Current and Future Developments in the Remote Laboratory NetLab

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***Abstract*—In this paper we report on current and future developments in the remote laboratory NetLab. After a short review of real, virtual and remote laboratories, NetLab – a remote laboratory created and operated at the University of South Australia since 2002, is introduced. Experiments conducted in 2015 using real laboratory and NetLab are presented and student feedback on those reported. Increasingly, both academics and students accept that properly structured, documented and supported remote laboratories constitute a valid complementation to and/or replacement of real laboratories. To increase the students' learning support in remote laboratories a development of an intelligent tutoring system based on the learning analytics is proposed and outlined in this paper.**

***Index Terms*—remote laboratories; student feedback; student collaboration; learning analytics; intelligent tutoring systems**

I. INTRODUCTION

The development of digital technology found its numerous applications in modern education. Over the past decades many universities have been developing remote laboratories to support delivery of practical component of their courses for both on-campus and off-campus students. Remote laboratories enable students to remotely access real equipment and perform laboratory experiments at anytime from anywhere.

Practical laboratory work is invaluable part of every engineering program. Employers of engineering graduates expect them to have a certain level of hands-on proficiency. Also, students highly value courses which give them the opportunity to put theory into practice and consequently acquire a better understanding of the subject material.

However, laboratory experiments often require costly equipment, the use of space and are often expensive to run. Remote Laboratories (RL) offer a compromise: one set of equipment can support large number of students; scheduling of laboratory sessions is generally not required and the sessions are usually not supervised. Although these give RLs economic advantage over real laboratories (also known as proximal laboratories), the more important emerging issues are if RLs are able to deliver desired learning outcomes and how are they perceived by students.

It is apparent that RLs have already been adopted by many universities worldwide and will be common features at many educational institutions. In this article we investigate how the students' perception of RLs evolved over the past decade or so. Specifically, we compare the student responses in surveys on perceptions of RL NetLab from 2004 [1] and 2015.

It is clear that students and staff are becoming more open to accepting RLs as the development of technology is progressing. However, to take the full advantage of this new learning environment there is a need to enhance the cognitive support for students using RLs. Thus, in this paper some new developments in NetLab that include applications of learning analytics and intelligent tutoring system are presented with the intention of improving student learning outcomes and student retention.

II. REMOTE LABORATORIES

New technologies developed over the past two decades enabled practical laboratories to be complemented and to some extent replaced with virtual and remote laboratories. Comparative studies have been conducted on advantages and disadvantages of all three types of laboratories [2].

Virtual experiments are proven not to be a good replacement for real experiments. On the other hand, real laboratories have limited accessibility and high running costs [2]. The remote laboratories offer the opportunity for students to conduct experiments at their own time and pace from any location. Remote laboratories have gained popularity in engineering education during the last decade. Not only do they offer the access that is not limited by time or location, but their cost effectiveness saves the ever shrinking financial resources allocated for conducting real experiments.

The first remote laboratories were control engineering and robotic laboratories [3, 4] because of the high cost and high technical skills required for their development. Since National Instruments released the LabVIEW Internet Server, development of remote laboratories has become much easier and now many universities around the world use them as part of their engineering and science curriculum.

Most of the existing RLs have been developed at universities for educational purposes. Their designers are in a constant search of better architectures for better performance within the limitations of today's technological environment. However, the technological developments are constantly expanding, and we believe that in the very near future, remote laboratories will become a feature of every educational institution not only at the tertiary level, but also at the secondary and even the primary education level.

It is becoming apparent that the biggest advantage of remote laboratories is the possibility of sharing them on a common worldwide computing network [5, 6]. This provides opportunities for creating large pools of diverse laboratory experiments accessible to almost everyone at any time anywhere. Some of the providers operate at a commercial model; others provide open access to a collection of RLs.

A number of publications in the field of remote laboratories shows high level of research activity in this field and includes two main streams, technical issues and educational issues which are often interlinked. The first stream looks into:

1. technical issues related to development of individual remote laboratories;
2. technical issues related to sharing remote laboratories over a common network between participating institutions;
3. designing architectures for a large scalability.

The educational stream looks into a broad scope of issues including:

1. effectiveness of remote laboratories in terms of students' learning outcomes
2. students' satisfaction and perception of remote laboratories
3. methods of integration of remote laboratories into the curriculum.

III. REMOTE LABORATORY NETLAB

NetLab is a RL developed at the University of South Australia and has been used in teaching a number of courses including Electrical Circuit Theory, Introduction to Electrical Engineering and Signals and Systems courses since 2002. It has gone through a number of redevelopments based on students' evaluations in many years of its implementation. The remote laboratory has been continually developed and improved by generations of UniSA students from Bachelor, through Masters to PhD levels.

The NetLab has been developed to resemble the students' work in real laboratory as closely as possible and includes provision for student's collaboration as a very unique feature.

A remote laboratory environment allows any participants to log on and conduct the experiments remotely on real equipment. There are very few collaborative remote facilities set-ups in the world. This is unfortunate as such an environment would allow the students to network and collaborate. This creates an exciting world without borders for all willing or encouraged to become part of the framework, to become engaged with students from different locations, cultures, religions and work habits. These generic skills are becoming increasingly important for professional engineers to become effective international team members.

A photograph of a physical set-up of the laboratory is shown in Fig. 1. The presentation of this section is based on the book chapter [7].

Physically, the laboratory is located in the Sir Charles Todd Building, named after the Postmaster General of South Australia, the leader of the overland telegraph line construction project from Adelaide to Darwin that has connected Australia with the rest of the world in the late 19th century. The laboratory is located at the at the Mawson Lakes Campus of the University of South Australia (UniSA).

A. Access

NetLab is an open access system, i.e. everybody can use it after creating his/her own account by registering and booking a time slot. This allows our University onshore and offshore students and any users from any location in the world to conduct experiments in NetLab. NetLab can be accessed through the Internet at http://netlab.unisa.edu.au/ or http://netlab2.unisa.edu.au/.

B. Architecture

The NetLab has its own dedicated server which is connected on the one side to the Internet allowing users to access the RL. On the other end, the server communicates with a number of programmable laboratory instruments via the IEEE 488.2 standard interface, also known as the General Purpose Interface Bus (GPIB). These instruments include a digital oscilloscope, a function generator and a digital multimeter. All these instruments and components are connected to a 16x16 programmable matrix relay switch which provides the user with an option to wire and configure various electrical circuits from available components and instruments.

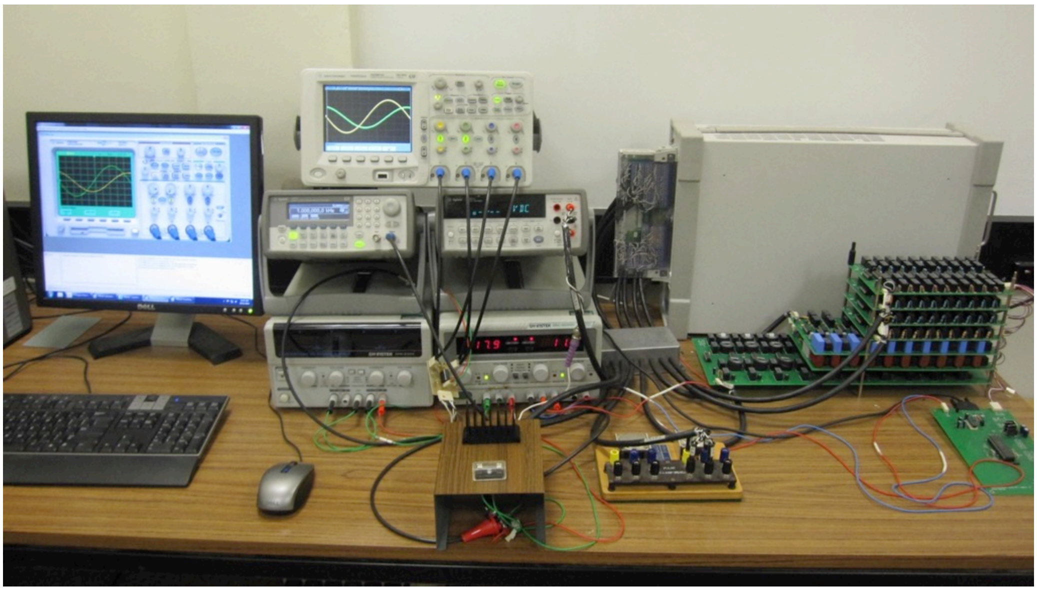


Figure 1. The real laboratory setup of NetLab2

C. Variable components

Variable components were created to give students the choice of setting up different values of resistances, capacitances and inductances such as in the real laboratory. The variable component block is visible on the right in Fig. 1, in front of the switching matrix. Different values of components can be selected by turning the knobs on the front panel of the animated images of the component box using a computer mouse pointer. Although it looks to users like a mechanical action, in reality the value is changed by sending commands from an animated graphical user interface (GUI) of the component box to an electronic board where the commands are decoded into positioning of a set of relays for a corresponding value.

Fig. 2 shows an example GUI of a variable capacitor. On the bottom left-hand side of component's GUI the range of the component is shown. Next to it is the value currently set up. Clicking on the OK button the user will change the actual value of the capacitance. This is a very unique feature of the NetLab which allows the use of a wide range of different parameters without the need to use as many matrix connection terminals that would be otherwise needed.

D. Circuit Builder

A special software tool named Circuit Builder has been developed for the purpose of remote wiring of electrical circuits. Its interface is shown in Fig. 3. The main hardware component that allows connection of selected circuit components is the 16x16 relay matrix E1465A module from Agilent.

This relay matrix switch requires supporting hardware that includes: E8408A VXI Mainframe and the E1406A Command Module. These components form a relay matrix-switching unit that is capable of communicating externally with the NetLab server through the GPIB. The VXI standard communication protocol is used for the internal communication within the Command Module.

The NetLab server uses an implementation of the Virtual Instrumentation Software Architecture (VISA) Application Programming Interface (API) to direct the commands to the appropriate programmable instrument. The VISA API allows software to communicate with a variety of hardware devices using the same software interface.

E. Graphical User Interface (GUI)

The NetLab Graphical User Interface (GUI) was initially written in LabVIEW, but later rewritten in Java. Therefore the Java Runtime Environment (JRE) must be installed to allow the NetLab application to run. The user can control the real instruments through the client software, consisting of the interactive GUI. The users' commands are sent to the NetLab server and processed by the server software.

The GUI consists of the instrument representations of the oscilloscope, the function generator and the multimeter, and the Circuit Builder. There is a communication window in the lower left-hand side corner which shows all users that are logged on and where users can exchange text messages. Voice and video communications are also available for NetLab users. On the lower right-hand side there is a window reporting all actions of the users (Fig. 4).

Figure 2. The 10µF range variable capacitor set at 100nF

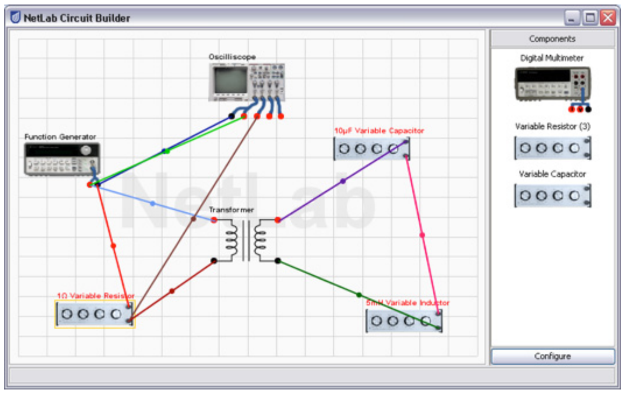


Figure 3. Circuit Builder Interface

The GUIs of NetLab instruments are created from photographic images of the instruments' front panels. The instrument GUIs can be enlarged for better readability. Fig. 4 shows an example of the interactive image of the oscilloscope that on a standard 17" monitor has approximately the same size as the real oscilloscope front panel (as illustrated in Fig. 1). Other instrument panels, the Circuit Builder and the camera window are also visible.

Users are able to interact with these instrument GUIs, via animated controls and displays, in the same way that they would when physically operating the instruments. For example, the mouse is used to click on a button or rotate a knob or a dial in the same way that a finger would be used to press the button or turn the same knob or a dial. The GUI represents the instruments with a sense of realism and functionality that matches the physical instruments.

The interactive realistic GUI gives students a sense of physical presence in the laboratory, since the instruments they observe and the tasks they perform are the same as those in the physical laboratory. Also, all of the buttons on the GUI give a form of visual feedback, such as button illumination or depression of the button, to show the user that the button has been pressed or activated.

F. The camera

The NetLab also includes a camera which has its own web server and is fully controllable by the remote user. The camera controls include pan, tilt and zoom functions (Fig.5). It has preprogramed positions pointing to most common objects in the physical laboratory.

The video feed from the camera is not part of any experiment and can be switched off to save on the bandwidth. However, it is an important part of the system because it provides distant users with telepresence in the laboratory. It is also proving to students that the experiments are on real equipment and are not simulations.

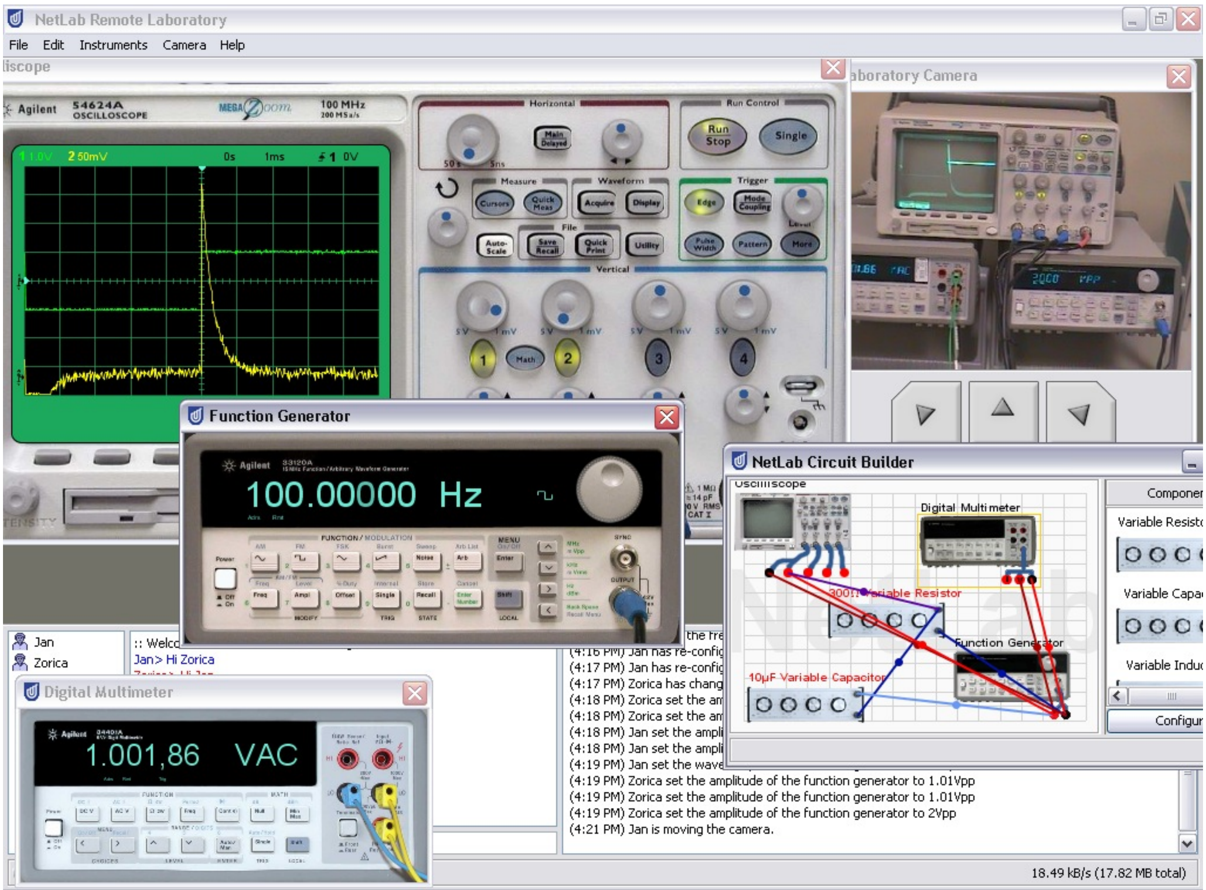


Figure 4. The NetLab GUI

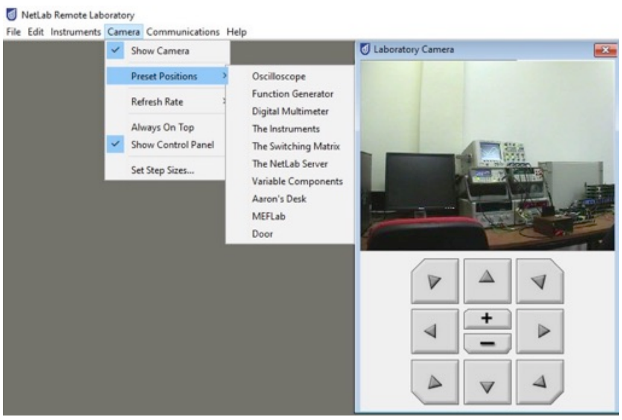


Figure 5. The camera view and controls

Figure 6. The booking system

G. The booking system

The booking system is an integral part of NetLab. It allows a user to book up to three one-hour sessions per week to have the system available to either to 1, 2 or 3 students at a time. The number of hours per week has been limited to three as some users booked excessively prohibiting other users' access. Technically, there is a possibility of any number of students working on the same experiment at the same time but as all of them have the full control over the circuit configuration it is not practical. The booking time is shown in student's own time zone. The example of the booking system is shown in Fig. 6. The time slots booked by the user are shown in blue, green are slots available and red are the slots booked by other users.

H. Comunication

Students whose are booked in the same time slot are able to communicate with each other using the build in chat window or the multimedia communication environment, a part of the NetLab or external, such as Skype. Academic staff with administrative privillages can also login to the NetLab without any booking and interact with the students working on the experiment.

IV. COLLABORATION IN NETLAB

NetLab is one of a very few collaborative RLs. Although there has been a number of initiatives [8-11] to introduce collaborative RLs as a standard or at least more common architecture, not many developers of RLs implemented this important feature despite that collaborative work in real laboratories is the common practice in most universities and in engineering practice in general.

In 2008 this unique feature of NetLab enabled us to attract an Australian Government competitive grant for the project "Enriching student learning experiences through international collaboration in remote laboratories" [12]. The project involved collaboration between Australian students and students from other countries on laboratory experiments using NetLab. In Table 1 below we show Australian and Swedish students' responses to questions that were developed in the project to encourage cultural curiosity. As predicted in [13], this international collaboration brought educational advantages that were way more important than shortcomings of the technology.

V. EXPERIMENTS

During the delivery of Electrical Circuit Theory subject offered by University of South Australia in early 2015, there were three experiments set up to give students an opportunity to utilize NetLab to perform circuit analysis as part of their practical activities. These experiments were created in a way where students were able to experience the full functionality of the remote laboratory NetLab. All students used both the proximal and the remote laboratory.

A. *Practical Experiment No.1 – An Introduction to NetLab*

This practical experiment first introduced the objective of a remote laboratory and its important role in remote learning environment for electrical and electronics engineering courses. Next, students were given detailed instructions on how to access the NetLab, registered an account, and how to make a booking to use NetLab to perform the practical tasks.

Practical Experiment No.1 also served as a getting started guide for students to learn how to build circuits using the NetLab Circuit Builder, shown in Fig.3, and also learned how to configure the function generator, multimeter, and the oscilloscope for signal generations and measurements.

TABLE I.
QUESTIONS THAT ENCOURAGE CULTURAL CURIOSITY

Responses by Australian students	Responses by Swedish students
Q1. What have you learnt about the foreign country from this collaborative exercise?	
In Sweden they have polar bears that are dangerous. They like to eat them :) They are 7.5 hours behind us & they have cool accents. They have to learn 3 languages before they leave school & they have an excellent sense of humor.	They have small bears that fall out of trees then they eat 'em for lunch ;) Koala bears sleep for 19 hrs a day. The only time people from Australia isn't watching out for koalas is when they go shark diving...
Q2. What have you learned about programs that your colleagues from foreign countries are doing (include differences and similarities)?	
They have to learn programming languages too… Lucky b (we swear a lot down here :)) – MATLAB……..! - can be a very frustrating program to use :D, …	Matlab is a part of the toolbox in the course, for our course we can use it if we have it but its not necessary nice to be a Lucky b ;) => graph is a very good program that gives us a lot (recommend)… Link to the webpage for Graph 4.3 (http://www.padowan.dk/graph/) the web page is even in English :-).
Q3.What have you learned about the course that your colleagues from foreign countries are doing (include differences and similarities in structure of the course, theory approach, simulation software used, etc)?	
We second that :)	Only familiar with this lab and it seems quite similar in the approach and theoretical prep.
Q4. What is your perception of foreign partners' knowledge background (i.e. is it at a similar level as yours, if not, is it higher or lower, or in some area higher and in other lower)?	
…although you guys are much better at dealing with graphs than some of us here :)	Impossible to know after a few hours but it's like in all courses we all have specialities and it would be better to be prepared for that before the experiment. In that way we could divide the task between us to get the exp more efficient.
Q5. Comment on cultural and behavioural differences that you have observed.	
I haven't noticed any ... other than accents - especially ours (the Australian accent is the worst on the planet I rekn :)) We dive with sharks - you eat polar bears :) what's different :)	we are all human and not that different and its always nice to see that it works :) I quite like your accent its comfortable
Q6. Do you think that you have enriched your collaborative learning by using different practices and knowledge?	
Absolutely but the importance of planning the experiment and prepare the conditions in advance is a critical point. We use the BTH labb… in a way like yours but we have for example a breadbord that we place components on. It's not java based	Yes - it would have been much more helpful to you guys if you had the NetLab info last week & we had a less laggy way of utilising laboratory environments….if we could have just used NetLab itself instead of ShareApps we all could have participated more in the actual prac. What is the laboratory environment that you guys use and how do you find it?
Q7. List what you consider as desirable attributes of an international group member.	
A GOOD SENSE OF HUMOUR - we had a GREAT time :)	Humour is a tool the best one :) if all are prepared and the experiment are well coordinated in time and what tools we are supposed to use => well its just a matter of communication skills to get the job done

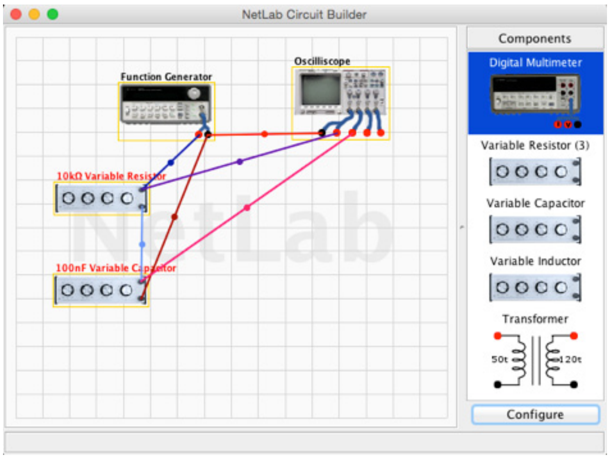


Figure 7. Low-pass RC filter on NetLab Circuit Builder

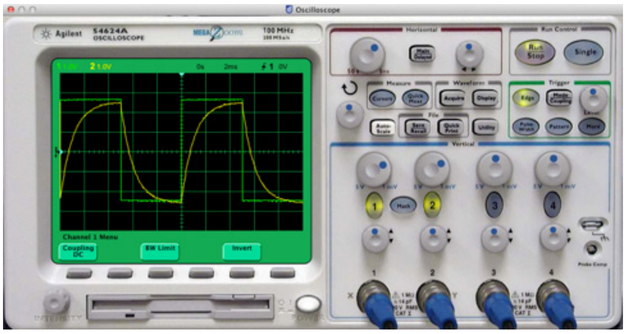


Figure 8. Transient response of the RC filter on NetLab

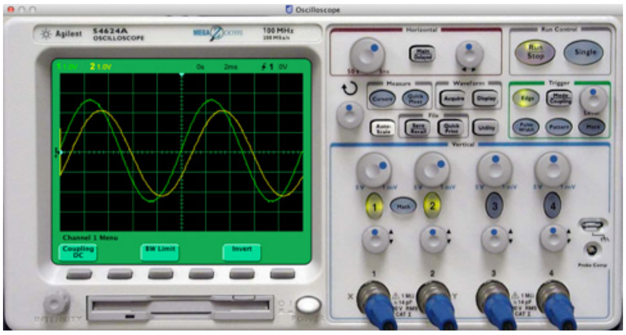


Figure 9. Input and output signals of the RC filter in NetLab

B. *Practical Experiment No.2 – Low-pass RC Filter Frequency Response*

In the second practical experiment, students were expected to build a series of RC circuit to represent a low-pass RC filter to investigate the frequency response of the filter. The low-pass RC filter representation on the NetLab Circuit Builder is shown in Fig. 7.

In order to investigate the frequency response of the low-pass RC filter, students were instructed to set the magnitude of the input sinusoidal voltage to 5Vpp and vary the frequency of the supply voltage over the range from 10Hz to 10kHz with steps of 50Hz.

To represent the frequency response result of the filter using the Bode plots, for each frequency, students were required to measure the magnitudes of the input and output signals, and the phase angle between them using the NetLab oscilloscope. Fig. 8 shows the input and output signals of the filter using the NetLab oscilloscope.

C. *Practical Experiment No.3 – Low-pass RC Filter Transient Response*

The last practical experiment required students to investigate the transient response of the low-pass RC filter. To do so, students were instructed to change the waveform setting of the supply voltage to square wave on the function generator, and set the frequency of the supply voltage to 100Hz. Again, students were required to capture the input and output signals of the filter using the NetLab oscilloscope, compared and verified the transient response of the low-pass RC filter with the pre-calculated results. Fig. 9 shows the transient response of the low-pass RC filter using the NetLab oscilloscope.

Once the students have completed the frequency and transient responses of the low-pass RC filter using the NetLab environment, they were then instructed to repeat the experiments again, firstly using a computer circuit simulation program and secondly using the traditional real laboratory setting with physical components, function generator, and oscilloscope.

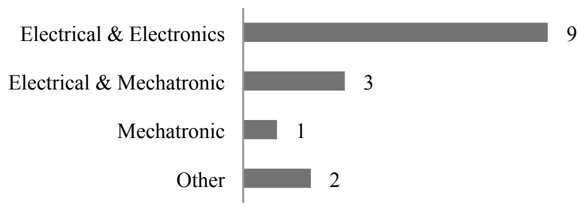
These allowed the students to compare the results obtained across three different platforms against discrepancies, and also served as a comparison on students' preference and personal view on using NetLab to perform experiments against using the software simulation programs and physical laboratory.

VI. STUDENT PERCEPTIONS

In 2004, a survey was performed to investigate the students' perceptions of their work in NetLab and compared it with their work in a real laboratory. One of the very significant results was that majority (76%) of students preferred working in the real laboratory. In 2015, a similar survey was performed with 14 participant students, 50% of students stated that they had no preference between working in real laboratory or using the remote laboratory NetLab, based on survey question 6 which can be interpreted as a good result for the remote laboratory.

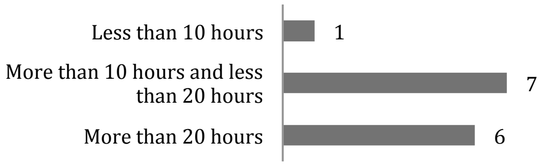
Completed students' responses to each question of the survey conducted in 2015 are presented below.

A. *Question 1: Which program/stream are you studying? Select all applicable.*

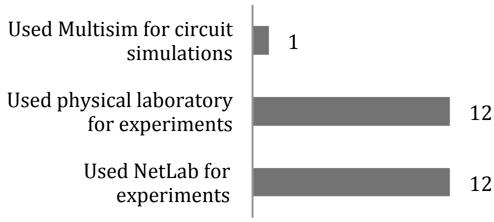


B. *Question 2: Do you think technology/internet is playing an important role in education?*

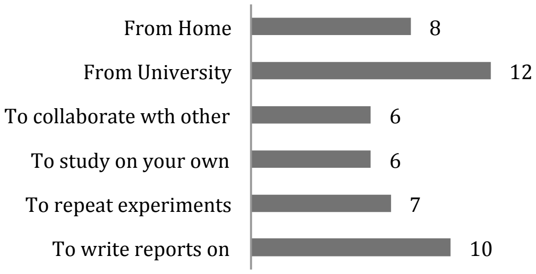
C. Question 3: How much time per week do you use the computer/internet for all your studying?



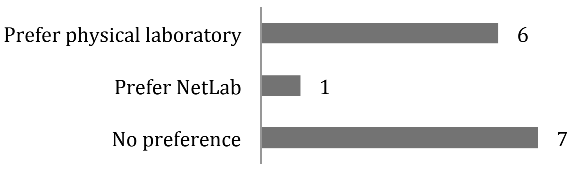
D. Question 4: Did you use the following in the course Electrical Circuit Theory? Select all applicable.



E. Question 5: Do you find NetLab convenient to use? Select all applicable.



F. Question 6: How NetLab compares with working in physical laboratory?



Over 80% of students show an appreciation of the convenience of using NetLab where they can access the remote laboratory from within and outside the university network at any time they want. Around 43% of students indicated that NetLab allowed them to collaborate with other students to perform experiment tasks, and as self-study tools to further enhance their understanding and knowledge on circuit theory. 70% of students will use NetLab as a tool to write reports on experiments.

No preference answer is really a compliment to the remote laboratory as the real laboratory has a supervisor to help and often to solve a problem for a student, as in the remote laboratory students need to rely on their own knowledge and skills alone.

G. Question 7: What were the good features of NetLab?

Most of the students commended about the interface of the NetLab being easy to operate, and less likely to make connection mistake compared to a real laboratory. Students also mentioned the convenience of using NetLab at any time to repeat practical experiment tasks and to check and verify theoretical calculation results. Repetition of experiments remotely which is usually not possible in real laboratories, leads to obtaining better experimental results, better marks and leads to students' deep learning.

H. Question 8: What difficulties did you have using Netlab?

Some students experienced difficulty accessing the NetLab. This was due to occasional internet interruption where physical rebooting of the NetLab server computers was needed. Other difficulties mentioned in the survey include the booking process (there is competition for preferred time slots in peak days before report submission) and hard to read results displayed on the oscilloscope screen. The latter one results from using laptops or tablets where relatively small screens can cause reading difficulty.

I. Question 9: If you did not use NetLab, explain the reason why.

Only one student responded to this question, stating using the real, physical laboratory equipment is better in conducting experiments.

VII. FUTURE WORK

Currently, the NetLab system replicates the physical laboratory equipment that would be used in a typical experiment. Planned future work will allow the NetLab system to also perform some of the duties that would typically be performed by a human teacher in a laboratory class. The system will analyse student learning, and support learning where appropriate.

A. Learning Analytics

Online learning environments record a log of data detailing the interactions that students have with the software. Learning analytics refers to the analysis of this data to provide information on the learning behaviour of the students [14]. Knowing about the learning behaviour makes it possible to optimise the learning process.

Learning analytics is a new discipline, about 8-9 years old, comprising among others, fields of education, computer science and psychology. It can be used to evaluate the implementation of new teaching technologies and curriculum [15]. Learning analytics can provide information on whether the user is using the new technology as planned, how often the user accesses the new technology, and how engaged the user is. Engagement can be judged based on the time that the user spends looking at particular content, or based on their actions that the user performs. On-line assessment results, to be analysed, interpreted and actioned, can form part of the overall strategy to improve student learning.

User action logging was added to a CAD package by [16] who wished to better examine the engineering design process used by a sample of high school students. The students were asked to use a CAD package to lay out a new block of city buildings of differing heights, in a way that would achieve the highest energy efficiency. Part way through the activity, the authors performed an intervention and presented some more information to the students. To measure how the added information changed the students' behaviour, the authors calculated the change in action density, or how often each action (such moving a building) was performed before and after the intervention. The action of moving a building is the primary action that improves the energy efficiency, and the authors found that most students performed this action more often after the intervention.

For diagnostic purposes, the NetLab system has always recorded student actions. Any action that would be broadcast to other users during a collaborative experiment – changing the supplied input signal to a circuit, reconfiguring a circuit, or taking a measurement using any of the instruments – is also recorded in a database. The system records the action and any relevant details, such as the new shape and amplitude of an input signal. The system also records the time at which each action occurred, and which user performed the action.

As in [16], the recorded data from the NetLab system can provide information on the learning process followed by students. To date, the recorded data has been used only for usage statistics. But, by analyzing how students use the system, patterns can be observed. Common incorrect sequences of steps may indicate a common misconception.

B. *Intelligent Student Support*

The NetLab remote laboratory makes it possible for students to conduct experiments at any time of their choosing. While collaboration is possible, it would be difficult for a human tutor to be present in every online session to assist students. But there is some existing work in the area of intelligent tutoring systems that may allow a piece of software to take the role of a tutor assisting the student.

Ms. Lindquist is a system that assists high school students with algebra problems [17]. Problems are presented to students in words, and students are expected to write equations that represent the system and can be solved. Using a student model and a tutor model, the system guides students towards the correct answer.

The student model describes the students, and in particular the mistakes they often make. To develop the system, transcripts from tutoring sessions between students and an experienced tutor were collected and analysed. From this, it was possible to identify key mistakes that occur in the students' answers, and the errors in reasoning that lead to these mistakes. In particular, 7 common mathematical errors made up 75% of the total errors identified.

The tutor model gives processes that can be followed to guide the student from a known mistake to the correct reasoning. If a student makes a mistake in their answer, the system can ask another question with a narrower focus. As students answer these guiding questions, they see where they have made mistakes and can correct their reasoning processes to arrive at the correct solution. Students provide input to the system by choosing words from drop down input boxes – this reduces the processing work that the system must do.

An intelligent help system has been applied to a remote laboratory for reconfigurable digital circuit experiments [18]. The system provides assistance to students conducting a practical in which they must develop a combination lock. Because students are always facing a particular challenge, this allows the system to be somewhat simpler than Ms. Lindquist. A student who requires assistance can click on a button, and the help system will then examine the student's solution for known issues. The set of known issues is somewhat smaller – the system can detect if the student has not applied power to the board correctly, or has not downloaded the configuration to the reconfigurable digital circuit.

However, the system by [18] does not attempt to model the reasoning process followed by the student. Therefore, it cannot identify why the student has a made a mistake, and must rely on the student to identify the root cause of the problem themselves.

When carrying out a practical, students typically follow some lesson plan, such as a practical workbook [19]. This guides the student through the activities that they must carry out. The authors of [19] suggest that if the lesson plan is in an electronic format, it can be combined with the remote laboratory interface. The plan can describe the various states that the experimental setup can be in, and the steps to take it from one state to the next. Such a system could guide students through the practical, and easily identify when they have deviated from the correct process for an experiment.

Given that students using the NetLab system are often following a known set of instructions, the system can be adapted to guide students in these. However, NetLab also provides students with the flexibility to design their own circuits using the available components. To be useful in all situations, a tutoring system must be able to assist users with most possible circuits.

A tutoring system may also be able to apply learning analytics techniques to better assist students. Just as a human tutor can vary their teaching style to assist students of different skill levels, a tutoring system that can monitor student actions could adjust the style of its teaching to better suit each student.

VIII. CONCLUSIONS

The remote laboratory NetLab at UniSA in Adelaide, Australia has been in operation for some 13 years. It is an open access, robust and user-friendly system, perfected over the years. Some ten thousand users from some 50 countries have accessed and used it for conducting experiments being part of their compulsory curriculum or for an educational/fun experience. The new intelligent tutoring system and knowledge based additions to it will expand the NetLab system to be a more adaptable and user friendly remote laboratory with demonstrable learning outcomes.

Overall, students showed strong satisfaction and acceptance on using the remote laboratory NetLab to perform circuit analysis tasks. The flexibility of using the NetLab anywhere, anytime, the ability to collaborate with other students from any location in the world, and the easy to use graphical user interface to set up circuits, give NetLab the preferred platform to enhance their electrical and electronics engineering skill building and their study experience.

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