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Complementing Neurophysiology Education for Developing Countries via Cost-Effective Virtual Labs: Case Studies and Classroom Scenarios

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Classroom-level neuroscience experiments vary from detailed protocols involving chemical, physiological and imaging techniques to computer-based modeling. The application of Information and Communication Technology (ICT) is revolutionizing the current laboratory scenario in terms of active learning especially for distance education cases. Virtual web-based labs are an asset to educational institutions confronting economic issues in maintaining equipment, facilities and other conditions needed for good laboratory practice. To enhance education, we developed virtual laboratories in neuroscience and explored their first-level use in (Indian) University education in the context of developing countries. Besides using interactive animations

and remotely-triggered experimental devices, a detailed mathematical simulator was implemented on a web-based software platform. In this study, we focused on the perceptions of technology adoption for a virtual neurophysiology laboratory as a new pedagogy tool for complementing college laboratory experience. The study analyses the effect of virtual labs on users assessing the relationship between cognitive, social and teaching presence. Combining feedback from learners and teachers, the study suggests enhanced motivation for students and improved teaching experience for instructors.

Key words: virtual lab, neuroscience, pedagogy, teaching tool, neuron simulator, ICT

Information and Communication Technologies (ICT) have enabled innovations improving teaching techniques and learning outcomes in the biosciences (Sheorey and Gupta, 2011). This ICT-induced thrust is evidenced in novel methods in teacher-student interactions and new pedagogical methods in teaching (Kennepohl and Shaw, 2010; Bocconi et al., 2012). A popular ICT-enabled tool in this trend is the virtual laboratory, an online environment that can be used to simulate a classroom laboratory experience (Kocijancic and O'Sullivan, 2004; Gomes and García-zubía, 2007; Sousa et al., 2010; Achuthan et al., 2011; Nair et al., 2012; Ray et al., 2012). Virtual labs enable remote accessibility to suitable environments and facilitate blended learning. These tools provide a learning experience similar to that of a classroom laboratory for those lacking laboratory experience and the distance-learning community in general (Kennepohl and Shaw, 2010; Achuthan et al., 2011). These labs allow deep learning in model-based knowledge domains and co-involve learning without much of the overhead commonly seen in traditional lab experiments (Korey, 2009). Many educational and research institutions have adopted ICT-enabled methods for teaching and learning purposes and ICT-based education has become an educational objective in many developing nations (Nair et al., 2012; Ray et al., 2012) (also see MHRD Sakshat NMEICT mission document at <http://www.sakshat.ac.in/PDF/Missiondocument.pdf>). This paper examines the use of a recently developed virtual lab project in the context of neuroscience education in India.

Our motivation was to develop a content-rich, freely available online tool to complement classroom-based introductory cellular neuroscience education that gives equal importance to the theory surrounding experimental techniques as computational modeling. Neuroscience courses are usually available at different levels based on the scope of the course (Bransford et al., 2000) and such courses often employ an interdisciplinary approach. An introductory neuroscience course taught at the undergraduate or master's levels in biosciences and biotechnology programs in India includes the study of single neuron properties and an overview at the system level (Ramos et al., 2011; Kennedy and Hassebrock, 2012). Teaching content related to single neuron properties involves demonstrating the function and activity of individual neurons, while systems level courses focus on studying the ensemble activity of neural circuits observed in various functional zones of the nervous system. A newer trend in classroom education is to include the contributions of computational neuroscience, which involves detailed modeling of biophysical behavior of nerve cells and use of such models to simulate certain physiological and pharmacological phenomena that are observed in the nervous system.

At the B.Sc. or M.Sc. level courses, in addition to animations of protocols such as voltage or current clamp techniques, the Hodgkin-Huxley computer model (Hodgkin and Huxley, 1952a; Hodgkin et al., 1952) of squid axon is used to illustrate an understanding of ionic mechanisms underlying the initiation and propagation of action

potentials. Such models serve as an excellent teaching tools for understanding basic neuronal behavior using mathematical equations. With increasing computational power, it is proposed that simulation of whole brain may ultimately be possible (Markram, 2006; Izhikevich and Edelman, 2008). Hence, teaching mathematical modeling in neuroscience has become important in classrooms alongside other modeling and simulations to understand neuronal behavior. However, this trend has yet to emerge in many universities and colleges in developing nations. Consider also that expenses associated with a typical patch clamp setup in India for laboratory use may cost as much as 20 million Indian rupees (It is to be noted that the direct cost of a patch-clamp setup may be around 3.7 million rupees-- about \$60,000-- but with animal, facility, and other costs included, the investment adds up to around 20 million rupees since most institutions lack basic facilities); it has been almost impossible or very difficult for most universities to set up such experimental units for undergraduate or postgraduate education. Apart from the cost of the set-up, a significant amount of effort is needed to teach the basic protocols used in electrophysiology including patch clamp, current clamp and voltage clamp techniques at the classroom level. Online education via content-rich virtual labs can be an attractive alternative to overcome these obstacles (Rohrig and Jochheim, 1999; O'Donoghue et al., 2001; Diwakar et al., 2011).

A variety of education tools in Neuroscience are available online or as standalone, executable free/commercial products that advance education in basic theory and concepts in neurophysiology and computational neuroscience. Although they can be excellent tools for education and research, the main difficulties with these products in the context of classroom/remote education are that most of them are not developed within an LMS (Learning Management System) template-based platform (adding newer content to these tutorials will not be an easy task), do not include online evaluation tools (faculty have to organize separate tests for the evaluation of the course),

lack some of the tools required for an instructor to teach the course, and, some are not online and not freely available to students. We specifically took these difficulties into account while developing the virtual labs, since a majority of students in India do not possess their own computer, and most students prefer teacher interaction during their learning process. A major focus was to allow student interaction in content-rich, freely available, online laboratory environments.

In this paper, we discuss usage and case studies of neurophysiology virtual labs which include mathematical simulations, remotely-triggered analog circuits (Parangan et al., 2010) and interactive animations devised for effective neuroscience education in the context of developing nations. Examining the fundamental relationships between patterns of new technology adoption, we also study the perceptions of relative advantage, compatibility, and ease of use by virtual lab users.

AMRITA VIRTUAL LABS OVERVIEW

Learning outcomes have been shown to be improved through development of quality content and subsequent, additional content consumption (Collis and Moonen, 2001; Anderson, 2007). Since our goal was to enhance learning outcome, we focused on the virtual neurophysiology laboratory as a teaching platform, developed to substitute for a classroom physiology course with details on techniques and protocols of a real laboratory (Figure 1, also see Diwakar et al., 2012). The online learning environment consisted of 20 experiments organized in two "virtual laboratories." Most experiments were chosen based on undergraduate course content focusing on cellular function and with emphasis on Neurophysiological techniques such as brain slicing, patch clamping, current and voltage clamp protocols etc. (see Figure 2).

Each experiment consisted of the following clickable tabs: Theory, Procedure, Self-evaluation, Assignment, Interactive animation or Simulation, or Remote-triggered

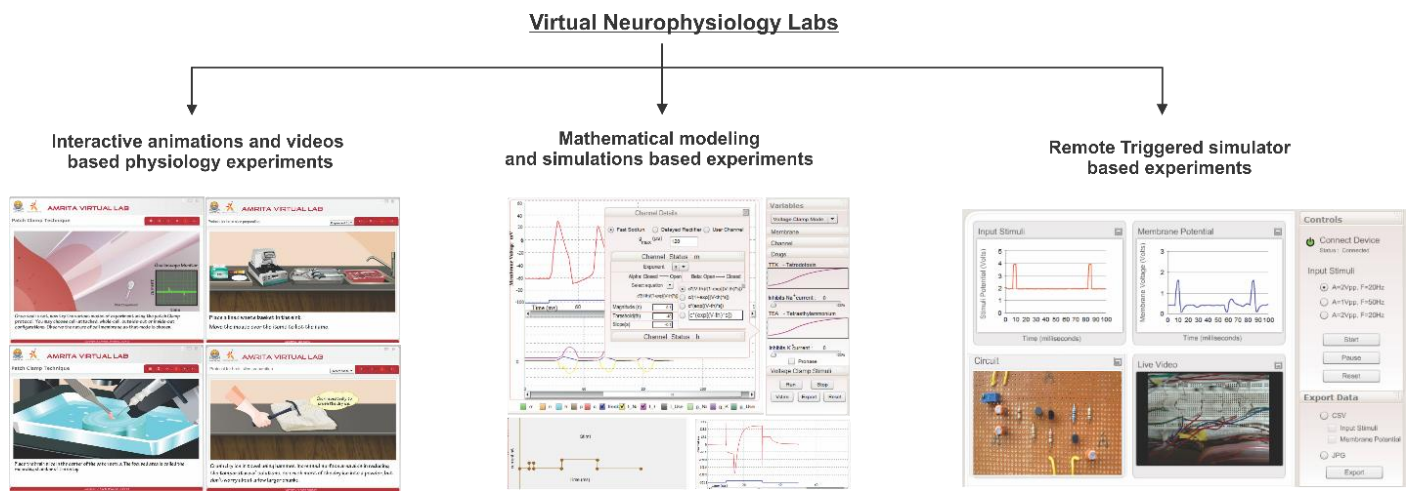


Figure 1. The virtual neurophysiology laboratory is a part of the Sakshat Biotechnology Engineering virtual labs of NME-ICT, an initiative of the Government of India. Organized as two labs, experiments were developed using three main components: interactive animations, mathematical simulators, and remotely triggered equipment.

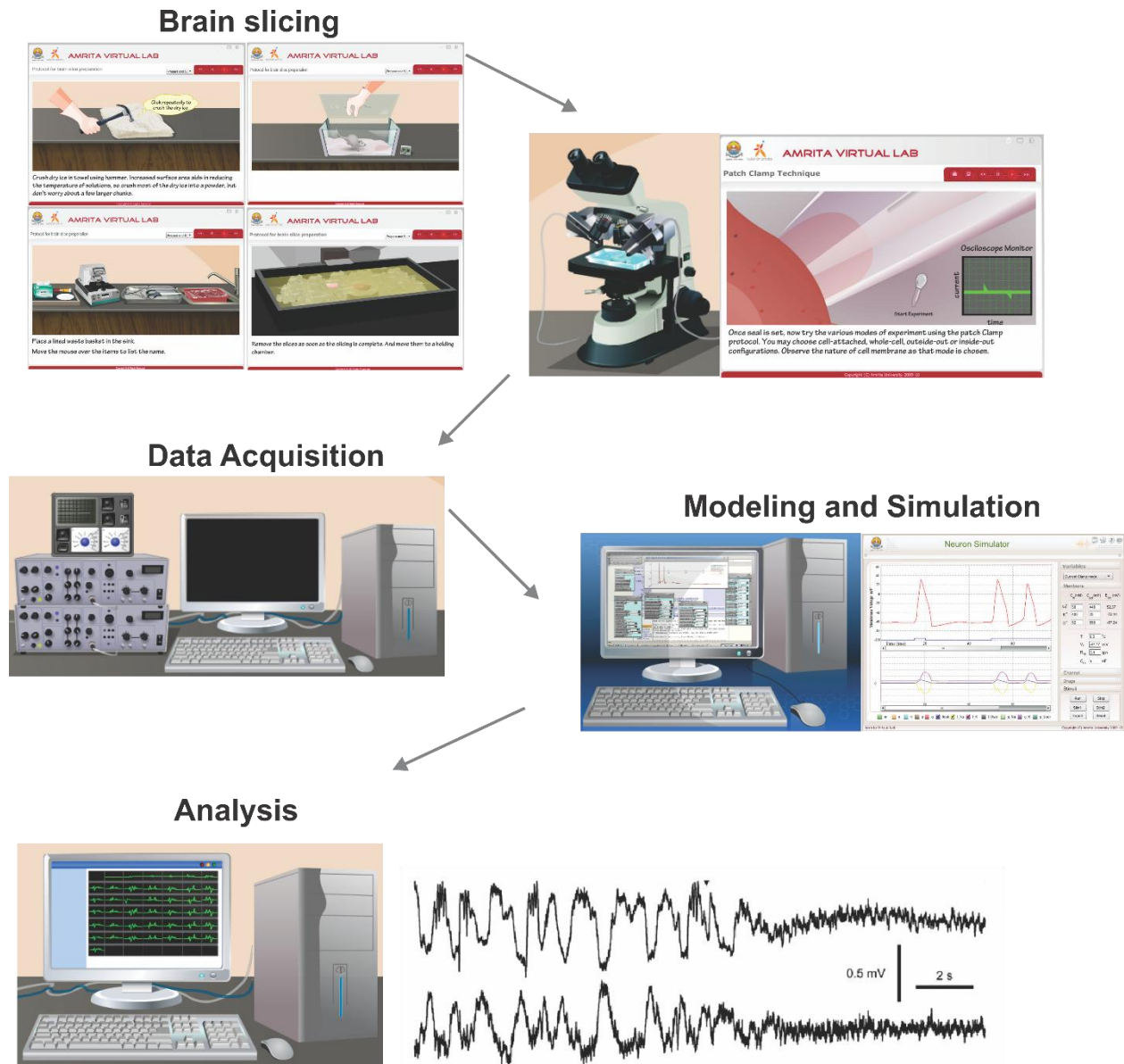


Figure 2. The virtual lab as a complimentary material for classroom Neurophysiology course (<http://amrita.edu/virtuallabs>). A Virtual Lab scheme showing the screenshots from experiments indicating the flow as material towards a classroom course. Virtual labs are being employed as “customized and interactive lab textbooks.”

device panel, References and Feedback. Clicking on the Theory tab opens explanations of the background theoretical content, while the Procedure tab gives access to explanations of how to run the animation/simulation or remotely-triggered experiment. A self-evaluation quiz was added to test a student user prior to completing virtual laboratory practice, animations or simulations. The Assignment tab allows an educator/lab instructor to post questions that student users can use as model questions. The Reference tab allows educators to post related content and students to reference them. The Feedback tab allows users to post comments and receive feedback on usage. All webpage tabs except the simulation, animation and remote panel are openly available without any restrictions. The simulation, animation (see Figure 2) and remote panel tabs are accessible via a free registration which can be

given through support email, open id or Yahoo or Google login. The virtual labs are hosted on CAP-VL (Raman et al., 2011) at <http://amrita.edu/virtuallabs>.

For easy accessibility and for web-based availability (Diwakar et al., 2011; 2012), we used Action Script (Adobe, USA) to develop the mathematical simulation of excitable neuronal membrane characteristics. The advantage of using this type of architecture is that it reduces the load at server end, increasing efficiency and speed of execution. On accessing the page, a copy of the simulator .SWF (flash executable file) is downloaded at the local machine's cache. The files are only a few kilobytes in size, minimizing bandwidth issues.

An 'Export' feature was added to facilitate the user to download the simulated trace as a CSV (Comma Separated Value) file in order that the instructor or student

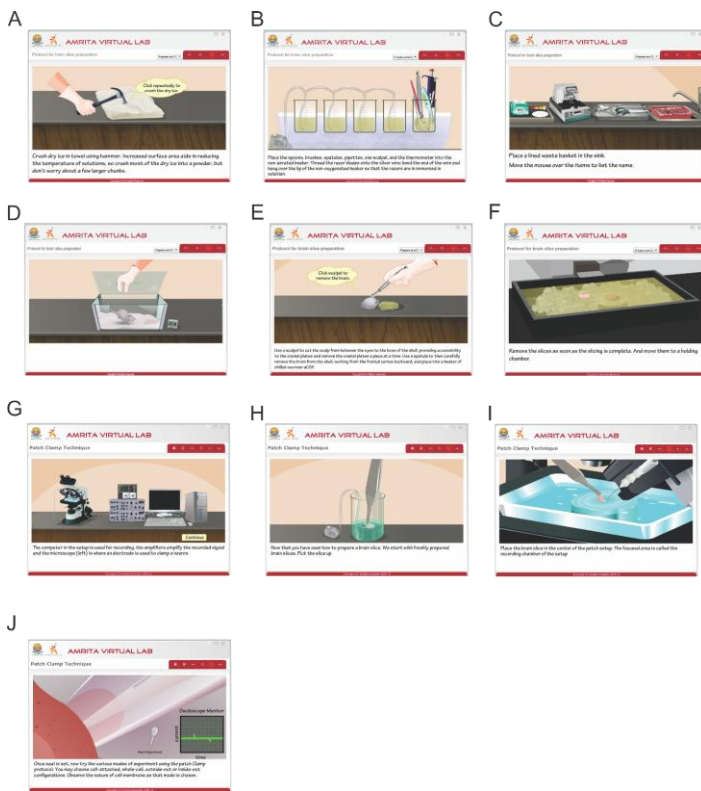


Figure 3. Screenshot of animated Brain slicing and Patch clamp protocol from Virtual Neurophysiology Labs. A-J shows sequence of steps a typical student is expected to navigate from preparation of platform to patching a cell.

may use the data in their assignments and project reports.

The need for experimenters and materials like chemicals, means that most colleges in India avoid classroom laboratory physiology at the undergraduate level. Physiology experiments also demand extensive knowledge and experience from the instructor. The rat brain slicing protocol, which is the first experiment (in the virtual lab) takes approximately 6-10 hours for a complete demonstration to a student in a real laboratory (see [Diwakar et al., 2011], Figure 3).

Graphical animations deliver a high degree of reality to the virtual labs by approximating the appearance and feel of the lab. Here, graphical animations illustrate experimental details. The text in the animation was designed to help the student to understand the protocol in detail and also to bring the flow of animation from one scene to next (see Figure 1). Graphical animations also cut out the complexity of the modeling process by increasing the “feel” of an experiment.

Previous studies have suggested that human and contextual factors exert greater influence than hardware and software in web-based education (Valdez et al., 2000). In order to enhance synergies between content and technology, a neuron simulator was built as a graphical web-based mathematical model based on the Hodgkin-Huxley type neuron. It was developed based on the MATLAB (Mathworks, USA) version of HHSim (Touretzky et al., 2004). The Neuron Simulator Virtual Lab and Neurophysiology Virtual Lab (<http://amrita.vlab.co.in/>

?sub=3&brch=43 and <http://amrita.vlab.co.in/?sub=3&brch=212>) can be used to study a variety of biophysical properties of a single neuron that includes modeling resting and action potential, voltage and current clamp protocols, and the pharmacological effects of certain drugs that block specific channels (see Figure 7). These classroom-based implementations as virtual labs were modelled as interactive textbooks and as tools for actual learning (Romiszowski, 1984; Moore, 1997).

METHODS

Feedback Collection

Users performed an experiment of their choice in the neurophysiology virtual labs and their online feedback was recorded. Each student was allowed to provide feedback more than once, depending on the number of virtual labs experiments performed. 174 unique user responses were used for this study. Our online feedback system collected user details and responses to a set of questions based on the technology acceptance model (TAM) ease of use, TAM usefulness (Davis, 1989) and IEEE Open Educational Resources (OER) survey. The user responses for TAM were considered on a Likert-scale (with ranges: excellent, very good, good, average and poor) and for a choice of agree/disagree for OER-related questions (some responses also included ‘neither agree nor disagree’ for some questions). Using the feedback, we calculated positive responses (agree), negative responses (disagree) and can’t say (neither agree nor disagree) responses.

Technology Acceptance Model (TAM)

TAM has been widely used to predict user acceptance and behavior in information technology and e-learning (Lederer et al, 2000; Legris et al, 2003; Park, 2009). We used a TAM model (see Figure 4) consisting of a set of constructs including student behavioral intentions, attitude and two measured cognitive constructs, namely perceived ease of use and perceived usefulness.

In our study, a basic TAM model was considered, with constructs of TAM (ease of use and usefulness). A new construct, “Relative Advantage” was also added to the model (Figure 4). Perceived usefulness has been defined as “the degree to which a student believes that using virtual labs would enhance their learning ability.” Perceived ease of use is the “the degree to which a student believes that using virtual labs would be free of cognitive effort.” Relative Advantage is “the degree to which something is perceived to be better than what it supersedes” (Rogers, 1983).

Feedback Analysis

In our studies to estimate relative advantage questions on learner quality (LQ), ease of learning (EL), higher engagement (HE), remembering concepts (RC) and overall advantage (OA) were used in the feedback survey. LQ indicated to question users whether virtual labs usage improved learning quality compared to that of classroom studies. EL indicated user’s responses on whether virtual lab usage made it easier for their studies. HE indicated whether virtual labs provided users with a higher level of

engagement during studies. RC indicated if virtual labs helped with remembering the concepts better. OA indicated if virtual labs usage was advantageous to user's classroom education.

In our studies to estimate Ease of Use (EU), questions on clarity and understandability (CU), does it require a lot of training (RT), is it easy to get virtual labs to do what user wants to do (ED), and overall ease (OE) were used. Responses from a user on CU indicated whether virtual labs were clear and understandable as an online tool. RT specified user's response on whether virtual labs usage required a lot of training. ED indicated whether virtual labs usage was easy and permitted what the user wanted to do. OE indicated a user's response to the question whether overall use of virtual labs was easy.

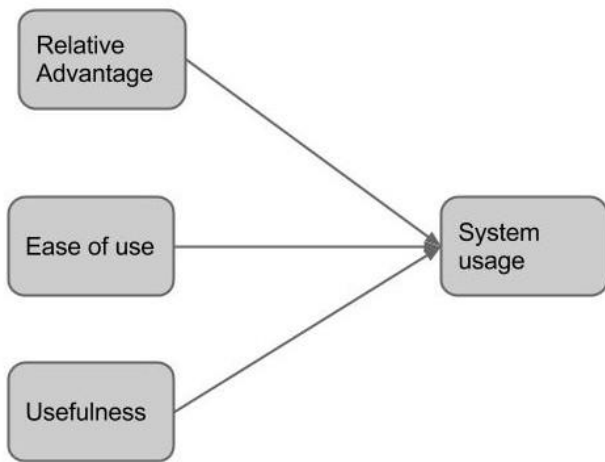


Figure 4. Technology Acceptance Model and virtual lab usage.

Likert-scale responses (ranges: excellent, very good, good, average and poor) were replaced with numerical values (5 to 1). To measure the internal consistency between these questions, we used Cronbach's alpha value (Cronbach, 1951) to measure the cross-correlations.

RESULTS

Evaluating Comparative or Relative Advantage

Most users agreed that virtual labs helped with remembering the concepts (RC) better and were found to overall be advantageous (OA) (see Figure 5, Table 1). About 160 positive responses for RC and 158 positive responses for OA were received. Among user responses, learner quality (LQ) and ease of learning (EL) follow, with 147 and 137 responses respectively. Very few negative responses were given by the users for these questions: 32 responses for EL, 23 responses for higher engagement (HE), 18 responses for LQ, 15 responses for OA and 13 responses for RC. 25 responses for HE and 9 responses for LQ were from users who indicated they neither agreed nor disagreed in response to some questions.

Cronbach's alpha indicated good internal consistency in our data. The overall reliability indicated by interrelatedness in user responses suggests there also was relative advantage for students using virtual labs in classroom-based education.

Questions	Yes (in %)	No (in %)	Can't Say (in %)
Using virtual labs will improve the quality of my studies	85%(147)	10%(18)	5%(9)
Virtual labs will make it easier to do my studies	81%(137)	19%(32)	0
Virtual labs provide higher level of engagement in my studies	72%(93)	13%(23)	15%(25)
Virtual labs help me remember the concepts better	92%(158)	8%(13)	0
Overall I would find using virtual labs to be advantageous in my studies.	91% (160)	9%(15)	0

Table 1. User responses on evaluation of relative advantage. 174 individual responses were taken into account. Numbers in brackets indicate actual responses for the corresponding percentages.

Questions	Yes (in %)	No (in %)	Can't Say (in %)
My interaction with virtual labs is clear and understandable	95.96	5.36	0
Using virtual labs will require a lot of training	59	39.32	0
I believe that it is easy to get virtual labs to do what I want it to do	91.8	8.32	0
Overall, I believe that virtual labs will be easy for me	88.8	11.32	0

Table 2. User response for evaluation of ease of use. Calculated for 174 individual responses.

Evaluating Ease of Use

Under the ease of use category, most of the users agreed that interaction with virtual labs was clear and understandable (CU), that the virtual labs were easy to use, allowed them to do whatever they tried to do (ED) and that overall, usage was easy (OE) across the experiments in virtual labs (see Table 2, Figure 5). About 169 positive responses for OE and 164 positive responses for CU were received. ED and RT followed, with 160 positive responses and 153 positive responses. The few negative responses include 16 for RT, 9 for CU & RT, and 7 for OE.

In order to find the internal consistency between test items, Cronbach's alpha value was computed. Ease of

Construct	Measurement Item		Mean	SD	Cronbach alpha value
Ease of use	1.	How do you rate the online performance of the experiments?	4.06	0.84	0.8604
	2.	To what extent did you have control over the interactions?	3.75	0.80	
	3.	To what degree was the actual lab environment simulated?	3.82	0.87	
	4.	Was the measurement and analysis of data easy for you?	3.64	0.96	
Usefulness	1.	A clear understanding of the experiment and related topics was gained?	3.82	0.88	0.8527
	2.	Were the results of the experiment easily interpreted?	3.92	0.79	
	3.	Were the links provided consistent with the objectives of the experiment?	3.67	0.91	
	4.	The manuals were found to be helpful?	3.74	0.95	
Relative Advantage	1.	Was the experiment/ process motivating enough?	0.74	0.63	0.8585
	2.	Did you get the feel of a real lab while performing the experiments virtually?	0.60	0.78	
	3.	Did you feel confident enough while performing the experiment?	0.59	0.71	
	4.	Do you think doing experiments through virtual lab gives scope for more innovative and creative research work?	0.83	0.52	

Table 3. Summary of Construct measurement of TAM. Each TAM construct was estimated individually.

use, Usefulness and Relative Advantage gave significant Cronbach's alpha values greater than or equal to 0.85 (see Table 3).

User Activity Assessment

A typical educational goal in virtual lab/class room education is to allow student users to reproduce their laboratory experience multiple times. The average time for the instructor to prepare course content for illustrating laboratory education was improved by 23% (Diwakar et al., 2011). In a survey-based study among the different users (see Figure 6), a large majority of users found the virtual lab to be a useful online tool; 19.87% of them rating it Excellent, 35% rating it as Very Good, and 29.12% rating it as Good. In contrast, 14.35% of them rated the virtual lab as an Average tool for understanding the concepts, and only 1.66% rated it as a Poor online tool.

Case study – Evaluating classroom performance

To study instructor-mediated education within a classroom context, 27 students from the same course were asked to perform a virtual clamp experiment, in which 22 (85%) students reproduced the V-I curve of squid axon activity, simulating the model while keeping the voltage at different step values of -60 to +60 mV with an increment of +10 mV. Students were also able to understand the use of TTX and TEA as ion channel blockers and understand the individual ion channel properties (as seen in studies by Katz and Miledi, 1969). Students also showed additional interest in repeating the examination of the role of pharmacological blockers by changing the conductance of ion channels (g_{Na} for TTX and g_K for TEA, see Figure 7).

In order to examine the extent that pedagogical aims for

student reception and replication (Romiszowski, 2004) were achieved, we quantified student's ability to demonstrate the reconstruction of the relationship between the stimuli and the response. Using the current clamp technique, most students could reproduce the typical neuronal behavior by (D'Angelo et al., 2001; Diwakar et al., 2009) plotting the F-vs-I plot and first spike latency -vs-current plot (VanRullen et al., 2005).

After the initial study, students were asked to provide feedback using the online feedback tab found in each virtual lab experiment (see Figure 8). From a total of 174 student feedback responses, 100 useably detailed responses were used to categorize the effectiveness (see Table 4, Figure 8) of virtual labs assessment. 18% indicated that the virtual lab could support explorative learning scenarios while influencing the application of knowledge from other domains while 62% of participants indicated that it could be used as a framework for training and oral examination (data not shown).

DISCUSSION

We find the use of virtual labs as additional classroom tools strongly helps to overcome a lack of appropriate facilities for teaching the skill-set needed for research in neurophysiology methods and protocols (Auer et al., 2003; Diwakar et al., 2011). We have used a standard TAM model to assess the usage roles in applying virtual labs amongst users. Most students report increase in perceived usefulness and a relative ease of usage.

We evaluated three main aspects based on the TAM model, namely relative advantage, ease of use and usefulness. Usefulness was seen as a criterion to estimate the acceptance of the virtual lab among users. As far as

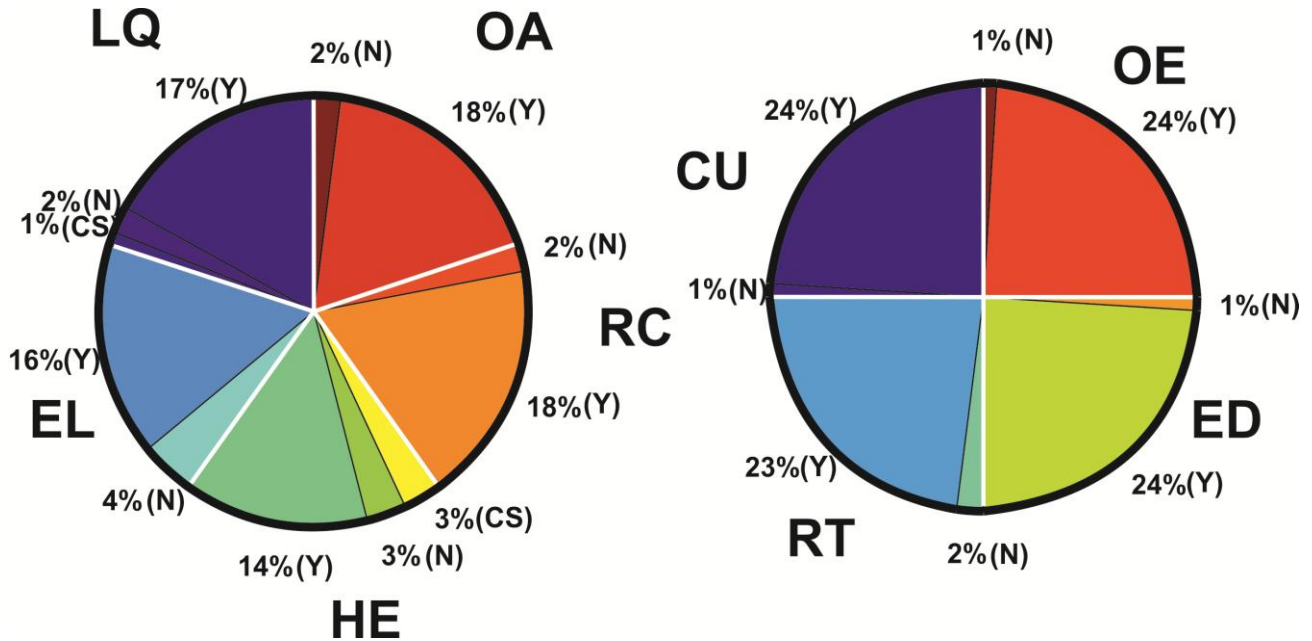


Figure 5. Relative Advantage (RA, left) and Ease of Use (EU, right) statistics. Some of the terms (shown in parenthesis in the figure) used in relative to percentage denote user responses. 'Y' denotes "yes", which means that users agreed positively for that study category. 'N' denotes "no", which means that this percentage of users did not give positive feedback for the same category. 'CS' denotes "can't say", explaining that the user could neither say 'Y' or 'N'. Note abbreviations: LQ - Learner Quality; EL - Ease of Learning; HE - Higher Engagement; RC - Remembering Concepts; OA - Overall Advantage; CU - Clear and Understandable; RT - Requires lot of Training; ED - Easy to get virtual labs to do what user wants it to do; OE - Overall Ease.

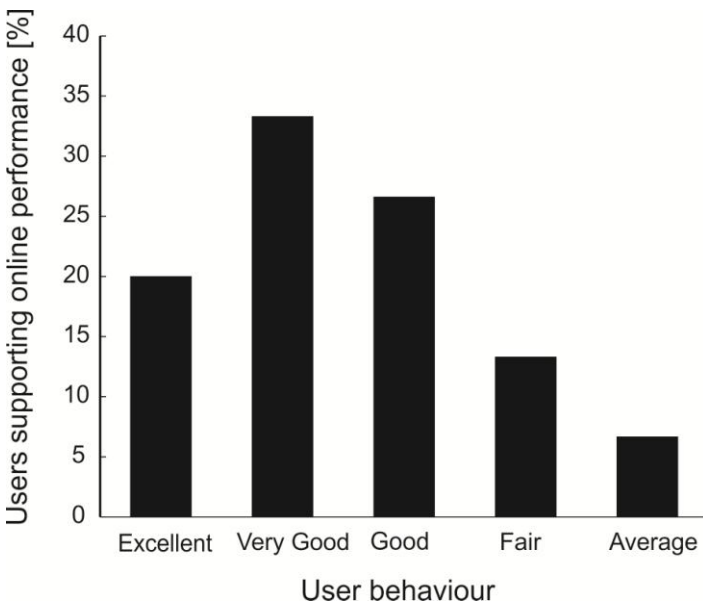


Figure 6. Virtual laboratories as an online educational tool. Percentage of users supporting virtual laboratories as an online tool is shown on Y-axis and Likert scale of user behavior on X-axis.

ease of use was concerned, web-based delivery is relatively new to students, but most users seemed comfortable in using an online tool in education. Most users did not need any training in that aspect of the

process.

Our initial studies with students also indicated enhanced outcomes in individual learning scenarios, and supported the view that multi-disciplinary demonstrations have a positive influence, although the current application suits blended learning that combines both face-to-face and computer-mediated instructions. Even though the simulator was used to conduct online exams for only one classroom of students, our current studies also recommend it to be a reasonable framework for pre-laboratory quizzes and examinations. Further, students also reproduced the biophysics of neurons with reduced instructor-dependence, suggesting the virtual lab has high utility as a demonstration tool (Nair et al., 2012) for classroom education.

Teachers agreed that several experimental aspects were not highlighted and could be further improved on. Those indicated include manipulator guidance and usage, setting the leak values, adjusting the amplifier, obtaining the seal, analyzing data in terms of runs, and statistics. Student users felt the virtual labs offered a relative advantage to learn neurophysiology and neuron modeling in comparison to traditional classroom education. Simulations, assignments and quizzes improved student-content interactions while personalizing their ability to respond and interact. Most students indicated that they learned more interacting with virtual lab exercises, and showed this in an ability to reproduce classroom exercises.

We avoided most of the often-reported failures in e-learning-oriented virtual labs (Romiszowski, 2004) by

Q. No	Items Questionnaire	Excellent (in %)	Very Good (in %)	Good (in %)	Average (in %)	Poor (in %)
1	To what extent did you have control over the interactions?	15	47	37	1	0
2	Was the measurement and analysis of data easy for you?	20	40	36	1	0
3	The manuals were found to be helpful	16	35	41	8	0
4	Did you experience any problem while performing the experiment?	21	47	29	3	0
5	Were the links provided consistent with the objectives of the experiment?	18	44	31	7	0
6	How do you rate the online performance of the experiment?	25	54	19	2	0
7	Did these study components / learning material covered all the aspect of the experiment?	17	32	44	7	0
8	A clear understanding of the experiment and related topics was gained	18	34	44	4	0

Table 4. Percent response to content, pedagogy and technology related items.

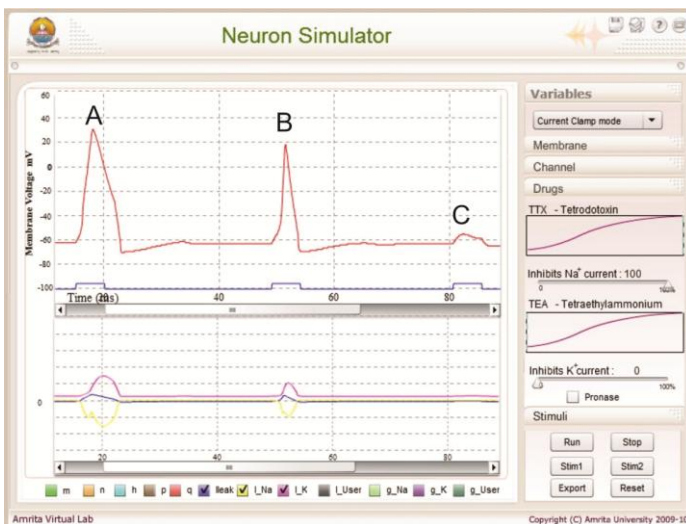


Figure 7. Student's reconstruction of effect of drugs (TTX and TEA) on squid axon model. Here students emulate CC in 3 conditions to study altered neural excitability by modifying conductance properties. A, shows the simulated action potential in control condition where no drugs were added. B, when 50% of TTX were applied. Note the amplitude and width of action potential were reduced by the application of TTX as seen in physiology experiment. C, when 100 % of TTX were added.

focusing on addressing students' common errors. Feedback generated through this interaction allowed us to selectively guide students through their learning objectives. The quiz module (self-evaluation tab) followed Hannafin's conception of inquiry, making the student's response a function of learning, due to the interaction between students and content (Hannafin, 1989). This promoted a style of student-student interaction in the classroom (study in progress) which allowed better academic achievement, improved motivation towards learning (Springer et al.,

1999) and augmented classroom quality (study in progress).

Since our designs included an LMS-based e-learning software environment (Raman et al., 2011), the studies suggest these virtual tools are helping to overcome some of the real problems associated with university laboratory courses appropriate for India and other challenging environments (Dangwal and Gope, 2012).

CONCLUSION

As a first comprehensive experience, we have moved into what is known as "virtual labs" in neurosciences via mathematical simulations and interactive animations. We have taken what was applicable for classrooms and have adapted it for learning groups located at a distance. The virtual lab protocols for neurophysiology and related sciences complement the usual classroom lessons and demonstrations at university campuses at the level of undergraduate and masters' education. The approach to virtualization has provided many key results in establishing virtual lab features, such as a teacher-independent/teacher-friendly approach to e-learning, although we know several aspects remain to be fully addressed.

To assess students and learning, further user-related feedback data may be needed. However, studies to evaluate the role of such online tools in meta-cognitive learning accomplished with pedagogy that in turn is based on virtual labs and combining them with real laboratory practices in classroom education may well require greater time commitments on the student than can be reasonably allotted. In terms of costs to benefits, the results obtained using these and yet-to-be-developed virtual labs may provide the next best opportunity to actual experimentation. Collectively, these studies support the role of ICT-based learning as a cost-effective approach to enhancing

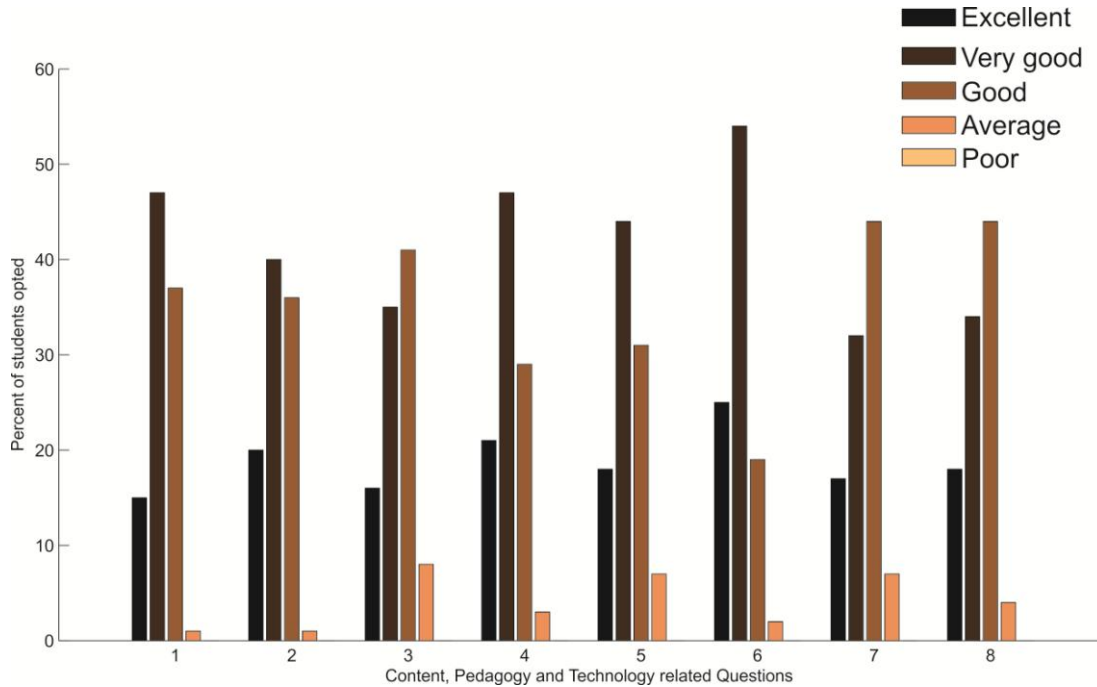


Figure 8. Statistical analysis of feedback. Questions on x-axis correspond to those in Table 4. 62% participants preferred the virtual labs as a framework for testing content and 18 % used it as an explorative learning tool.

neuroscience literacy in general, and especially, in financially and geographically challenged nations like India.

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