Introduction

Thanks to the radical progress of information technology (IT), e-learning and open-learning resources are accessible to anyone, anywhere through the Internet. True open-learning resources can be freely accessed, reused, modified, and shared without restriction. Over the last decade, Open Course Ware (OCW) resources, originally initiated by MIT and the Hewlett Foundation, accelerated the spread of knowledge outside of the United States and Europe for global distribution, and were introduced in many Asian countries, including China and Japan [1–4]. However, high-quality educational resources for biotechnology and other life sciences disciplines are lacking [5]. The need for these open-learning programs in the broad field of biotechnology is 2-fold. Cutting-edge scientific research requires access to the latest techniques, which must be constantly refined to achieve greater accuracy in results; however, keeping pace with these techniques is no small feat. Economic crunches and perpetually limited educational resources make it difficult for most of the institutes to afford even the most basic laboratory set-ups [6]. Even well-funded institutions must limit their infrastructure to what they require for research purposes, and access to advanced labs is most often restricted to authorized research personnel.

Virtual labs, where simulators are used to create interactive tutorials that provide students a visual demonstration of techniques, may circumvent many of these roadblocks. While in conventional labs, students have only a short time to assimilate lessons, virtual labs provide unlimited access to class materials, thus facilitating better understanding. Virtual labs cannot replace hands-on training as yet, but the use of interactive simulations gives students an idea of what to expect in the real lab, thus cutting down the time spent learning
Figure 1. Schematic representation of the step-wise development of Virtual Proteomics Laboratory. Virtualization of proteomics data and experimental procedures from "bench-side" and storage in discrete compartments on the common "Virtual Lab server" for development of the course contents. Every experiment is explained in a step-by-step manner that follows the order of the tabs: theory, experimental procedure,
new methods [7]. Virtual labs provide a risk-free learning environment, where individuals can learn from repeated practice, at their own pace, without using expensive resources or high maintenance equipment. Although virtual labs can link theoretical knowledge to practical applications in a lab set-up, these resources can’t be expected to place individuals on an equal footing with those who have real-world training. Nonetheless, these platforms can be considered as a stage where students get a feel of what to expect in real-life experiments, acquire the necessary knowledge, and apply these concepts in physical labs at a future date. Virtual labs have already been shown to enhance student learning when used in conjunction with other teaching methods. Students are able to retain more information when visual and audio materials make classes more interactive and compel student participation.

Among the various virtual biotechnology labs in different stages of development, the HHMI Biomedical Interactive labs, MIT OCW, and the Virtual Labs Media Library at Stanford, are the most popular (Texts S1 and S2). India’s first comprehensive set of virtual labs are initiated through the “Sakshat” mission on higher education by the Ministry of Human Resource Development of the Government of India with an initial budget of nearly five billion Indian rupees. “Sakshat”— a Hindi word used to describe the witnessing of something that had previously only been imagined—is a content-delivery portal developed with an intention to portray India as a “knowledge super power” [8]. There are several emerging biotechnology virtual labs under this project covering different areas of modern biological sciences (Text S1). Virtual Proteomics Lab of Indian Institute of Technology (IIT) Bombay, one of the simulation-based virtual labs under this project, aims to share digital publication of high-quality research, college and university-level educational materials on proteomics, a newly emerging discipline of biotechnology, freely across the world.

The VPL at IIT Bombay is part of this national project and solely dedicated to high-throughput proteome separation and analysis techniques, which are commonly used in basic and applied proteomics research (see Box 1). Already available at the URL http://iitb.vlab.co.in/?sub=41&rr=118, the lab consists of 12 experiments organized into three modules (Text S3). Students begin with protein separation through 2-D gel electrophoresis (2DE), identify the separated proteins using gel imaging techniques, then try to correlate the banding pattern with existing databases. Module II deals with the identification of these proteins using MALDI-TOF-MS. It consists of five experiments that take the students through all the steps of protein processing and preparation for mass spectrometry study. Students then learn the principles and operation of MALDI-TOF (Figure 2B) and how to use the peptide spectrum to identify proteins of interest with the help of software and databases. Module III (bioinformatics) is dedicated to four different bioinformatics techniques for protein analysis. Students first learn to look for homologous proteins using sequence alignment. This step is followed by structural prediction using homology modeling and functional annotation (Figure 2C) using available software and ontological databases, respectively. The molecular docking experiment teaches students the basics of protein-protein interactions and how these can be used to design ligands that can exert a specific effect on the target protein. The “do-it-yourself” assignments and self-assessment quizzes round up every experiment and allow students to evaluate themselves. All the material is available in pdf files and
Module-I: Gel-Based Proteomics

Module-II: MALDI-TOF MS

Module-III: Bioinformatics
Figure 2. Organization of the course contents in the Virtual Proteomics Laboratory at IIT Bombay. (A) Module I (an overview of gel-based proteomics) consists of three experiments: gel-based proteomics (2DE) to analyze human serum, bacterial, and plant proteome; and analysis of differential expression of proteins between test and control samples. (B) Module II (an overview of MALDI-TOF MS) is focused on MS-based proteomics and consists of five experiments: in-gel digestion of proteins for MS analysis; sample preparation for the MALDI-TOF MS analysis; MALDI-TOF instrumentation and analysis of serum proteins; MS data analysis, peptide mass fingerprinting (PMF); and molecular weight determination of intact proteins. Schematic representation of MALDI-TOF instrument and operation procedure for generating peptide/protein spectrum for protein identification. (C) Module III (an overview of bioinformatics) covers the bioinformatics tools that are commonly used in proteomics. This module includes four experiments: sequence alignment, homology modeling, functional annotation, and molecular docking. Structural analysis and 3-D modeling of target proteins has been depicted.

doi:10.1371/journal.pbio.1001353.g002

power point presentations for the experimental procedures and results are available. References are also provided for an in-depth study. There is a feedback section where students can leave their comments.

Virtual Proteomics Labs of the Future

Our major aspiration behind creating this VPL has been to make a consolidated practical proteomics resource, where students can learn several important practical techniques in one program, because most of the programs are scattered among other online biology resources. It is a remarkable initiative for developing high-quality educational materials organized as courses for global distribution, originating outside of the USA or the EU. Since the materials associated with Virtual Labs Project of Government of India can be accessed freely through a common website: website, we expect the contents to be incorporated into the academic curriculum of different universities and colleges in India as per their requirements. The recent web site statistics—233,570 site visits and 1,034,443 page visits within just the last 6 months—and number of registered users—over 4,500 from 134 countries—certainly anticipate the forthcoming utility of this Virtual Labs Project at a global scale [9].

Course content of VPL has already been incorporated in the proteomics course curriculum of IIT Bombay, which is delivered to M.Sc./M.Tech./Ph.D. level students. The student response has been enthusiastic. Furthermore, quite a few educational and research institutes across India have shown interest in the course content and intend to introduce it as a part of their curriculum. The Virtual Lab project has been recognized in various publications recently, providing valuable platforms for disseminating the course contents to a wide variety of users at global level [10–12]. Though presently VPL covers only the most commonly used research techniques associated with gel and MS-based proteomics, we plan to expand its base to include protein microarrays and other advanced proteomics techniques, as well as a remotely triggered virtual proteomics laboratory. In the future, courseware could be individualized to fit every student’s learning style and current knowledge base [13]. The material should preferably follow a predefined style that is readily understandable even to the beginners. We hope our endeavor can serve as a model for the future virtual proteomics labs and related subjects.

Supporting Information

Text S1 Some world leading virtual labs, e-learning, and open-learning resources for biotechnology and related disciplines. (DOC)

Text S2 Virtual labs, definitions, and descriptions at a glance. (DOC)

Text S3 Overview of Virtual Proteomics Laboratory at IIT Bombay. (DOC)

Acknowledgments

The help rendered by Panga Jaipal Reddy in drawing the figures and Meeti Soni in data collection is gratefully acknowledged.

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