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Biotechnology Virtual Labs: Facilitating Laboratory Access Anytime-Anywhere for Classroom Education

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1. Introduction

Biotechnology is becoming more popular and well identified as a mainline industry. Students have shown greater interest in learning the techniques. As a discipline, biotechnology has led to new advancements in many areas. Criminal investigation has changed dramatically thanks to DNA fingerprinting. Significant advances in forensic medicine, anthropology and wildlife management have been noticed in the last few years. Biotechnology has brought out hundreds of medical diagnostic tests that keep the blood safe from infectious diseases such as HIV and also aid detection of other conditions early enough to be successfully treated. Medical kits for diabetes, blood cholesterol and home pregnancy tests are also biotechnology diagnostic products. Industrial biotech applications have led to cleaner processes that produce less waste and use less energy and water in such industrial sectors as chemicals, pulp and paper, textiles, food, energy, and metals and minerals. Laundry detergents produced in many countries contain biotechnology-based enzymes making them nature friendly and safer. Agricultural biotechnology benefits farmers, consumers and the environment by increasing yields and farm income, decreasing pesticide applications and improving soil and water quality, and providing healthful foods for consumers. Biotechnology has created more than 200 new therapies and vaccines, including products to treat cancer, diabetes, HIV/ AIDS and autoimmune disorders.

This rise in application has led to an increased rise in the number of students undertaking University-level biotechnology courses. However, biotechnology education requires an eclectic approach of combining various sub-disciplines. Biology courses and chemistry courses in biotechnology have diversified the approach of the topic. Most common courses that biotechnology degree programs focus at the University level in India consist of cell biology, molecular biology, microbiology, immunology, ecology, statistics and biophysics.

A brief description of the courses will be sketched so a better picture can be understood on the university-level curriculum at most places in India and abroad. Cell biology is a course that focuses on theoretical fundamentals behind the structure, function, and biosynthesis of cellular membranes and organelles; cell growth and oncogenic transformation; transport, receptors, and cell signaling; the cytoskeleton, the extracellular matrix, and cell movements; chromatin structure and RNA synthesis. Molecular biology course covers a detailed analysis of the biochemical mechanisms that control the maintenance, expression, and evolution of prokaryotic and eukaryotic genomes. The topics also include gene regulation, DNA replication, genetic recombination, and mRNA translation. In particular, the logic of experimental design and data analysis is emphasized. Microbiology course introduces students to the principles of infectious agents. Fundamental techniques in microbiological researches, such as sterilization, isolation, morphological observation, and cultivation are usually covered. Immunology courses focus on the mechanisms which govern the immune response. This will usually include the cells, organs and molecules that mediate the innate and adaptive aspects of the immune system as they apply to infection, tumor recognition, autoimmune diseases, immunodeficiency, cancer and hypersensitivity. Population ecology courses introduce students to major concepts in population ecology including topics such as mathematical models of population growth, population viability analysis, habitat fragmentation and meta-populations, dispersal, population harvesting, predation and population cycles, competition, and estimation of population parameters in the field. Biochemistry course explores the roles of essential biological molecules focusing on protein chemistry, while covering lipids and carbohydrates. It provides a systematic and methodical application of general and organic chemistry principles. Students examine the structure of proteins, their function, their binding to other molecules and the methodologies for the purification and characterization of proteins. Enzymes and their kinetics and mechanisms are covered in detail. Metabolic pathways are examined from thermodynamic and regulatory perspectives. A typical course in biochemistry provides the linkage between the inanimate world of chemistry and the living world of biology. Biophysics is a course that usually links to the study of underlying physical phenomenon in biology and their function. Biophysics course usually cover techniques, methods and applications besides molecular structure and function. Topics in biophysics covered will include an introduction to cell and molecular biology, biorheology, Brownian motion, molecular interactions in macromolecules, protein and nucleic acid structure, physics of biopolymers, chemical kinetics, mechanical and adhesive properties of biomolecules, molecular manipulation techniques, cell membrane structure, membrane channels and pumps, molecular motors, neuronal biophysics and related biophysical mechanisms. A very significant yet seemingly unrelated course is biostatistics. A single introductory course in biostatistics involves an emphasis on principles of statistical reasoning, underlying assumptions, and careful interpretation of results. Topics covered include descriptive statistics, graphical displays of data, introduction to probability, expectations and variance of random variables, confidence intervals and tests for means, differences of means, proportions, differences of proportions, chi-square tests for categorical variables, regression and multiple regressions, an introduction to analysis of variance.

Using software technologies for education has become a new trend. Computer-based technologies developed by academic institutions as well as industries worldwide are revolutionizing the educational system. A new field involving the use of virtual reality techniques is becoming the training environment. Through virtual labs, a new interdisciplinary field of science brings together biologists and physicists to tackle this grand challenge through quantitative experiments and models. Using several pro-learning even distance education courses have started using virtual laboratories to enable students to access equipment since they are independent from opening hours and the work schedule of the staff. In many engineering courses within India, simulation is the most effective tool in training students in the use of sophisticated as well as complicated instruments that are routinely employed in modern biological and chemical laboratories. For the life sciences, this also circumvents the use of expensive and hazardous biological and chemical agents which toxic to the experimentalists as well as to the environment. Above all, the virtual lab technology is cheap as well as cost effective.

Education in many universities and research institutes include their own virtual laboratories on the web, which are accessible to people around the world. Although some laboratory practice requires getting one's hands 'dirty', it has already been established that the Virtual Lab enables the students to understand the underlying principles and the theory behind laboratory experiments. E-learning plays and will play an important role in diverse regions such as India where the traditional lab facilities at Universities are not very well localized to suit requirements of all sub-regions. With multi-campus scenarios as in some Universities such as ours, offering cross-disciplinary courses needs to exploit the use of extensive e-learning facilities (Bijlani et al., 2008).

Biotechnology lab courses richly rely upon new up-to-date content and various techniques that require a new synergy of knowledge and experimental implementation. Hence a new kind of experimental science that can be brought as a virtual simulation based laboratory is necessary. The developments of the virtual labs include mathematical techniques in biology to study, to hypothesize and to demonstrate complex biological functions. However virtual labs in heavy engineering topics such as analyzing nanomaterials with high-power microscopes and lab courses in biotechnology or biology will also have to exploit multiple techniques besides simulators alone as many scenarios cannot be reproduced mathematically while retaining the "real" lab-like feel.

In this chapter, we focus on the development and use on the virtual biotechnology laboratory courses through a combination of techniques to try completing the learning experience as that of a regular University laboratory.

2. Why virtual labs?

There are many main reasons to focus on creating virtual labs for University education (Auer et al., 2003). Among the primary reasons include the cost and lack of sufficient skill-set for facing the current growth in biotechnology sector. The setup cost of laboratories puts a large overhead on the educators. The Universities also need to setup laboratories to educate sufficient target group with the details of common biotechnological techniques and protocols (O'donoghue et al., 2001).

Another new motivation is the need to introduce and focus well-explored potential virtual lab areas which use computational methods, mathematical modeling and biophysics, computational biology and computational neuroscience. Computational biology and biophysics are upcoming areas and most techniques derive basis from real laboratory experiments. Another intention of using virtual labs via a computational approach is to train young scientists in the field of the mathematical thinking for life sciences and related environments. Main goals of cross-disciplinary sciences include the need to ensure that the students will be able to integrate different exhaustive models into a larger framework, i.e. in the perspective of comprehensive biological systems such as cells and biological networks. Such a role will also give an overview of the modeling approaches that are most appropriate to describe life-science processes. For the everyday biologist, the major use of virtual labs will also be in the learning perspective of advanced but common-to-use simulation tools.

Virtual labs and use of virtual tools should lead to an increase the awareness of a crucial need for standard model descriptions. Most simulators and common-use tools require various formats and schema and with the explosion of data, the use of virtual labs across the country or across multiple countries is also intended to unite educators to work towards common model descriptions and standardization of their data.

For the biotechnology sector, a highly favoring motivation for the shift to the virtual lab paradigm is the explosion of data-rich information sets, due to the genomics revolution, which are difficult to understand without the use of analytical tools. Also, recent development of mathematical tools such as chaos theory to help understand complex, nonlinear mechanisms in biology seems to push the need for information-rich virtual labs in simulation domain.

To aid further, an increase in computing power which enables calculations and simulations to be performed that were not previously possible, have set a new trend in the concept and use of computing. Simulations in the past that needed more intensive computers now can plainly be run through long battery-life laptops (Aycock et al., 2008), given that in many cases laptops today even host servers.

A slightly different reason that also pushes the concept of virtual labs for undergraduate and master level education at the Universities also seems to be an increasing interest in in silico experimentation due to ethical considerations, risk, unreliability and other complications involved in human and animal research.

Given all above reasons and motivation, virtual labs are today’s experimental approach towards a newer trend in future education. However the virtual lab environments are still under severe testing and newer models seems to switch to more intelligent and adaptive platforms that can yield efficient knowledge dissipation. One such common model is the adaptive learning system (ALS) currently employed by many e-learning applications strewed on the internet.

3. Other virtual labs and online courses in biosciences

Very little work has been actually done in the biology sector. There are online "dissections" of frog tutorials by Mable Kinzie developed in 1994 and an improved version of the same was hosted in 2002 (http://curry.edschool.Virginia.EDU/go/frog/menu.html). Quick "movies": http://www.bio.unc.edu/faculty/goldstein/lab/movies.html Virtual “experiments”: Biology Labs On-Line (BLOL) is a collaboration of the California State University system Center for Distributed Learning and Addison Wesley Longman, with partial funding provided by the National Science Foundation (http://biologylab.awlonline.com). A project titled "BIOTECH Project" developed by University of Arizona, with aim of supporting Arizona teachers to conduct molecular genetics (DNA science) experiments with their students and assists teachers in developing new activities for their classroom (http://biotech.bio5.org/home). "Protein Lab" by A.J. Booth, is a computer simulation of protein purification. These labs are extremely helpful for beginners in the art of protein purification. It gives them a chance to get beyond the details of individual techniques and get a sense of the overall process of a protein purification strategy. (http://www.booth1.demon.co.uk/archive).To enhance education, there is a great need for individualized courseware to provide educational content that fits to the learner's learning style and knowledge base. University of Utah's genetic science learning center has its very animated genetics labs at http://learn.genetics.utah.edu/gslc. The labs were developed with the mission in making science easy for everyone to understand. Similar projects at Howard Hughes http://www.hhmi.org/biointeractive/vlabs and at Pearson's http://www.phschool.com/science/biology_place/labbench have been useful as virtual education websites.

Online biotechnology courses are available through several leading universities around the world, including the Massachusetts Institute of Technology (MIT), Osaka University and the Open University. OpenCourseWare (OCW) from TUFTS and MIT offer courses on the Web that containing all or some of the materials from the university's original on-campus classrooms. Many biotechnology courses on OCW make use of several different learning materials available online or by download, lab notes, assignments, lectures on scientific communications and study materials. Online biotechnology courses are known to be very helpful for students to study/prepare for the positions as lab technicians, research assistants and quality assurance analysts in such fields as agriculture, pharmaceuticals and manufacturing.

4. Amrita VL

Amrita University's Virtual and Accessible Laboratories Universalizing Education (VALUE) initiative was initially targeted towards making biotechnology, physics and chemistry courses virtually accessible for undergraduate and postgraduate education. The project led to the development of 14 labs in biotechnology and 13 labs in physical and chemical sciences. The schema of virtual labs was based on one of our studies.

An average survey of the VL framework software was performed and the tests were shown (see Table 1 in Diwakar et al., 2011). The developed virtual labs are available for public use (See http://amrita.edu/virtuallabs). Any user may login with an open-id or Google's gmail account and access the authentication-compulsory regions such as the remote-panel, simulator and animations. The website uses the name and email address that provider gives only to set up an user account.

5. Techniques – Animation, simulations and remote-triggered experiments

The key learning component in many biological laboratories is the complexity of the procedure and details of the step-by-step protocol carried out in the laboratory. Although some of these biological processes can be replaced by mathematical equations modeling the system, most of the "feel" is in performing the detailed procedure which is not derived from sets of equations. Graphical animations deliver a high degree of the reality to the virtual labs through their seeming closeness to the appearance and feel of the lab. Graphical animations also cut out the complexity of the modeling process by increasing the “feel” of experiment. Like the proverb goes, “a picture is worth a thousand words”, animations reveal better information that cannot be easily conveyed via text alone or static illustration.

In our biotechnology virtual labs, the animation type of experiments include the use of 2D flash based animations for illustrating detailed procedures such as wet lab protocols and heavy engineering techniques that are out of scope for simulation due to various reasons like complicated equations, numerical issues in simulation, lack of modeling data etc. Besides animation, another common technique in our virtual labs included engineering-based approaches such as remote-triggered experiments or remote-controlled experiments.

The very common and research-inspiring approach is the use of mathematical simulators to model biological and biotechnological processes or sub-processes. Although mathematics has long been intertwined with the biological sciences, an explosive synergy between biology and mathematics seems poised to enrich and extend both fields greatly in the coming decades. Among the various scenarios to study biology and disseminate information effectively and efficiently, includes the use of e-learning as a medium to offer courses.

Applying mathematics to biotechnology for virtual lab creation has recently turned into an explosion of interest in the field. The NASA virtual laboratory or the HHMI virtual labs at Howard Hughes Medical Institute or the Utah genetics virtual laboratory are some examples.

For our labs, a combination of user-interactive animation, mathematical simulations, remote-trigger of actual equipment and the use of augmented perception haptic devices are used to deploy effectively the real laboratory feel of a biotech lab online.

6. Models in biology – As virtual labs

Design of simulation labs requires basic mathematical models. Some models that were used to develop the virtual labs are listed below.

6.1 Neurophysiology and neuronal biophysics

In order to understand neuronal biophysics and simulations on voltage clamp and current clamp in detail, we modeled a section of excitable neuronal membrane using the Hodgkin-Huxley equations (Hodgkin and Huxley, 1952) that can be accessed a graphical web-based simulator. Various experiments using this simulator deal with the several parameters of Hodgkin-Huxley equations and will model resting and action potentials, voltage and current clamp, pharmacological effects of drugs that block specific channels etc. This lab complements some of the exercises in the Virtual Neurophysiology lab.

6.2 Population ecology

As part of population ecology virtual labs, we developed a set of mathematical ecology models to understand the basic dynamics and behavior of population in various aspects. Some models include:

- Exponential growth with continuous and discrete rate of growth. If a population has a constant birth rate through time and is never limited by food or disease, it has what is known as exponential growth. With exponential growth the birth rate alone controls how fast (or slow) the population grows. The objectives include the study the growth pattern of a population if there are no factors to limit its growth, to understand the various parameters of a population such as per capita rate of increase(r), per capita rate of birth (b) and per capita rate of death (d) and to understand how these parameters affect the rate of growth of a population. A case study on tiger population will indicate the applicability of exponential models as classroom tools.
- Leslie matrix is a discrete, age-structured model of population growth that is very popular in population ecology. It (also called the Leslie Model) is one of the best known ways to describe the growth of populations (and their projected age distribution), in which a population is closed to migration and where only one sex, usually the female, is considered. This is also used to model the changes in a population of organisms over a period of time. Leslie matrix is generally applied to populations with annual breeding cycle.
- Study of meta-populations using Levin's model shows a simple model to understand population changes. Meta population is a population in which individuals are spatially distributed in a habitat to two or subpopulations. Populations of butterflies and coral-reef fishes are good examples of metapopulation. A virtual lab using Levin's model explains how to understand the basic concepts and dynamics of metapopulation and population stability with the help of mathematical models. In addition it is a study on how variations affect the population dynamics and how the initial number of patches occupied in a system affects the local extinction after a few years.
- Lotka-Volterra Predator Prey interactions (Wangersky, 1978) and logistic growth functions.

6.3 Biochemistry, cell biology, microbiology, immunology and molecular biology

Simple linear equations were used to understand molecular mass flow in AGE, PAGE exercises. No differential equations were used in biology oriented virtual labs where the focus was on the look and feel. In many cases, animation played a major role in these areas rather than mathematical simulations. As in the case of realistically animating experiments there are a lot of advantages; although it cannot be considered as a complete replacement of real labs due to its limitations. One solution was to provide the necessary details of the instruments we were using for the lab. Per say, if we use cooling centrifuges for an experiment in the virtual lab, one may not fully show all details corresponding to the operating methods of the centrifuge. But in the case of a real laboratory the student gets an opportunity to have a hands-on experience on the equipment while doing the experiment. Also, many of the experiments require instrumentation facilities. Also instruments from different companies have slight differences in design and operating mechanisms, which may not be shown in the virtual labs. Thus even though virtual lab meets the major target, it shadows the minor details of the experiments. Not all parameters such as changes in temperature during an experiment especially (where small changes do not matter) may not be included in the virtual lab for the sake of simplicity. In a real lab, curious students can perform these kinds of interesting experiments but to do the same in virtualized experiments is difficult.

7. Major challenges

Setting and developing AMRITA virtual labs (see Fig. 2) as a complete learning experience has not been an easy task. Amongst the major challenges we faced included usage/design scalability, deliverability efficiency, network connectivity issues, security and speed of adaptability to incorporate and update changes into existing experiments.

Owing to the scientific domain, biotechnology lends the following challenges to establishing virtual labs:

- The development of analytical solutions in the arena is limited as biological processes are typically non-linear and are coupled systems of differential equations in various forms.
- The mathematics behind models is hidden by their complexity and appears refined through simulation platforms.
- Most simulation platforms need direct hands-on experience between teachers and students.
- The number of students that can be catered at any given time is restricted.
- Besides, such courses also need simultaneous theoretical explanations which may need classroom-like scenarios with video presentations, white-board and other tools. We could overcome the issue here using a collaborative suit, AVIEW (Bijlani et al., 2008).
- There are not many courses in India developed for this scenario.

In order to address some of these issues and to overcome restrictions, we deployed virtual lab experiments as web-client based animations or simulators besides remote triggered experiments. The virtual lab was based on a website that was designed for favorable use within intranets and internets. However, efficiency depended on the internet bandwidth and connectivity. Our target was any campus with a download link of 256kbps should suffice. To retain this compatibility the animations had to be size-delimited. To overcome the problem, longer experiments had to be sliced to smaller portions, each loading in sequence. This was possible as we maintained the virtual lab experiments as flash animations (Adobe, USA). Having labs in flash environments allowed the scalability and access although flash based action script programming needed additional programmers and training.

Other e-learning issues such as student-teacher collaboration via chat, video interfacing etc. were overcome via AVIEW-like environment (Bijlani et al, 2008). The intention of the virtual labs was also to extend the facility to develop an applied computational laboratory.

8. Methodology

Amongst others, the focus of having and designing virtual labs was also based on John Keller's ARCS model of motivation. Design of courses, simulations and models for computational approaches in biology will be the highlight. A lot of attention was on courses whose content will be applicable to the existing P.G. programs.

Fig. 1. Sakshat Amrita virtual labs. Accessible at http://amrita.edu/virtuallabs

For all biotech virtual labs, we had set the following lab-level objectives as general guidelines.

- Virtual labs should be adaptive. An adaptive e-learning system is a system in which modifies its behavior (the learning process) in response to the changes in the learners input data and information gathered from various teaching process. It should be able to incorporate data and user changes as and when possible.
- Introduce and focus virtual lab areas in core computational and protocol-based biotechnological sciences.
- To train young scientists in the field of the mathematical thinking for life sciences and related environments.
- To ensure that they will be able to integrate different exhaustive models into a larger framework, in the perspective of a comprehensive biological systems such as cells and biological networks.
- To give an overview of the modeling approaches most appropriate to describe life-science processes.
- To give a practical introduction to advanced but common-use simulation tools.
- To increase the awareness of a crucial need for standard model descriptions.

The implementation of animation and simulation based virtual labs was mainly done in Action Script 3 in Adobe flash in order to bring better definition to 2-D graphics. Action script allowed flash swf files as output thereby allowing both a better look-and-feel and an enhanced interactivity with the software. The physics simulator tools worked reasonably well. We did not use java as a programming medium in our learning tool to make sure we have complete cross-OS, cross-browser compatibility, to reduce initial loading time and also to consider support for the commercial operating systems such as Microsoft's Windows platform that support flash better than Java plug-in.

We used a new VLCOP platform (Nedungadi et al., 2011) in its full functionality for the virtual labs. The minor intention was to deploy preliminary platform with a learning environment and later render the environment adaptive and intelligent as per the user-audience. The main reason to precursor with such a test was cost-efficiency. Cost-efficiency of e-learning programs has been increasingly important because some institutions have failed due to the lack of well-thought out financial plans (Wentling et al, 2002; Morgan, 2000).

Virtual Labs use self-assessment based on questionnaire to evaluate user's experience. Although not implemented, an advanced form of the lab is being planned to include teacher's assessment, peer-assessment and collaborative assessment. Teacher assessment will actually have a "real" instructor on the deployment site to evaluate the lab user/student. Peer-assessment will include any student or teacher to assess another. Collaborative assessment will include both the instructor and the student to perform assessment on the completion of an experiment.

For our installation and deployment, we focused to reduce internet downtime. A 2004 study indicated that overall downtime costs companies an average of 3.6% of annual revenue (internet sources, see www.sentinelbussiness.it) indicating leading causes for downtime being software failure and human error. Through our studies, we managed to reduce unnecessary events and maintain downtime to less than 27 minutes for 6 months (not as in Amrita Learning software, see Table I in Diwakar et al., 2011). However, this could be because of our lack of full incorporation of the complex adaptive learning system as it was done for the schools where it was tested. However a test on real-time upgrade to such a model based on our previous experiences (data not shown) with Amrita learning (Nedungadi and Raman, 2010) indicated that overall loss of virtual lab in terms of downtime will be significantly less.

9. Feedback and assessment

Feedback is usually not used as an evaluator but an assessment tool for student quality. With that in mind, the virtual lab evealuation criterion was focussed on measuring and estimating the student's involvement in the particular experiment of a particular lab. A way to increment the quantity and timing of feedback is to provide enough detail. Through animation, we have also increased evaluatory criterion and details in the virtual environments. It was noted that in more than 95 experiments performed by more than 30 people within a particular time-window there were more than 91% of appreciation (further statistics pending, data not shown) when two experiments, one with detail oriented interactive animation and other without interaction were delivered to assess the involvement of the students in terms of their self-assessment.

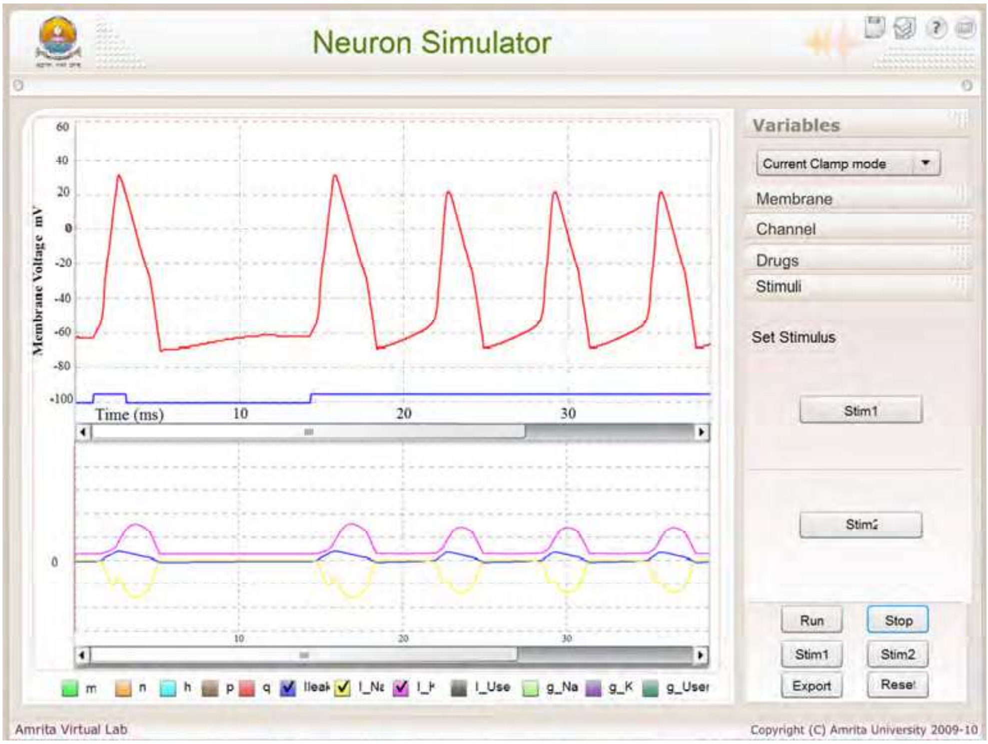

Fig. 2. Neuron simulator. The Neuron simulator lab uses Hodgkin-Huxley equations to study and analyze the action potential properties. The simulator allows some pharmacological studies and complements the neurophysiology virtual lab.

10. Case study: Virtual neurophysiology laboratory

Our preliminary studies in the biotech sector were on neurophysiology techniques. The virtual neurophysiology laboratory provides an opportunity for students to substitute classroom physiology course with detailed techniques and protocols of a real laboratory. Besides the material like chemicals, physiology demands extensive knowledge and experience from the instructor. For example, rat brain slicing protocol which is the first experiment (in the virtual lab) takes approximately 6-10 hours to complete training and about 2-3 weeks to train one student in a real laboratory.

With the focus on time (Rohrig et al., 1999) and learning know-how, we adapted the usual lab experimental protocols as user-interactive animations of the neurophysiology lab experience. The work involved both animators and programmers. For some experiments such as brain slice preparation, animations were sufficient whereas for some others such as Hodgkin-Huxley neuronal model (Hodgkin et al., 1952, see Fig. 3.) for demonstrating behavior of single neurons, we used Java based simulator. The same simulator was embedded into other experiments such as voltage clamp protocol and current clamp protocol to allow the student to see the corresponding behavior as seen in real neurons (Koch, 1999).

A new set of experiments developed included the use of electronic resistance-capacitance (RC) circuits that could be remotely triggered as mimicking the electrical dynamics of a passive neuronal membrane. Passive neuronal membranes are modeled as RC-circuits with high resistance and low capacitance (for more details see Koch, 1999). In the simulation lab that was developed to complement the exercises of the VL, a model detailed study was added. Some of the main objectives and experiments using a neuron simulator included:

- Modeling action potential
- Modeling resting potential
- Modeling sodium ion channel and its effect on neural signaling
- Modeling delayed rectifier potassium channels
- Modeling passive membrane properties
- Current clamp protocol
- Voltage clamp protocol
- Understanding pharmacological implications of ionic currents
- Capacitive transients using Voltage Clamp
- Effect of temperature on neuronal dynamics
- Plotting F-vs-I curve
- Plotting V-vs-I curve

Also as part of the labs, we follow a particular formatting for each experiment within the lab. The goal was to allow the student to study the theory, the approach and do a self-test before actually going into the simulator or the virtual experiment. Covering some explanations and incorporating the same theory into the actual "lab" part of the experiment has been one of the primary goals. Each experiment in the labs (especially in Biotechnology) opens by default with the textual theory, which can also be randomly accessed by clicking on the icon "theory".

All the control and experimental parameters are explained in the "manual". The instructor and the student are informed on how various parameters change in the experiment in the very context of the virtual experimental lab procedure. For those experiments that have both an animation learning component and simulator component, each of the user controls and the variable parameters are explained. Also included in the manual is a help that actually explains the usage of radio controls and icons covered by the experiment. The intention was to evaluate the basic info that once the student completes the familiarization process by going through the theory and manual sections, he/she can take a "self-evaluatory" quiz module that chooses to test the student on some questions based on the theory background of the experiment.

The "simulator" tab actually leads to the experiment workbench. "Protocol for brain slicing" that is actually a detailed lab process that would take 6-10 weeks for post-master's student to learn and about 3-10 hours per procedure. That experiment we have virtualized by means of an interactive action script based animation. The second neurophysiology experiment concerns the modeling of a neuronal cell. In this case we have used a Flash based learning component along with a HH-simulator of a biophysical neuron.

The "assignment" icon is the lab experiment question with which intention the student performs the experiment. An instructor version of the assignment will include a model solved question or key tips in case of a protocol-like experiment. Additional reading material and reference information and other details will be found in our “misc info” icon.

Among the various methodologies the lab covers simulation-based, animation-based and remote-triggered experiments. The simulator was that of a bio-realistic model cell and was combined with an interactive animation-based learning-tool made using Flash. Maldarelli et al. (2009) report the advantage of virtual lab demonstration as an effective lab tool. The remote-triggered experiments were based on real electronic circuits that mimic the phenomenon observed in neuronal cells. The basic behavior of Resistance-capacitance circuits that can be modified remotely by a user to study and imitate real neuronal circuits as he/she does in a neuronal biophysics laboratory on a patch of a neuronal membrane.

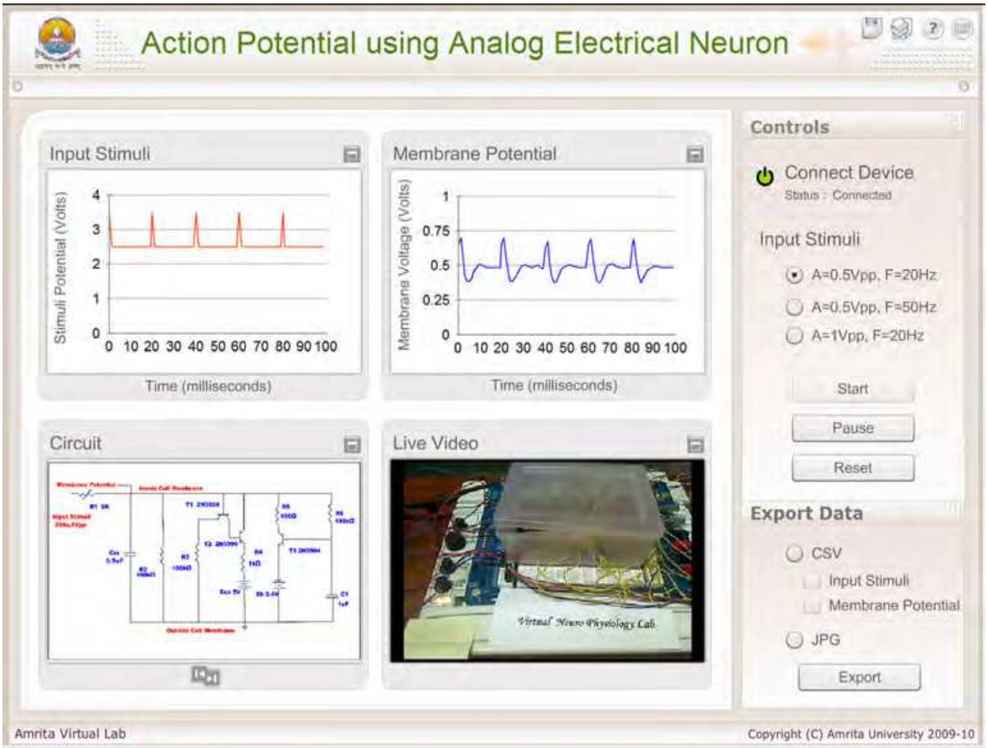

Fig. 3. Remote-triggered Experiment. Remote panel is also made with re-configurable panels and control options. This experiment emulates action potential generation using analog neurons.

We also tested the virtual lab via a questionnaire-based feedback for overall quality. Among the major questions, several virtualizations related questions were presented in the questionnaire. The general developer/designer related questions included in the lab were to rate the experiment that was most recently completed, extent of control on the interface, closeness to lab environment and feel, measurement and analysis of data, user-manual quality, adequacy of bibliography and references, results interpretation, whether any clear information was gained by using the virtual lab, any problems faced, how helpful the lab was and overall motivation.

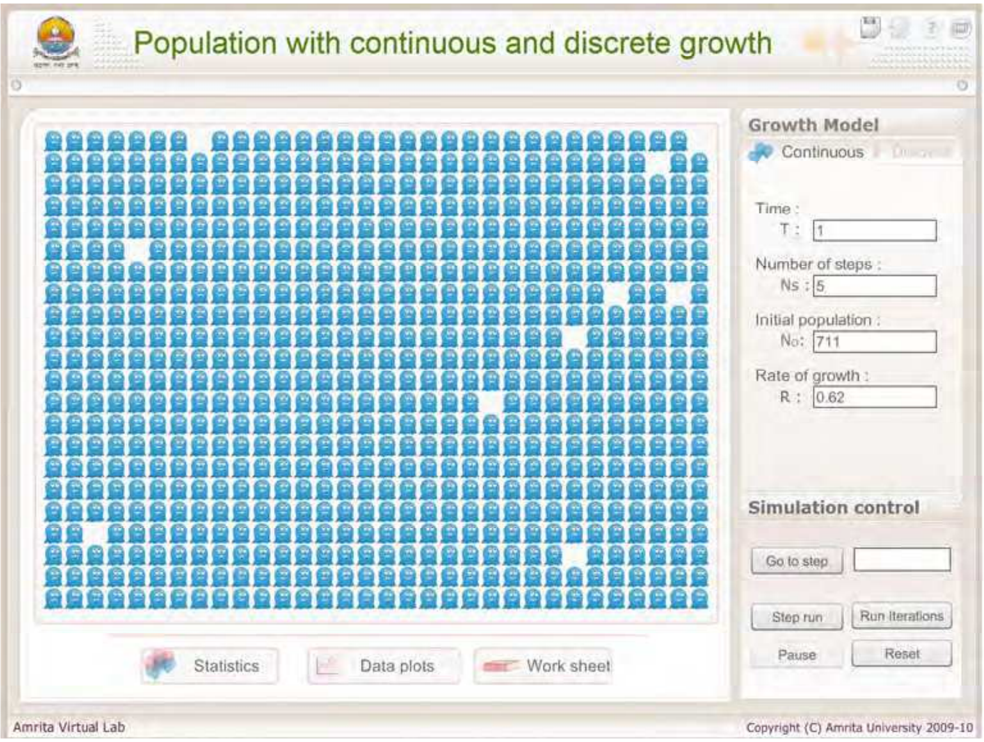

Fig. 4. Tiger population study. Using exponential growth patterns to predict tiger population in India.

11. Taking project tiger to the classroom: A virtual lab case study

Using a virtual lab was not our only objective. We wanted to test a real scenario and see if the virtual lab could be used a as research tool. Tiger population study uses virtual labs to take India's Project tiger to the classroom. Half of the tiger population in the world is in India. Due to reduction in their population in large numbers, from 1969 onwards the 'tiger' was declared as an endangered species (by CITES). Educating about tiger populations is vital. Typically courses in population ecology deal about population variations. In this section, we suggest on the applicative use of population ecology simulators as classroom models to complete the learning experience for a population ecology laboratory course. This section also reports the analysis, interpretation and some preliminary predictions in variations of tiger population in India.

Here we used the exponential growth model experiment in population ecology lab 1 (at http://amrita.edu/virtuallabs). First step is to select an experiment followed by selecting a mathematical model which is described in the experiment from the set of experiments (see Fig. 4). Some existing data tested indicated the validation of the technique. (Fig 5B).

11.1 Data collection

Statistical data for this study was collected from Project Tiger which includes the tiger population from 1972 – 2002 of various tiger reserves (see Table 1). And the second data set was the crime reported for the numbers of tiger that have been killed in past few years were from WPSI's Wildlife Crime Database (14. WPSI's Tiger Poaching Statistics, http://www.wpsi-india.org/statistics/index.php).

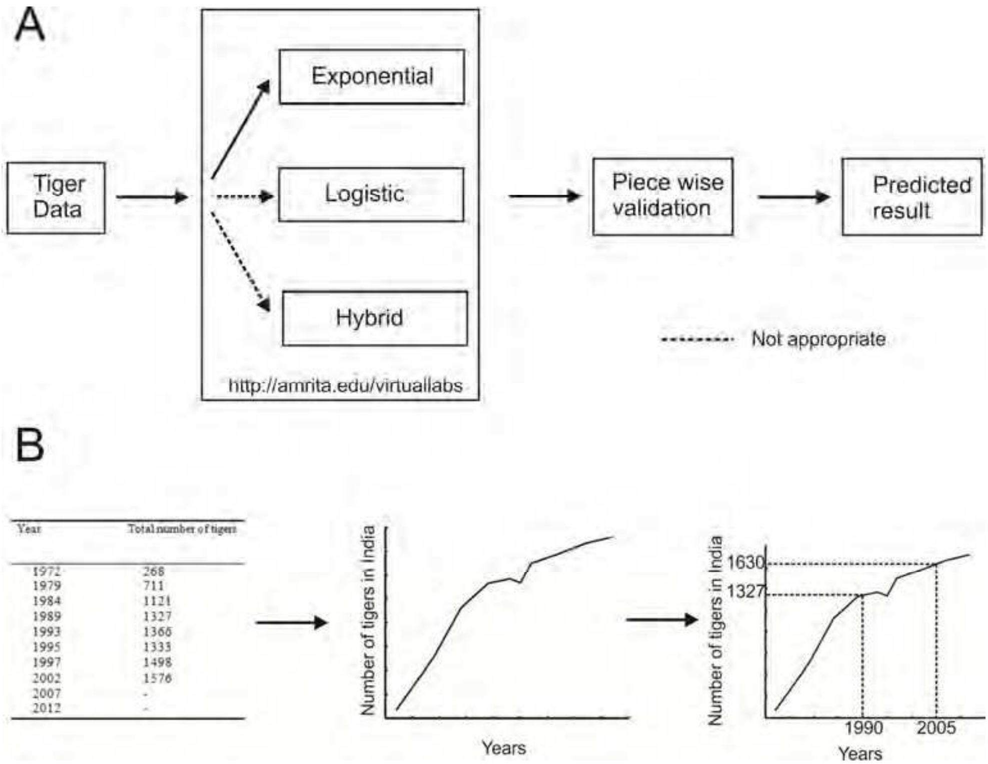

Fig. 5. Virtual Lab model for tiger population study. Note that exponential model was chosen based on decline in populations. Predictions with other models such as Lotka-Volterra and Logistic growth were inappropriate or had errors.

Growth rate has been calculated by using the formula, Growth rate $g(t) = \frac{(t+1)-t}{N_{(t+1)}}$. where $N_{(t+1)}$ is the total number of individuals at t+1, t′ represent the time in years.

11.2 On-screen methods

We have used an adaptive growth rate for different periods as shown in Table 1. Simulator's viewable window contain three main tabs, 1) Statistics button will show the growth of population while the simulation is running 2) Data plots button, will Population size Vs Time, 3) Worksheet button is an implementation of the model in excel.

11.3 Assumptions with tiger populations and growth model

Population ecology models include several assumptions, in order to realistically apply the model on data. Growth of prey population is exponential in absence of predators;

- Tiger population grows/declines exponentially within a short duration (10 years)
- The rate of change of tiger population is proportional to its size.
- During the process, the environment does not change in favour of one species and the genetic adaptation is sufficiently slow.

Although the assumptions make it difficult to actually call the simulation 'realistic', the validations showed a realistic trend and hence for this model, a simple exponential growth simulator was used.

Year	Total number of tigers	Total number of tigers predicted by the model	Growth rate
1972	268	-	-
1979	711	-	0.6230
1984	1121	-	0.3657
1989	1327	-	0.1552
1993	1366	-	0.0285
1995	1333	-	-0.0247
1997	1498	1521	0.1236
2002	1576	1586	0.0409
2007	-	1664	0.0468
2012	-	1718	0.0314

Calculated average growth rate was = 0.1545

Table 1. Shows the statistical data for tiger population from 1972 – 2002 and extended (prediction column) the curve to 2012 using continuous growth model simulator (data collected from Tiger project India at http://projecttiger.nic.in/populationinstate.asp).

11.4 Results

Taking real data to class rooms have been very difficult with population ecology due to its high unpredictability and model-related unreliability. However, using a simple growth rate simulator and using patterns from a short period, the model shows promise.

The simulation showed predictability in the growth of tiger population in India for the years 2003- 2012 by extending the behavioral pattern of tiger population in India for last 30 years (see Fig.6). Predicted tiger population for the year 2007 was 1664. According to National

Tiger Conservation Authority (on 2008), the total tiger population reaches 1,411 (i.e. ranging between 1,165 and 1,657). The difference in number of tigers from predicted to this statistical report may be because of some environmental factors, number of tigers that have been killed in past few years and the census by National Tiger Conservation Authority was only partially included West Bengal.

11.5 Conclusion

The predicted data (Table.1, third column) for tiger population in India showed standard deviation of 10% from real data. With some assumptions, it was possible to use simple models like exponential growth models for studying tiger populations. For a very short duration (such as in the data shown in Table 1), basic growth show a slowly saturating exponential and hence data matched the predictions (see Fig. 6). Online population ecology experiments developed on the basis of mathematical equations could help students to get a deeper understanding on model dynamics by exploring the parameter space provided by the model. Also it is always feasible for the user to supply the real data as input and observe the corresponding dynamics. The possibility to study such experiments has value. Biotechnology studies often include data collection and such models allow building simple hypothesis based on the dynamics. This new e-learning environment engaged and motivated the students to practice and explore the parametric space provided for the population ecology experiments.

Newer studies for analyzing fish populations and deer populations are being developed as part of the ongoing process. Such data will be made available as a virtual lab for continued use and study. We also noticed that the undergraduate and postgraduate students show an increased attention to details when we trained them on virtual labs instead of plainly explaining the theory. There was a 23% (metric not shown) improvement in interest to critically analyze population models among students who were introduced to population ecology studies directly virtual labs.

12. Cost of virtual labs

In order to estimate the true financial cost of our virtual lab project, we had to include both project development and delivery and maintenance costs. As indicated by Kruse (see http://www.e-learningguru.com/articles/art5_2.htm), design of courseware needed more initial costs than instructor-led learning but delivery and maintenance is affordably cheaper. We estimate, based on Amrita learning software experience that there will be negligible costs for maintain web-based experiments. The main post-deployment costs included administration and maintenance. The administration and maintenance estimates included tracking of user-behavior, technical support, content updates and technology updates. Student material development, instructor costs and subject expert costs were included in the development expenses.

13. Some evaluatory setbacks and associated feedback

What we know from the Virtual Lab studies performed is that user-involvement in assessment is vital for improving the knowledge-experience for the user. Self-assessment hints preliminary results but are not comprehensive. Users tend to show implicit behavior patterns indicating favor of the tool rather than the experiment for their choice of vote. Interactional voting behavior is also dependent on age and other characteristic learner attitudes. In our studies, younger students mostly at the undergraduate level evaluated the tool using mid-range scores compared to the varying yet favorably high votes of the Master’s and Graduate students in the feedback assessment. Although this may need further testing, we believe that scores from the higher age-experience level indicated statistically relevant reliability much more than undergraduates (data not shown due to pending experiments).

Overall, 27 Master's level students who helped in intensive evaluation of the Virtual lab platform as part of their regular class-room course, appeared predominantly positive about the value of virtual labs in e-learning, but anxieties were also expressed about the potential for e-labs to replace face-to-face teaching and labs in the economically challenged regions of the country apart an indication either of the value on the personal and face-to-face tutoring through an expressed preference for it. Students who were positive about their experiences of virtual labs indicated that they had received appropriate introductions and felt supported by staff, indicating the importance of sound inductions into the use of institutional systems and technologies.

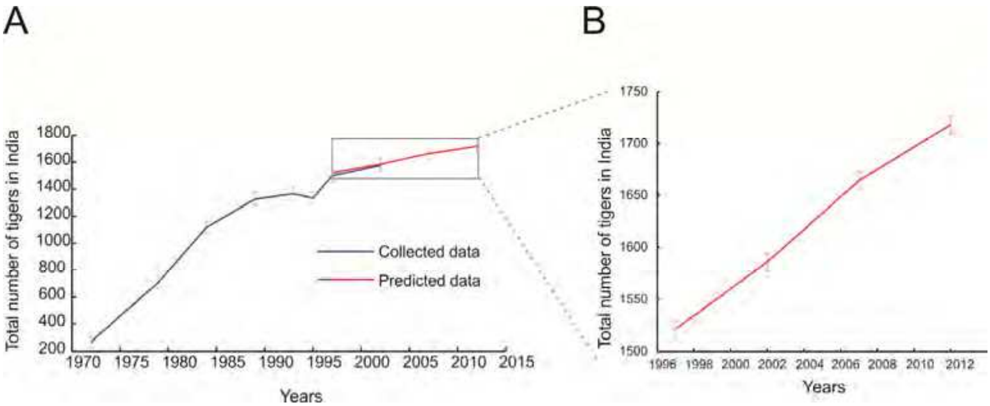

Fig. 6. Growth of tigers with predictions. A. The plot shows the nature / pattern of statistical data for tiger population in India from 1972 – 2002 (blue line) and an extended prediction (red line) of the curve to 2012 using continuous growth model simulator. The model assumes a 10% standard deviation shown by the error bar. B. The plot shows the enlarged curve of predicted piece-wise continuous growth of tiger populations in India

14. Conclusion and further remarks

Education using VL has been the new venture to better education and provide extensible laboratory experience to University students. The virtual lab protocols for neurophysiology and related sciences have been a successful complement to the usual theoretical education that happens at our school of biotechnology at the level of masters and undergraduate education. Although the elements can be improved, our approach to virtualization has answered many key results in establishing the virtual lab features such as teacher-independent/teacher-friendly approach to e-learning.

We tried to avoid the most usual failures in e-learning labs (Romiszowski, 2004) by focusing to avoid the common failures. Our design issues were based on a successfully tested e-learning software environment (Nedungadi and Raman, 2010) and included a clear identification and analysis of the real problem associated with University laboratory courses. Each virtual lab included overall strategic design decision such as structure of the courses, technologies employed and mode of experiment. Each experiment and the lab was considered with instructional design and elements that were evaluated so to motivate the learner experience. Such elements included the choice of graphical front-ends and authoring tools. We had also previously estimated issues related to dissemination for rapid, efficient and cost-effective usability taking into consideration both pedagogical and infrastructural complicacy.

Large scale tests will be needed to analyse and provide the assessment. These tests will also require both learners and educators (lab faculty) to use the software platform. Some tests in biotechnology are already underway via the VALUE initiative (Diwakar et al. 2011).

Several users raised the issue of how to support learners using VL. In real-world labs, learners work in the same place at the same time so there is teacher or peer support available. This kind of support is not immediately available to remote learners.

From our experience, the most vital requirement for each virtual lab is that of technical coordinators and subject matter experts whose inputs improve the lab's knowledge bank and usability. The Virtual lab project is already online for public preview via http://amrita.edu/virtuallabs or the National mission site http://vlab.co.in

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16. References

Auer M., Pester A., Ursutiu, D., Samoila C., Distributed virtual and remote labs in engineering, IEEE International Conference on Industrial Technology, Vol. 2, 2003, pp. 1208-1213.

Aycock J., Crawford H., deGraaf R., Innovation and technology in computer science education (Proceedings of the 13th Annual Conference on Innovation and Technology in Computer Science Education, Madrid(Spain), 2008, pp. 142-147.

Bijlani K., Manoj P., Rangan V., VIEW: A Framework for Interactive eLearning in a Virtual World, Proceedings of the Workshop on E-Learning for Business Needs 2008/BIS, Innsbruck(Austria),2008, pp. 177-187.

Hodgkin A.L., Huxley A.F., A quantitative description of membrane current and its application to conduction and excitation in nerve. Bull Math Biol, 1990, Vol 52, pp. 25-71.

O'donoghue J., Singh G., Dorward L., Virtual education in universities: A technological imperative, British Journal of Educational Psychology, 32(5), 2001, pp.511-523.

Rohrig C., Jochheim A., The Virtual Lab for controlling real experiments via Internet, Proceedings of the 1999 IEEE International Symposium on Computer Aided Control System Design, 1999, pp. 279 – 284.

Nedungadi P and Raman R. Effectiveness of Adaptive Learning with Interactive Animations and Simulations. Proceddings of the 2nd International Conference on Computer Engineering and Applications (ICCEA 2010), Bali, Indonesia, March 2010.

Wentling T and Park J. Cost Analysis of E-learning: A Case Study of A University Program, Proceedings of the AHRD, University of Illinois at Urbana-Champaign, p.1-11, 2002.

Morgan BM. Is distance learning worth it? Helping to determine the costs of online courses. Eric number 446611, 2000.

Maldarelli GA, Hartmann EM, Cummings PJ, Horner RD, Obom KM, Shingles R and Pearlman RS. Journal of microbiology & biology education, pp. 51-57, May 2009.

Romiszowski A. How's the E-learning Baby? Factors Leading to Success or Failure of an Educational Technology Innovation Educational Technology, 44(1), Jan-Feb 5-27, 2004.

Koch, C. Biophysics of Computation: Information Processing in Single Neurons,Stryker, M. (ed.) Oxford University Press, 1999.

Wenger E. Artificial Intelligence and Tutoring Systems: Computational and Cognitive approaches to the communication of knowledge. Morgan Kaufman Ed., 1987.

Diwakar S, Achuthan K, Nedungadi P and Nair B. Enhanced Facilitation of Biotechnology Education in Developing Nations via Virtual Labs: Analysis, Implementation and Case-studies, International Journal of Computer Theory and Engineering vol. 3, no. 1, pp. 1-8, 2011.

Nedungadi P, Raman R, Achuthan K, Diwakar S. Collaborative & Accessibility Platform for Distributed Virtual Labs, Proceedings of 2011 IAJC-ASEE International Conference, University of Hartford, NY, USA, April 29-30, 2011.

Wangersky P. Lotka-Volterra poulation models, Ann. Rev. Ecol Systems, 1978, 9:189-218.

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