Solar Energy Logging Laboratory

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CONTEXT
Remote laboratories exist as a way to allow students to access their practical content remotely instead of needing to be physically present in a laboratory. Research into this area focuses not only on students' ability to retain information, as well as students focus on learning outcomes and perceived learning objective. This paper outlines the design of a remotely accessible data logging laboratory focusing on solar energy logging and analyses the students' experiences and perceived learning objective in a method similar to that used by Euan D. Lindsay and Malcolm C. Good in 2005.

PURPOSE
In the created renewable energy laboratory, what are students perceived learning outcomes and what are their experiences completing the remote laboratory.

APPROACH
Students were invited to complete the laboratory and once completed a survey was created to assess their experiences in the laboratory. Both written feedback as well as Likert scale questions were used. This data was then compiled into a more accessible format.

RESULTS
Current results indicate students saw the experiment as either an exercise in either signal analysis or general engineering principal. As more students complete the laboratory trends in this direction are expected. Written feedback indicates students understanding of the topic, in addition to questioning why the laboratory was not directly assessed for the unit (laboratory was presented as an extra resource).

CONCLUSIONS
The paper found that students completing this remote laboratory approached it with signal analysis in mind, meaning if it was desired for students to approach learning this way it would be possible to influence this. In addition, a tendency for students to want everything completed to be directly assessed was observed, with some students refusing to complete the laboratory as it was not a marked aspect of the course.

KEYWORDS
Remote laboratory, Student Experience, Pedagogy.

Introduction

Engineering education has evolved past the point of students being expected to sit in a classroom and learn from only lectures and tutorials. New styles of presenting information are being developed, such as remote laboratories, and therefore it is not enough to merely rely on older teaching styles and methods.

Remote education as an education medium has received scrutiny to ensure it is as beneficial as being physically present for education. Simulations and remote laboratories are often used in parallel with standard teaching methods (i.e. hands on laboratories). An issue with remote education is that the attrition rate of the students can be up to 10-20 percent higher than on campus units (Angelino, L.M., Natvig, D., Williams, F.K., 2007). Therefore methods of further engaging students in remote education should be continued along with the current studies that involve analysis of student feedback (Lindsay, E., Liu, D., Lowe, D., Murray, S., 2007)

When looking at personal perceptions of effectiveness between simulation and physical laboratories, 72 percent of students found the laboratory to be “about the same” as traditional laboratories (Corter et al, 2004) yet it has also been found that students scored higher on reports written from a simulated laboratory compared to a physical laboratory (Balakrishnan and Woods, 2013). These findings are of interest when you consider the debate between Clark and Koza (Clark, 1983, 1994 Kozma 1994, 2000), who looked to analyse if presenting information through a specific medium had educational benefits, or if it leads to any change whatsoever.

Students are also known to interact with different equipment in different ways. Students interacting with remote laboratories show a tendency for students to become engaged in self-directed learning (Böhne, Faltin et al. 2002, May, Terkowsky et al. 2013). While not a new concept, it is most certainly a requirement for distance education where the student must actively engage in learning the material without an instructor present. It has also been shown that in a remote laboratory, a student will approach the learning material with a different mindset than with other mediums(Lindsay and Good 2005). Lindsay and Good found that when focusing on students’ belief of objectives in a remote laboratory, it was found that 20 percent of students thought that the remote laboratory was about understanding the hardware, while only 6 percent of people undertaking the same practical whilst using a simulation believed this.

Remote education, including remote laboratories and simulated experiments, possess the ability to educate in ways that are not possible when using the standard laboratories (Cooper and Ferreira 2009). Due to the requirement of most simulations and remote laboratories to be completed by a student without an instructor present, a student must be able to interact with the medium in entirely different ways, including hybrid labs that involve elements of remote, simulated and hands on laboratories (Abdulwahed and Nagy 2013). Comparing remote laboratories to simulations, students have a preference for being able to witness the experiment being completed, and having one trust in the authenticity of the results (Jona, Roque et al. 2011).

To add to this, when students perceive an experiment as being real, or using real equipment compared to being modelled in a simulated computer environment, they interact with the experiment differently (Sauter, Uttal et al. 2013). This interaction is important, as with proper understanding, the students focus could theoretically be manipulated into focusing their attention on a desired learning objective.

This paper aims to present students with a remote laboratory showing outputs of a solar inverter, and to analyse their experiences in this laboratory.

Laboratory overview

The laboratory discussed in this paper was made available to students studying undergraduate engineering. The unit it was introduced in aims to allow students to investigate renewable energy systems, and to allow them to gain exposure to the outputs of such a system. It requires students to run a simulation of a renewable energy system for a chosen location accounting for factors such as changing lighting conditions throughout the entire year, as well as average wind speeds and other weather effects. Students are required to select a location and simulate the energy generated by a renewable energy system of their own design.

In an attempt to increase student exposure to solar energy systems, a remote laboratory was designed to show the outputs of a solar inverter located at the university. The remote laboratory was not graded, and was instead given to students as an extra resource to allow them to view the inverter outputs. Since the laboratory was not assessed, it allowed students to view all outputs in their own time, taking however long they required.

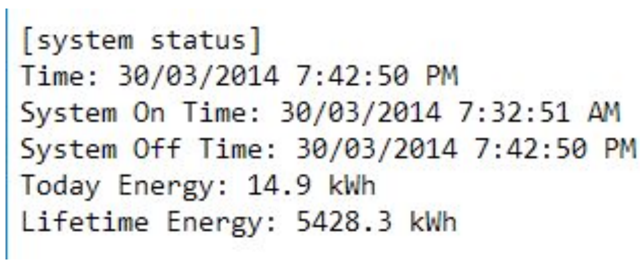
The outputs of the laboratory allowed students to see the changing joules and watt output generated by the panels. This data was updated at ten second intervals. In addition to the live updates, it is also possible to see a snapshot of the last two and twenty-four hour periods. This allows students to quickly and easily see trends with the output power with respect to time of day. In addition to viewing the information, students can also download a CSV file that again shows the generated power at ten second intervals for the last 24 hours, or a log file of the daily averages and maximum power outputs over the past three years.

Table 1: Example of outputted log file starting at 9.00AM 26/02/2016

Id	Joules	Year	Month	Day	hour	minute	Second	watts
1407706	5416	2016	2	26	9	0	4	541.6
1407707	5387	2016	2	26	9	0	15	538.7
1407708	5360	2016	2	26	9	0	26	536.0

Table 1 displays the data generated by the short term logged file. Every entry has a unique Id, and shows the total amount of joules generated over the last ten seconds, as well as the year, month, day, hour, minute and second this data was generated. For ease of use, the logged output also shows students the value converted to watts.

Figure 1 shows the daily summary information. This was included to allow students to see long term trends for the power output. Instead of a data point every ten seconds, the file presents energy generated every ten minutes, as well as the daily total and lifetime energy generated for the system. The system on time and off time are also given, showing the operating hours of the system for every single day.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[system status]
Time: 30/03/2014 7:42:50 PM
System On Time: 30/03/2014 7:32:51 AM
System Off Time: 30/03/2014 7:42:50 PM
Today Energy: 14.9 kWh
Lifetime Energy: 5428.3 kWh
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Figure 1: Outputted log file from 30/03/2014

The laboratory was available to students during the entirety of the unit. Its primary purpose was to give students exposure to the outputs of a solar inverter, and to enforce the inverters behaviour, such as having zero power output during the night, and very unreliable outputs during cloudy days. The intention of this was to encourage students to look into or consider possible solutions to providing reliable power to a simulated environment, and to look at systems that would provide power at times that solar is unavailable.

The students were given information on how to access the laboratory in a news item posted on the subject page accessible by all students and teaching staff for the unit. To access the laboratory, students simply needed to open a specific URL and it would immediately take them to the laboratory.

Case study Outline

A case study was completed by students initially accessing the laboratory. This study used students already enrolled in a renewable energy undergraduate engineering second year unit. The subject is a requirement for completing both the electrical and electronics engineering major, and the mechatronic engineering majors.

The subject required groups of students to observe solar and wind outputs for a location in Australia from sources such as Bureau of Meteorology. They were then required to create a renewable energy system capable of providing enough renewable energy to either allow the location to live completely off grid, or to feed energy back into the grid. Students were required to analyse all renewable energy sources over the entire year and decide on the most beneficial way to implement their renewable energy system, as well as to answer questions such as how many solar panels would be used in an array, what direction should they face and what percentage of energy can be made completely renewable.

Completing the laboratory consisted of students accessing the laboratory through the provided URL. Students were then given the chance to analyse the changing outputs, and to consider the implications of such a system in their own design. They could also access the long term log files to see the change in outputs of a renewable energy system at different times of the year.

At the completion of the unit, students were asked to fill out a survey of their experiences in the laboratory, focusing on their perceived learning objectives. This was similar to the study presented by Lindsay and Good (2005) which aimed amongst other things to analyse different perceptions of learning objectives between different educational mediums and access modes. The survey also allowed students to give general feedback on both the subject and the laboratory and to provide feedback on if they perceived the data and system to be simulated or real.

The survey consisted of 8 questions (refer to Appendix A) and took an estimated 10 minutes to complete. It was issued at the completion of the unit and open during the inter trimester break. Completion of the survey was completely voluntary. Student responses were anonymous and did not have implications over their final mark.

Results

The survey (refer to Appendix A) completed allowed for both the gathering of qualitative and quantitative data. By collecting student responses it was possible to look at both the way students were interacting with the laboratory as well as their opinions on the laboratory. An overview is given in Table 2, 3 and 4.

Table 2 shows the written responses to the survey question “What do you feel the primary learning objective of the remote laboratory was?”. Answers from this question trended to one of two possibilities, those being either ‘real time visualisation of outputs’ or ‘power and PV cells’, with other responses being recorded in the misc/other category. The percentage of responses for each category, as well as example responses are given in Table 2.

Table 2: Sample of student responses from Question 2 (Appendix A) of survey

Question 2		
Response Trend	Example	Percentage of responses
Real time visualisation of outputs	"access to real practical results anywhere anytime"	31.6%
	"Visualisation in real time"	
Power and PV cells	"To study the power output from the solar energy as the source"	52.6%
	"To analyze power generation characteristics"	
Misc/Other	"apply technical knowledge and the use of computer assisted applications"	15.8%
	"To receive live data for students that cannot make it to class/labs"	

Table 3 shows the additional comments to the survey question "the remote laboratory could be improved". Answers showed students primarily thought improvements could consist of more control over hardware, or to have more instruction on the functionality of the laboratory. Since the laboratory was an optional resource, it was never the focus of a lecture and students were never given formal instruction on the laboratory. This is something that can easily be modified in future years. Other responses are shown in the table as 'misc/other'. Again, examples of each response are given.

Table 3: Sample of student responses from Question 7 (Appendix A) of survey

Question 7		
Response Trend	Example	Percentage of responses
More control over hardware	"Could not manipulate controls, nor access sun/weather conditions"	36.4%
	"Including interaction with the configuration of the system"	
Further instruction on laboratory functionality	"Lecturers need to explain what the data is to be used for and why it is relevant"	27.2%
	"More relating to the encouragement and training regarding the program"	
Misc/Other	"enable access of data for longer periods e.g. past 6 months"	36.4%
	"More time could be made available to the students to learn more or perform more activities or observations"	

Table 4 shows the comments from students when give the opportunity to provide general feedback at the end of the survey (Question 8, Appendix A). There were very few responses to this section. The responses given have been separated into positive comments, negative comments and misc/other.

Table 4: Sample of student responses from Question 8 (Appendix A) of survey

Question 8		
Response Trend	Example	Percentage of responses
Positive comments	"Overall the remote lab provided a stimulating and informative insight into the function of renewable energy sources."	60%
Negative comments	"The data I downloaded was not comma delimited, so it could not be properly viewed"	20%
Misc/other	"I feel very few students even knew of the existence of the data"	20%

Students were presented with a range of study areas as shown in Figure 2 and asked what they believed the primary learning objective was. These objectives were all general engineering objectives instead of ones specific to the laboratory. Since the data asked about each subject individually, a method of comparing results together was required. To do this, each response from very little focus to specialised focus was given a weighted value, 0-4 respectively and then multiplied by the total number of responses. After this, a total was discovered and multiplied by the total number of responses. Once this was completed, the values were converted to percentage values. These numbers are represented in Figure 2.

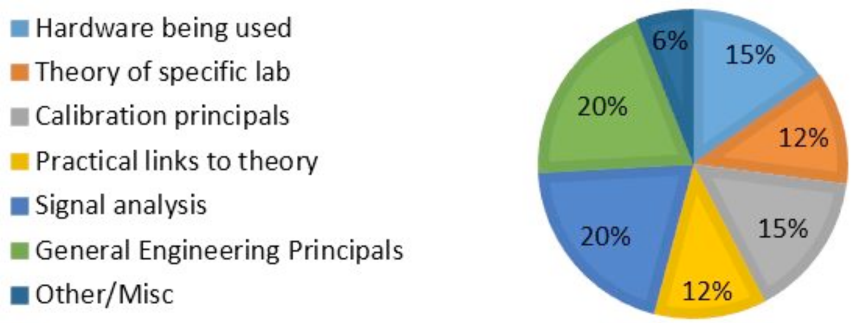


Figure 2: Students perception of primary learning objective of the laboratory

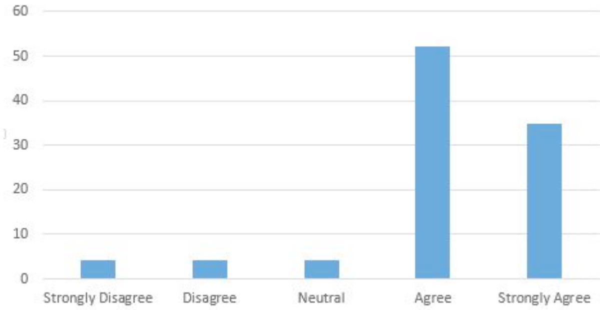
Most noticeably, 'Signal Analysis' and 'General Engineering Principals' show as the largest perceived focus of the laboratory with 'Theory of Specific Lab' and 'Practical Links to Theory' ranking the lowest (ignoring the other/misc. option).

Figure 3 shows Question 5 of the survey (Appendix A), which looked into how real the students believed the data being generated was, focusing on:

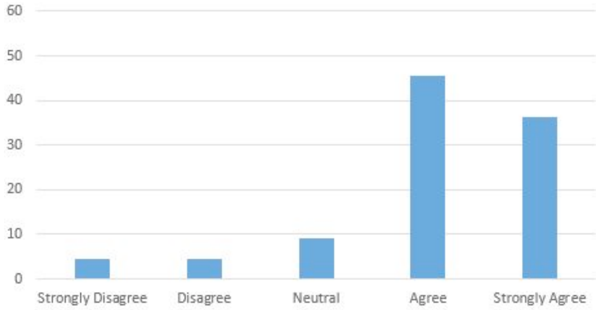
a) did they believe the data was real

b) did they believe the equipment was real

The data was taken from a likert scale generated by the students' responses to this question.



Question 5-a (Appendix A) response



Question 5-b (Appendix A) response

Figure 3: Students perception of realism of results and equipment

Discussion

When looking at the feedback of all students, specific trends started to arise. When asking students the purpose of the laboratory, the students focused on exposure to photo-voltaic cells. This can be seen by the response to Question 2 (Appendix A). With regards to this question, it was positive to see students observing the cell output, however there were very few responses focusing on the long term logged data from the laboratory. Ideally students would have observed the logged data as well as the live data to view the different styles of output. In addition to this, real time visualisation of the solar energy output was another focus for students. A live output of this data was the first thing students viewed when accessing the server.

Another trend was for students to leave feedback regarding presenting the laboratory as supplemental information instead of a required practical exercise. Feedback indicated that students expected the laboratory to be directly related to assessment material. Therefore, when viewing the laboratory information, some students did so believing it would directly correlate to marks in a specific assessment, as seen by responses to Question 7 (Appendix A). Another improvement students commented on was the lack of direct control over the solar panels. This was due to hardware limitations, however a future iteration could be created to have this level of control of hardware.

Responses also indicate a lack of properly introducing the laboratory as an additional resource. An example is students requested longer time periods of access, and access to more logged data. Since the students were informed of the laboratory only in a forum post alerting them on how to access it, this can easily be improved in future classes by having a lecture informing students of exactly what resources they can access from the laboratory.

An interesting trend was for comments to also request features that were already implemented. Requesting data from the last six months when this data was included in the log files. However this most likely relates to students requesting more instruction on lab functionality, an aspect that can be improved in the future.

In addition to looking for qualitative feedback, students were also asked to assess what they believed the focus of this laboratory was. This was done in an attempt to view what relevance the students perceived the information to have over their studies. To do this, they were presented with the question “How much did you feel the remote laboratory focused on the following areas:” and asked to select an option between ‘very little focus’ and ‘specialised focus’. As seen in Figure 2, 'General Engineering Principals' and 'Signal Analysis' showed the largest amount of responses from students, showing that if attempting to have students approach material with these specific mindsets, a laboratory such as this one could possibly be used. However, more research in this area is required before a conclusive statement can be made. By being able to create a laboratory that focuses on renewable energy and also allows students to prepare for a further understanding of signal analysis, it may be possible to control not only what material students learn, as well as the way in which they approach the material, ideally supplementing specific aims of a course.

Finally, when reviewing students' perception on if the equipment used was real, it can be seen in Figure 3 that a majority of students selected either agree or strongly agree. This is interesting as a web camera or other video/photo device was not used to display the panels, and students were only given access to the system outputs. It was hypothesised that a large percentage of students would question the realism of the data, however it appears that this was not the case. A future iteration of this study will include a web cam on the solar panels to see what increase/decrease this has on students' perception of realism.

Conclusion

This paper aimed to analyse students' feedback of their experiences in a solar energy laboratory. The results from this study show a trend towards 'Signal Analysis' and 'General Engineering Principals' as the perceived learning objective in this laboratory, noticeably not the hardware being used. Larger groups of students will be using the same laboratory during their studies, which will allow for a much larger number of responses, and therefore more conclusive results. It also showed students perceiving the data as real instead of as a simulation.

In future uses of this laboratory, more care will be taken to insure that students are properly and fully informed about the functionality of the laboratory. They will also be informed of the fact that it is aimed as supplemental knowledge, solving the issue of students looking for a direct link between this lab and assessed material. In this way, the written feedback from students has been helpful in providing information on how to best present an online laboratory such as this one to future classes.

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Appendix

Appendix A-Survey Questions

	Question	Response style
Q1-a	To what extent do you agree with the following statements?	Likert scale
Q1-b	Why/Why not	Written response
Q2	What do you feel the primary learning objective of the remote laboratory was?	Written response
Q3-a	To what extent do you agree with the following statements? I felt like I was completing a computer simulation	Likert scale
Q3-b	I felt like I was completing a laboratory using real equipment	Likert scale
Q4-a	How much did you feel the remote laboratory focused on the following areas: Hardware being used Theory of specific lab Calibration principals Practical links to theory Signal analysis General Engineering Principals	Likert scale
Q4-b	Other (please specify)	Likert scale/ Written response
Q5-a	To what extent do you agree with the following statements? I felt like the data being generated was real	Likert scale
Q5-b	I felt like the equipment being used to gather data was real	Likert scale
Q6-a	To what extent do you agree with the following statements? The remote laboratory was helpful for understanding the topics covered in this unit	Likert scale
Q6-b	Why/Why not	Written response
Q7-a	To what extent do you agree with the following statements? The remote laboratory could be improved	Likert scale
Q7-b	Additional comments	Written response
Q8	Do you have any additional comments about the remote laboratory? Additional comments	Written response