

Is it worth investing in Remote Online Network Accessible Laboratory Devices?

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***Abstract:** In this paper we investigate a remote-access networking laboratory. In particular we attempt to answer the question: “Is it worth investing in Remote Online Network Accessible Laboratory Devices (RONALD) to provide students with 24/7 access to real networking laboratory devices?” In answering this question we discuss the experiences of both staff and students in the use and deployment of such a facility in a number of data-networking subjects. We explore issues such as cost, performance, educational outcomes and the provisioning of both access and support to students outside designated laboratory times. Survey results of the student experience using the remote learning facility are presented. These results outline issues such as student engagement through usage patterns, student perceptions of the facility’s value and exploration of concepts not covered in the laboratory exercises. These student results are contrasted with the educators’ experience.*

Introduction

Much of today’s educational rhetoric is based around flexible learning and diversifying teaching methods so that they better match the learning styles of students. One approach to meet this goal is to offer access to teaching materials in an online environment. Traditionally laboratory exercises have required students to attend face-to-face classes. When performing laboratory exercises outside of scheduled class times, practical/economic constraints dictate that simulation tools are used. A better solution to simulation is to provide online access to real laboratory equipment. Whilst this approach may be ideal for students, it may require significant costs in providing the infrastructure and support.

In this paper we explore the value of using a remote-access networking laboratory. This paper is structured as follows. In the Background Section we outline our motivation for the implementation of a “Remote Online Network Accessible Laboratory Devices” (RONALD). In the Results Section we report on the experiences of both the students and academic staff with RONALD and present and analyse some quantitative data. In the Conclusion Section we outline our findings and make suggestion for further work.

Background

In the early 2000’s the popularity of the networking subjects within our Faculty increased to the point where there was an urgent need to provide additional access to the real networking equipment outside of the allocated laboratory time. This need arose in order to allow students further time to practice and to consolidate their learning. Due to issues such as the security of the equipment and lack of available laboratory room-times during the week, outside of their allocated classes, the Faculty employed sessional staff to supervise weekend access to the networking laboratory. This particular solution became unsustainable from an economic point of view as these sessions were poorly attended and the students’ arrival times were sporadic. Other issues such as classroom management (access to buildings and individual classrooms), lack of technical support, staffing costs, and finding suitably qualified sessional staff that were available on weekends made this solution impractical. In addition

this solution did not scale well with the growth in the number of students taking these networking subjects. As a consequence of these issues in 2005 the Faculty investigated the use of a remote online learning system. This resulted in the deployment of a RONALD facility based on the “Netlab Academy Edition (Netlab)” system from NDG (NDG, 2010a). This facility has been specifically designed to host real networking devices. This system has the flexibility that it can be used by students either individually or in teams, 24 hours per day 7 days per week, both for blended distance learning or instructor led learning/training. Netlab is at the heart of the RONALD environment.

From the literature there seems to be three main approaches to providing remote online networking laboratories without using a simulator. The first method is to deploy a customised in-house solution where various software tools and hardware are packaged together in order to provide remote access to real networking equipment (Aravena & Ramos, 2009; Vivar & Magna, 2008). The main disadvantages of this approach are that the expertise to build the system must exist within the Faculty a-priori, the hidden costs of the administration and ongoing maintenance of the tools requires continual training of staff so that the expertise is not lost. Other disadvantages are that the network security and the reliability of the system may be questionable, and that the design costs are high as this is a customised solution. The second approach is to simulate networking devices using “jail hosts” running on a remote server (Armitage & Harrop, 2005). The main disadvantages of this method are: the creation of the software to implement the jail hosts; the configuration of the system; as well as the fact that this solution uses emulation to create virtual devices as opposed to real networking equipment. The third approach is to use a readily available commercial solution such as Netlab (NDG, 2010a). The advantages of this approach are: there is a good knowledge base of networking experts, it is flexible in that new devices are easily incorporated, it is scalable as more capacity or other services such as curriculum content can be provided with little effort. These commercial solutions usually have a maintenance agreement which means that the ongoing development and maintenance are outsourced, thus relieving the teaching staff of the maintenance issues. Remote administration is available and the class scheduling is in-built (Lloret, Jimenez, Diaz, & Lloret, 2008; Stiubiener, Ruggiero, Korolkovas, Skopp, & Meiler, 2008) (Makasiranondh, Maj, & Veal, 2010). The main disadvantage of this solution is the initial high cost of the system. The Faculty chose the commercial system because it would take too long to develop the expertise to build an in-house system and it would remove the burden of administration, maintenance and upgrades of the system.

Description of RONALD

RONALD consists of two Netlab servers (NDG, 2010a), one serving the students from the fundamental networking subjects and the other serving the students from the advanced networking subjects. Each server provides students with 24/7 access to real equipment which can be accessed remotely via the internet or through the university LAN. Each server has a flexible booking system that allows the student to book a 4 hour session twice per day at some future date and time. Students can also access RONALD during their formal laboratory class time; however, RONALD is not intended to replace the equipment housed in the laboratories as students are encouraged to physically handle the real networking equipment and the necessary connecting cables. Students can either load existing lab topologies which are set out in the curriculum or start out with blank devices and make up their own topologies, within limitations, in order to explore and consolidate their learning and understanding.

The cost of each Netlab server is approximately \$US6,800, additional control devices required for the correct operation of Netlab are: a Cisco 2960 Switch, a Cisco 2811 router with one or two HWIC-16A modules and switched power outlets. The total cost of these control devices is approximately \$US7,200. Thus the initial setup cost without the equipment required by the students to carry out the laboratory work is in the order of \$US14,000. There is an additional annual maintenance fee of \$US2,395 which allows NDG to provide server updates and to continually develop Netlab so that it can cater for changes in curriculum and laboratory requirements (NDG, 2010b).

Each Netlab server can house up to 8 pods of laboratory equipment, shown in Figure 1, thus giving access up to 8 students simultaneously. The maximum capacity of each server is 192 hours per day. Each pod can contain different combinations of equipment to cater for the various subjects. In order to

fully furnish the Netlab server with 8 pods of equipment the total cost would be between \$US 45,000 to \$US 60,000 depending on the equipment combination (assuming that a discount of around 70% is available to academies from Cisco Systems). Each pod of equipment can also provide support for a maximum of 5 remote PCs by the implementation of virtual machines through 3rd party products such as VMware server from VMware (VMWare).



Figure 1 Netlab Servers and associated laboratory equipment

Results

The study undertaken is comprised of two components involving 91 students and 5 staff members. The two components were a survey and statistical evaluation of student usage and performance.

Experiential Outcomes

The views of the students and academic staff on various aspects of using Netlab in the RONALD learning environment are outlined below. Both groups were surveyed using questionnaires to elicit views on the worth and usefulness of this tool as well as their personal experiences. The student questionnaire was comprised of 8 questions with pre-defined options and 4 questions which solicited verbal responses (the questionnaire can be obtained from the authors). The students surveyed were from the advanced networking subjects as they have had experience in using RONALD during their course.

The student questionnaire allowed the 74 respondents to the survey to express their experiences with RONALD through their likes/dislikes and usage patterns (13 undergraduates and 61 postgraduates). The results for these surveys are summarised below.

Students perceive the strengths of using RONALD to be:

- Convenience
 - 43% found it very useful to be able to undertake the labs at their own pace and in their own time either on campus or off campus.
- Educational value
 - 25% found it very useful to be able to extend their learning by further practice or creating their own scenarios. The students could further consolidate their understanding by repeating the laboratory exercises or to prepare for the upcoming laboratory exercises.
- Use of real equipment
 - 12% felt the use of real equipment was beneficial in enhancing their learning as simulation doesn't always reflect reality.
- Other or no response
 - 20% replied with vague or no answers.

Students perceive the weaknesses of using RONALD to be:

- Fixed cabling of equipment pods
 - 16% viewed that the pre-connected laboratory scenarios meant that they couldn't practice their troubleshooting skills as there was no scope for incorrect wiring, using incorrect cables or using faulty cables. In addition, the students also felt that not all of the laboratories could be performed on RONALD since the cabling/topology could not be altered remotely.
- Slow response of the RONALD experience
 - 5% felt that response time was too long due to a variety of reasons, such as slow internet connections.
- Faults
 - 7% felt that the routers on RONALD did not behave in the same manner as the routers in the laboratory and that some commands were not available on the RONALD equipment. This is surprising as RONALD uses identical equipment to that in the laboratories.
- Scheduling Problems
 - 27% believed the following:
 - session times were too short (not able to book the equipment the whole day)
 - time between bookings was too long
- Some interesting responses not categorized are:
 - 11% complained of lack of realism. For example "You can't physically touch the equipment" and hence they felt they had a lessened experience.
 - One student ($\approx 1\%$) felt that the use of a simulator was more flexible than using RONALD and therefore was preferable.
- No weaknesses
 - 4% felt that there were no weaknesses with RONALD.
- The remaining students (29%) did not respond to this question.

Of the students surveyed 34% claimed they used either a simulator or an emulator in addition to RONALD and 16% used only a simulator or an emulator.

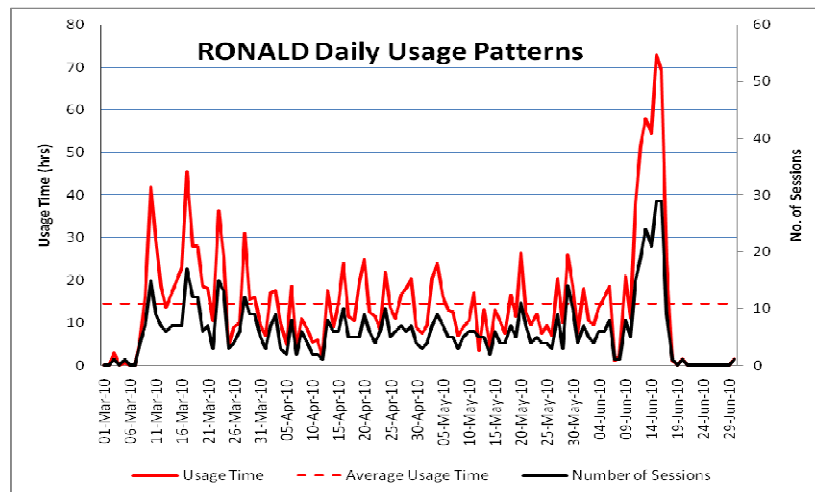


Figure 2

The main conclusions to be drawn from the qualitative analysis of the students' survey responses are that RONALD makes it convenient for them to access real equipment and that they believe it to be a useful tool to consolidate and extend their learning. On the negative side they believe that the session times were too short and the time between allowed bookings was too long (Note students could book a 4 hour session twice a day). However, we see in Figure 2 that overall usage time averaged out to 14.5 hours with an average of 6 sessions per day for the majority of the semester. The main usage occurred during the examination period, in particular from June 11th - 17th, note the actual exam was on the 18th of June. Overall the actual availability of RONALD is quite high, in contrast the students' perception.

All 5 full time staff involved in teaching the networking subjects were surveyed using a questionnaire (consisting of 2 questions with pre-defined options and 7 questions which solicited verbal responses) to obtain the academics perspective of using RONALD. Staff perceive the strengths of RONALD to be:

- 100% believe it to be a worthwhile learning tool as it gives students a greater degree of access to real-world equipment. The staff also felt that RONALD augments the students' learning experience by allowing them to:
 - complete unfinished laboratories.
 - explore challenging concepts.
 - work ahead and learn through self-directed activities.
- 60% believe that it provides value for money.
- 80% believe that it is a superior product to the use of a simulator.
- 100% think the ease of class set-up and management is a strong positive benefit.

Staff perceive the weaknesses of using RONALD to be:

- 100% believe it is not a substitute to the instructor led laboratory classes, where the students interact with fellow students as well as the staff.
- 100% believe the fixed topologies mean students cannot re-wire the equipment and hence limit the experience.
- 20% believe the start-up of the booked equipment is too slow. Additionally possible equipment resets can consume large parts of the booked time.
- 100% believe the lack of peer/instructor interaction to be prohibitive to interactive learning, unless students are working collaboratively using the same PC.
- 40% believe that this mode of learning is affected by the individual's internet connection speed.

The main conclusions to be drawn from the qualitative analysis of the staffs' responses are that they believe RONALD to be a worthwhile learning tool with the caveat that it is not used as a substitute for attending face-to-face classes.

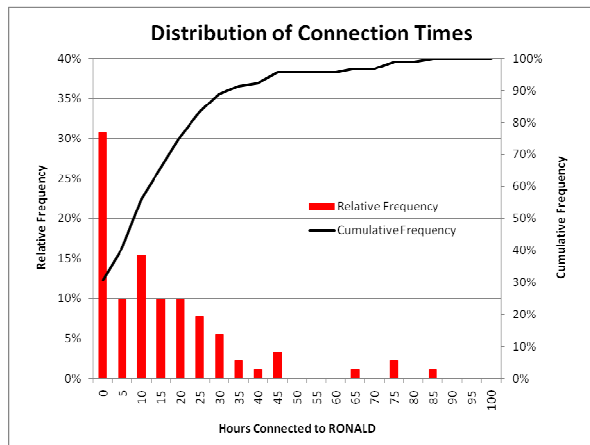


Figure 3

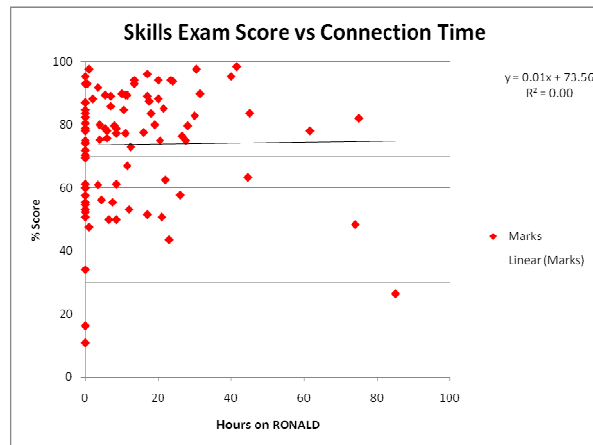


Figure 4

Educational Outcomes

In addition to the qualitative results based on the experience with RONALD, we looked at the actual number of hours that students used RONALD over the semester. The results presented are from a population of 91 students who were enrolled in one of 2 advanced networking subjects. Each student had a 3 hour scheduled laboratory class per week. On average students spent 13.4 hours with a standard deviation of 17.5 using RONALD over the entire semester. From the cumulative distribution function for the time spent on RONALD (Figure 3) we can see that the median number of hours that an individual student remained connected and accessed the equipment remotely was 8 hours. This number is quite low considering that the facility is available every day of the semester. From the survey results 91% of the students claimed that they used RONALD. However, the usage data shows that only 69% of the students actually used RONALD. As not all students responded to the survey this

discrepancy may have introduced some bias in the results. Given these usage patterns one may question whether the investment in this facility is worthwhile. Further work needs to be undertaken to confirm or deny this initial finding.

Figure 4 shows a scatter plot of the number of hours that students were connected to RONALD and their overall score in a practical skills examination at the end of the semester. As can be seen there is no correlation between the connection time and the overall performance in the skills examination ($R=0$). This result is unexpected, as one would imagine that increasing the amount of time devoted to effectively practicing skills would somehow improve performance. The average score of the students who used RONALD for less than the 8 hours (median) was 70% compared to 77% for those who were connected for longer times. A t-test indicated that the means of the two populations were the same. A possible cause for this result is that students may actually prefer to use either an emulator or simulator to practice their skills and thus they do not require access to RONALD. Another possible reason is that some students may feel that they learn enough during their face-to-face laboratory classes and that they do not need the extra time to practice outside of designated laboratory class times. In the current implementation of RONALD the students work through the exercise on their own, thus we cannot be sure that the time spent on RONALD is actually effective. Further work needs to be conducted to try to determine the answer to these issues.

Conclusion

In this paper we have described a “remote online accessible laboratory devices” facility, which we have deployed to allow students to access real networking equipment outside of designated class times. Staff and students perceive that RONALD is a valuable facility in that it allows students freedom of choice in study times, greater access and increased flexibility in their learning. Thus we believe that the cost is justified on these grounds. The usage of RONALD varies over the semester with higher usage at the start and significantly greater usage closer to exam time. In terms of educational outcomes, one should question the value of this expenditure as there does not seem to be a correlation between the number of hours spent on RONALD and the grades attained by the students. Further work needs to be undertaken to draw a definitive answer to this question. Additionally the study should be extended to include the experiences of the students in the fundamental networking subjects in order to obtain a broader view.

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