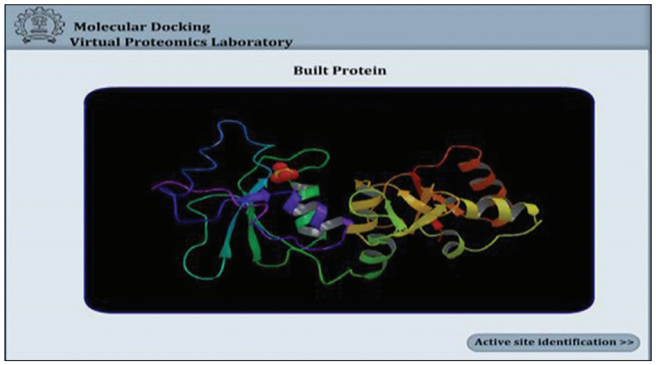

Figure 12: Molecular docking virtual lab

CONCLUSIONS

This review can act as a good database of virtual labs for a student studying pharmaceutical and related sciences. In this review, we have covered the virtual labs of various subjects such as biotechnology, biochemistry, pharmacology, pharmacognosy, pharmaceutics, pharmaceutical spectroscopy, and pharmaceutical chemistry. All virtual labs are having one common feature that it is easy to understand and interesting to play. Through these simulations, the student can easily understand tough topics in short time without requiring any laboratory infrastructure, chemicals, and sophisticated instruments. In a nutshell, these virtual labs are a great asset for a student to learn about pharmaceutical and related sciences in a simple, easy, and interesting way.

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