Development of an Effective Remote Interactive Laboratory for Online Internetworking Education

Shyamala C. Sivakumar‡, William Robertson‡
†Computing and Information Systems, Saint Mary’s University, Canada
‡Director Internetworking Program, Dalhousie University, Canada
E-mail: shyamala.sivakumar@smu.ca, bill.robertson@dal.ca

Abstract

The Faculty of Engineering at Dalhousie University, Halifax, Canada has been offering a Master’s degree program in Internetworking since 1997. The program also provides comprehensive “hands-on” laboratory experience in configuring, maintaining, troubleshooting and simulating networks. The university intends to increase its student base through online education retaining the same quality of interactions as the onsite program. In the online context, the design and the implementation of an effective remote interactive laboratory (RIL) environment is highly challenging on account of the special hardware, simulation and computing needs of the Internetworking courses. This paper focuses on translating the onsite laboratory elements into the online RIL environment by allowing students at geographically remote sites to access and interact with internetworking devices located at Halifax. The RIL is devised using de-facto networking standards, free software and commercial Internet browser. Real-time interaction and information transfer with the Halifax site are achieved independent of the technology available to the remote student. The RIL design and delivery mechanism are tailored to i) provide a constructivist pedagogical approach ii) model a collaborative learning environment for group interaction iii) match the characteristics of the delivery media to specific learning processes (media-synchronicity theory) including the provision of unambiguous feedback, and guidance iv) design appropriate roles and v) determine desirable learning outcomes. A 4-tier role architecture consisting of faculty, facilitators at both local and remote sites and students, has been determined appropriate and adapted to maintain academic integrity and offer the same quality of interaction as the onsite program.

1. Introduction

The Masters in Engineering in Internetworking [1] offered by the Faculty of Engineering at Dalhousie University in Halifax, Canada is one of the first of its kind in the world, offered since September 1997. The program intends to increase its student base through online education aimed at fulfilling the needs of remote students. The program places great emphasis on laboratories that account for approximately 40% of program content. The online internetworking program must continue to offer the same quality of interaction with the faculty and the laboratory that it now offers its onsite students [10, 11, 12]. Remote laboratories have been successfully used in Electrical Engineering education to interact with spectroscopy, measurements and control systems laboratories [29-33]. This paper describes the pilot version of a remote interactive laboratory that is used to deliver Internetworking laboratories to students at remote sites. In a remote delivery scenario, it is important that the delivery mechanism, laboratory course content and instructional design be tailored to i) model an active remote learning environment that engages the student in achieving learning outcomes ii) model a collaborative environment for group interactions iii) match the characteristics of the media (delivery medium) to specific learning outcomes and processes including the provision of unambiguous feedback, and guidance iv) design appropriate roles and v) determine desirable learning outcomes.

A discussion of the salient pedagogical features of the onsite program is provided as this is important to understanding the requirements and implementation issues faced by the online program. The onsite program consists of ten courses, each offered in a compressed two-week format, and is scheduled over a ten-month period, followed by a project. The onsite program employs three types of interaction to ensure effective learning: i) lectures by expert instructors ii) hands-on laboratories and iii) group interaction with peers through case studies, projects and group work that
correlate with the three well known pedagogical approaches viz., objectivist, constructivist and group interaction respectively [2, 3, 4]. The objectivist approach emphasizes that students learn by explicitly being informed or taught by subject experts. The constructivist approach is based on learners learning by performing authentic activities and constructing knowledge in authentic learning environments. The group interaction approach is based on groups of learners engaging in collaborative problem solving that increases student engagement with the subject matter resulting in better learning.

The onsite lectures account for 50% of course content, emphasize the underlying fundamental principles of study and the theoretical foundation of internetworking in a chiefly objectivist knowledge-centric environment [2]. The hands on laboratories build practical internetworking abilities and skills in students and correspond to a constructive, collaborative, situated, learner-centric environment [3, 4, 5]. Situated learning has been used in technology-based courses to present academic knowledge in a practical context to teach students problem solving skills [5] and is employed in the Internetworking laboratory to transform the novice students into experts in the context of the industry in which they will ultimately work. In the labs, the students gain a broad range of hands-on experience and a large repertoire of knowledge to understand the practical conditions under which to apply specific internetworking principles, theories and techniques. The laboratory employs state of the art networking equipment, simulators and other hardware in a learner centric environment that engages students in collaborative activities. Students learn to apply theoretical knowledge to practical networking issues, hands-on configuration of equipment, strategies and techniques for troubleshooting networks. Purely collaborative activities such as case studies/project work account for the 10% of course content and capitalize on specific interests of students in a group-oriented setting.

Most internetwork engineering activities in a modern enterprise is conducted in a collaborative setting with a lot of interaction among team members. This makes it imperative that the program model and implement a collaborative environment onsite to facilitate acquisition of problem solving, reasoning and management skills required of potential employees in the workforce [6]. Collaborative student interaction is met by suitably designing laboratory activities such that they are carried out by students in groups of 2-3.

The onsite program located at Dalhousie University, Halifax owns all the state-of-the art-equipment used for delivering hands-on experience and comprehensive exposure to networking equipment. One of the challenges faced by the program include equipping and maintaining a state of the art internetworking laboratory. Specifically, maintaining devices that are not obsolete in order to provide an up to date “community of practice” to the students has been an important requirement. In the internetworking community devices typically are replaced every 3-4 years. This necessitates that the program follow the same time-scale for refurbishing its laboratory facilities with modern equipment. However, such upgrading of equipment is expensive. Typically, the onsite program uses the internetworking lab 6 hours a day over the two-week period when the course is offered. One approach for the program to increase its student base is through online education aimed at fulfilling the needs of remote students. Therefore, a good strategy is necessary to enable online students to access the equipment from remote geographical locations. This should help with the expenses involved with refurbishing equipment and staying current.

The online program uses an integrated web engine (IWE) that accommodates three different modes of technology-enabled learning that correlate with the three well known pedagogical approaches and types of onsite interaction. They are: (i) Remote Lecture Room (RLR); (ii) Remote Interactive Laboratories (RIL); and (iii) Interactive Home Learning (IHL). The RIL emulates a classroom environment and corresponds to the objectivist approach. The RIL is aimed at delivering remote laboratory experience, is moderated by laboratory facilitators and corresponds to the constructivist pedagogical approach that uses collaborative methods to achieve learning outcomes. The IHL facilitates inter-student communication to encourage peer interaction and uses group processes in learning. In this framework the word “online” is used to indicate a number of remote sites with several students at each remote site as shown in Figure 1. The word “onsite” indicates the Halifax site which is where the Internetworking equipment facility and the onsite classrooms are located. The Halifax Internetworking equipment facility (HIEF) together with the various remote site facilitation rooms (RSFR) constitutes the RIL.

The paper is organized as follows: Section 2 describes the remote interactive laboratory. Section 3 describes how the people involved in the program are part of 4-tier role architecture. These sections outline the progress made by the program in reengineering the internetworking laboratory to enable students to interact online with the devices in the Halifax equipment room. Section 4 describes the typical work scenario in the remote interactive laboratory. Section 5 discusses user authentication of remote students. Section 6 discusses the issues that affect online
internetworking lab education. Section 7 discusses system limitations and provides directions for future research in this challenging area.

2. Factors influencing Remote Interactive Laboratory (RIL) design

A critical analysis of the metrics that can be used for evaluating student interaction with an electronic learning system from student, university/instructor/facilitator and technology viewpoints is provided in [12, 13]. Good e-learning begins with effective, real-time, reliable and secure student interaction with the e-learning system. All other steps in the e-learning process rely on this crucial student interaction phase. The most important measure that a student will use for repeat interaction with an e-learning system of a university is the ease in using the system. From the universities viewpoint, the ease in using an e-learning system is a function of system design and is determined by several factors such as its accessibility, usability, reliability of system, help available, responsiveness of the system and appropriateness of system response to student input and support for many simultaneous users [12]. The communication channel characteristics, protocols and technology must be designed for real time applications. The metrics by which an e-learning resource may be evaluated include: i) an expert curriculum ii) ease of use; iii) involve continuous assessment; iv) allow real-time feedback to track student performance; v) employ multimedia simulations, laboratories and user interaction to create a dynamic, engaging environment for learning vi) enhance problem-solving techniques on an individual or group basis [10, 12, 13, 15].

The internetworking laboratory involves the use of hardware such as routers and switches obtained from internetworking vendors including Cisco Systems [7] and Nortel Networks [8], network analyzers, network simulation software OPNET [9], personal computers and servers. A screenshot of the webpage used to access lab resources remotely and the logical architecture for delivering labs to remote sites is shown in Figure 2. As seen from this figure, the equipment is placed on eight racks in the laboratory. Each rack consists of several Cisco 36xx routers, Cisco 3512 switch, Nortel Passport 100 router/switch and several Ethernet and Token Ring hubs. Also, each rack in the Halifax facility is equipped with a terminal server. The terminal server connects a device’s port to the Internet and thereby supports multiple simultaneous student interactions with the equipment.

![Figure 1: Remote Interactive Laboratory Framework for Internetworking program](image1)

![Figure 2: Logical architecture for delivering INWK labs to remote sites](image2)
The onsite internetworking laboratories have been redesigned and the equipment rewired in a manner that allows both online and onsite students to construct different networks topologies without much change in the physical wiring/cabling. The wiring diagrams for lab equipment is easily accessible from the program website. A screenshot of the wiring diagram access webpage and an example of the INWK wiring diagram for V.35 Connections is shown in Figure 3.

The university has also addressed the need for a reliable authentication mechanism to verify the identity of genuine students and limit access to instructional material and online laboratories to genuine users. This is achieved by restricting access only to authenticated remote students using an access control server at Halifax. Authenticated remote students now access the devices in the laboratory using the software Teraterm [14] to connect to the terminal servers at the Halifax site. Teraterm, is a free Windows based terminal emulator and Telnet client software, was chosen as the university needs to balance the conflicting metric of finding a cost effective e-learning solution with student satisfaction. The availability of free off-the-shelf software is a prerequisite to lowering the cost of the e-learning system. Also, secure communication and preventing security threats is essential to addressing the security and privacy concerns of students. In addition, the communication itself must be encrypted to ensure secrecy. Teraterm has been extended with a secure shell extension to Teraterm Secure Shell (TTSSH) for PCs using the Windows OS. TTSSH is used to provide secure access to the Internetworking laboratory to the students at the remote site and a screenshot of the system is shown in Figure 4. In addition, students privacy issues are addressed by reassuring them about the nature of the information collected, why it is being collected and how it is used. Also, the program assures the student regarding the security measures including authentication, encryption, authorization and other measures that are in place to ensure their privacy.

Most courses require the students to interact with the devices in the laboratory. For this purpose, onsite students access and configure the devices in the laboratory using a command line interface (CLI) or a graphical user interface (GUI). A key issue with the remote delivery of the Internetworking laboratory content is to convert the onsite student interaction with the devices in the laboratory into online real-time interaction with the devices. The remote site
facilitation room was suitably designed to enable students at the remote sites to access the CLI of most networking devices using the Internet. The CLI was chosen over a GUI, as students need feedback from the equipment at Halifax in near real-time and transmitting information using a GUI is relatively slower than CLI. Also, the CLI is a reliable, direct, simple method of executing network operating system commands on networking equipment. The CLI allows greater flexibility and control as all options and operations are invoked in a consistent manner and is therefore, easier to use. In addition, CLI can be easily used to write scripts to automate repeated configuration procedures. Furthermore, the use of CLI for remote access requires a communication channel with moderate bandwidth requirement which allows the access of CLI to be achieved through the Internet. A screenshot of the CLI accessed remotely is shown in Figure 5.

Some labs in the program require the use of LAN/WAN analyzers and cannot be accessed using the CLI. The LAN/WAN analyzers are located at the Halifax site and are used to analyze the LAN/WAN traffic. Similarly, simulation tools such as OPNET use a graphical user interface (GUI). A key issue in the use of LAN/WAN analyzers and simulation software is to find a suitable method for remote site students to access these analyzers/simulators in the Halifax equipment facility. This problem is overcome by running Virtual Network Client (VNC) software on the remote site computers, which enables the remote students to access and view the output of the network analyzer(s)/simulators on their remote site PCs. However, the use of the VNC at the remote site requires that the remote sites must have a minimum broadband access capability of at least 56 kbps per PC.

In summary, the minimum system requirements at the remote site are that a) each student at the remote site is equipped with a PC, b) the client PC has software for establishing Secure Shell Telnet sessions using Teraterm [14], VNC software, and MS Office suite and c) Broadband access of 56 kbps per remote PC. These requirements can be easily met as they use prevalent hardware, free software for establishing secure internet connectivity, minimal broadband access and commonly available commercial software.

3. Learning theory and its influence on role design in the RIL environment

In addition to a rich repertoire of learning resources and aids, e-Learning includes tailoring learning modules to address how students engage in learning, fostering effective e-learning strategies, and instructional design that incorporate the latest techniques in pedagogical research to support learning at a pace that is comfortable to the student [12, 15]. These objectives can be met with either a self-paced environment in which the student learns at a rate comfortable to the individual or a directed environment in which the student has to follow a particular sequence of instructions. The learning environment can also be classified as synchronous requiring the simultaneous participation of students in the class or asynchronous in which a student may participate at a time convenient to them [16]. Also, the characteristics of a media used in communication can be assessed using media synchronicity theory (MST) and include characteristics such as a medium’s capacity to provide feedback, symbol variety, instruction of multiple students, tuning message content, extent to which message can be reprocessed and unambiguousness [17, 18, 19]. MST, when applied to the problem of remote learning, helps online education designers to match the characteristics of media to learning outcomes or processes to encourage remote students to work on a specific laboratory oriented activity. MST suggests face-to-face communication facilitates feedback and is useful in arriving at a group analysis or decision [17, 18, 19, 28].

One of the challenges facing the online program is how best to mimic the onsite face-to-face interaction between students and faculty, which is critical to learning technology-intensive courses. Most on-site students benefit from face-to-face interaction with instructors provided the faculty to student ratio is at reasonable levels. The same interaction can be achieved in an online program using a well designed facilitation approach. In fact, programs in professional development graduate level courses to teams of
Teachers have used facilitation to successfully mimic face-to-face interaction in an online scenario [20]. In the Internetworking program, facilitation is used in a remote laboratory scenario, to maintain the quality of the educational experience while not sacrificing educational standards [12]. This is addressed, by appropriately modifying the 3-tier role hierarchy of the traditional onsite university consisting of faculty, teaching/laboratory assistants, and students. This is done in the internetworking program by replacing the Tier 2 teaching/lab assistants with local site facilitators (LSF) at Halifax and remote site facilitators (RSF) at the remote site and results in 4-tier architecture that better accommodates the objectives of remote learning. The Internetworking program uses facilitators to foster strong student interaction and to maintain the academic integrity of the program by a strong demarcation of roles at the Halifax site and at the remote site and is shown in Figure 6. In this architecture, at the university end, Tier 1 consists of the Faculty and Administration (including the Director), Tier 2 consists of LSF, Tier 3 consists of RSFs and Tier 4 consists of the students. In the RIL, face-to-face communication moderated by the RSF is used to speed up the understanding of new information and arriving at a consensus. RSF in effect refers to such diverse roles including remote site administration and remote site teaching-assistants. The Tier 1 administration handles, financial, enrolment, registration and other functions associated with disseminating program information. The faculty, are the sole course content providers in charge of designing an expert Internetworking curriculum. They also administer tests, examine and assess students, provide feedback on student competencies, thus meeting the e-learning resource metrics of expert curriculum. It is also the responsibility of Tier 1 personnel to maintain the integrity of the educational process. The LSFs (Tier 2) maintain and update lab notes for each course. In addition, they test and configure the devices in the Internetworking laboratory for proper use, and create and maintain user account information based on information from the administration. In general, the LSF, guided by the faculty maintain a dynamic, engaging electronic-laboratory environment that is easy to use and meet e-learning resource metrics (ii) and (v) outlined in Section 2. The LSF also provide the student with reference material (in addition to standard content) during the performance of the lab. The RSF (Tier 3) support, maintains, and upgrades network services on servers and workstations at the remote site including maintenance of student drive quotas, and backups. They also verify that the laboratory at Halifax is remotely accessible from the computers at the remote site, maintain the operating system, configure the student LAN at the remote site; install, update and maintain the licensed software such as TeratermSSH, VNC, and any software that might be required in the courses.

To summarize, the RIL is modeled as a remote synchronous, collaborative and directed learning environment as remote students interact simultaneously with Internetworking equipment under the active supervision of the RSF and guided by the LSF to achieve specific learning outcomes. The RIL uses streaming video/audio, with its rich media characteristic of providing unambiguous information to multiple concurrent users, to inform remote students about equipment cabling and wiring in the labs. In addition, video-conferencing (whose media is rich in conveying information unambiguously to multiple users with moderate feedback characteristics) is used to provide remedial laboratory instruction thereby, enhancing the remote laboratory learning experience and will be discussed in Section IV.

![Tier 1: Director, Administration, Faculty](image)

**Figure 6: 4-Tier Role Architecture employed at remote site labs**

### 4. Typical remote interactive laboratory work scenario

Students typically work in groups of 2-3 per group in the introductory and intermediate labs. In the advanced labs e.g., BGP or OSPF in Network Architecture, they have to configure the networking equipment by group and then have to interact across groups. It is essential that the remote site laboratory design makes use of active learning strategies in a collaborative environment to ensure quality [4, 21]. Hence, the activities in the remote Internetworking laboratory are modeled to implement the nine instructional objectives as outlined by Gagne [22, 23]. These instructional objectives are: (i) gain learner attention, (ii) inform learners of the objective, (iii) recall prior learning, (iv) present stimulus, (v) provide learning guidance, (vi) elicit performance, (vii) provide feedback, (viii) assess performance, and (ix) enhance
retention and transfer [22, 23]. A typical scenario for remote laboratory work includes:

4.1 Activities that capture the student’s attention, inform of laboratory objectives and recall prior learning

The remote students are given the lab handout a week ahead of actual performance of the labs. In the first stage of learning, the components of the lab are modeled assuming a single user interacting with content [2]. The RSF coordinates with the LSF to define and inform the learner of the objectives, learning outcomes and the results to be submitted by the student and corresponds with steps (i) and (ii) of the Gagne methodology. The RSF keeps track of individual results. This stage of lab learning is also used to recall prior learning and corresponds with Gagne’s step (iii) and addresses the preparation or background study to be accomplished before actual interaction with networking equipment. The RSF then set up a question/answer session that requires students to answer questions regarding the lab and corresponds with Gagne’s step (vi). If teamwork is involved, the RSF assigns the work to be performed by each member of a team. Face-to-face communication between remote students with the RSF is used to achieve learning process convergence [20] and helps students identify a) skill building activities for each lab b) objective of the lab, c) the commands used in configuring equipment appropriately, d) the physical fixed wiring of the lab (if appropriate), e) actual steps in achieving a lab outcome and how to measure/record output or simulation results, f) the correct/expected output and is in accordance with Gagne.

4.2 Active remote interaction with laboratory equipment – present stimulus, provide guidance and elicit performance

The RSF coordinates with the LSF to ensure that the remote students can interact in real-time with the equipment in the Internetworking lab at Halifax. At this level, the student has already acquired some knowledge (e.g., has configured a particular interface correctly and is now ready to proceed to the next stage of the lab). The student must submit results to the RSF after the completion of each sequence in the lab. The RSF keeps track of the knowledge acquired, its measurement and conveys this to the learner e.g., “you are now ready to proceed to Step 3 of the lab”, and corresponds to Gagne’s steps (v) to (vii). Students practice under the guidance of the LSF which allows the LSF to provide corrective feedback. According to Gagne corrective feedback is one of the most effective teaching strategies that enhance learning and long-term retention. At this stage, the labs can be thought of as being “directed” with distinctly defined sequence of branches [26] and may involve collaborative learning strategies [4]. Specifically, the collaborative approach is advantageous especially when more advanced peer students explain difficult theoretical concepts or demonstrate advanced equipment configuration, troubleshooting techniques to less knowledgeable students and exploits the prevalence and power of learning by observation [24]. Thus, more advanced peers can instruct less knowledgeable peers to help reinforce important concepts resulting in better retention.

4.3 Handling wiring changes

The RSF may also make requests to the LSF regarding changes to the physical fixed cabling on the equipment in the Halifax laboratory. Wiring or cabling information at the Halifax site is communicated to the remote student using the website (as shown in Figure 3) or sometimes with streaming video. The requirement for streaming video in the remote site is minimal as the remote student requires cabling information on equipment only at the beginning of the lab and thereafter whenever a topology change is made. The decision to use streaming video stems from its media synchronicity characteristics such as conveying wiring information in an unambiguous fashion to multiple students at the remote site. In addition, the video clip can be reprocessed i.e., can be reused to verify/confirm cabling configurations at any stage in the laboratory. It is possible to use the video effectively as different groups of students require cabling information pertaining to specific racks of equipment with which they will interact.

4.4 Troubleshooting – provide guidance and feedback

Lab objectives are clearly defined in that they evaluate the student on demonstrating particular skills or knowledge of techniques [25]. The RSF identifies the stages of the lab that are likely to be most problematic to the students from an analysis of the evaluation criteria not met by most students. To remedy the situation, the RSF also provides remedial material after consultation with the LSF if the student has difficulty in meeting particular lab objectives. Such guidance may include scheduling demonstrations of proper configuration/simulation techniques using video conferencing from the Halifax site. The LSF or faculty at Halifax demonstrates troubleshooting
techniques. In addition, video conferencing easily allows the remote student to interrupt and seek clarification from the LSF or faculty at Halifax. This medium has high concurrency, moderate feedback and is suitable for conveying information unambiguously.

4.5 Verify learning outcomes – Assess performance

The RSF also helps to verify that the student has accomplished the lab outcome and corresponds with Gagne’s step (viii). In addition the RSF helps co-ordinate intra-group discussion on the results [4].

4.6 Track student progress – Enhance retention and transfer

The RSF collects student outcome measures and forwards these to the LSF for evaluation purposes. Actual student evaluation is carried out by faculty or by the LSF under guidance of the faculty. Appropriate evidence of student competency in the lab include: a) answers to questions b) appropriate response from configured equipment c) plots and printout of graphical output from simulators d) the maximum time in which the lab objective is accomplished and e) and the context in which steps a-d are accomplished [26] f) analysis and discussion of results. Teaching and assessment methods that enhance knowledge retention and transfer in students are outlined in [27]. Accordingly, faculty at the Halifax site, assess student for competency based on their a) understanding component skills and b) aggregation of component skills into comprehensive skills c) applying comprehensive skills to solve problems and d) analysis and critique of the proposed solution. On obtaining student assessment from the faculty/LSF, the RSF may generate a skill map (graphical), which outlines the competency acquired by the student and may help motivate the student to focus their learning to acquire the desired competency level.

This pilot project in remote Internetworking laboratory education will help us identify techniques that a) enhance online interaction b) minimize failure in online laboratory based learning c) relate the laboratory material to theoretical course content in the online lecture session d) build strong capabilities in troubleshooting networking equipment e) build proper data collection and result analysis techniques.

5. Remote interactive laboratory (RIL) user authentication issues

Secure communication and preventing security threats is essential to addressing the security and privacy concerns. In addition, the communication itself may be encrypted to ensure secrecy. The program has addressed the issue of a reliable authentication mechanism to verify the identity of genuine student. The program securely authenticates remote students using (userID, password) before allowing remote access to the terminal servers at Halifax. This involves the use of an access control server (e.g., Cisco’s ACS – access control server) and the user authentication architecture is shown in Figure 7. In addition, students are assured explicitly regarding the security measures such as, authentication, encryption, authorization and other measures that are in place to ensure their privacy.

6. Issues affecting remote Internetworking laboratory education

When the program expands to more remote sites, issues that the program still has to address include facilitator training. Currently, the remote and local site facilitators are former students of the program. Also, the RSF are specifically trained on techniques that emphasize how to facilitate well at the remote site for a two-week period for every course they facilitate. In addition, facilitators and faculty are trained to have an understanding of the various components of the e-learning system, their capabilities and deficiencies for a better appreciation of the role of e-learning in the program and helps achieve better employee acceptance of the new technology.

The Internetworking program will further evaluate the remote student’s online interaction with the laboratory equipment in order to ensure that it meets the unique requirements of the program. We are
confident that this pilot project will help us improve the quality of the laboratory component of the online Internetworking program by answering questions including: i) Identifying fundamental learning activities achieved in the onsite Internetworking laboratory environment that must be replicated in the online learning environment for ensuring successful laboratory learning ii) Does the online environment require the same amount of interaction as the onsite laboratory iii) What is the right amount of time required to complete an interaction with equipment? iv) How should the program handle questions regarding problems understanding the lab handout? v) How often must video conferencing be scheduled to demonstrate troubleshooting techniques and provide corrective feedback? vi) How do we train competent RSF? vii) What is a good ratio of student to RSF? viii) Will the remote student’s ability to make indirect cabling changes (if required) hamper their understanding of the laboratory? And if so, to what extent, if any.

7. Lessons learned, system limitations and directions for future research

In the early stages, much of the development of the remote interactive laboratory, has focused on understanding the system requirements and developing a viable test-bed to deliver the labs online by connecting students at remote sites to internetworking equipment at Halifax. Future research will focus on analyzing user activity, and evaluate the system with respect to usability of the system and student satisfaction with using the system. Work also needs to be done in evaluating how the facilitation process together with system use result in achieving the pedagogical goals of each course. System limitations include the fact that the current INWK laboratory can accommodate only 30 students maximum in a given time slot. Also, the program employs one remote site facilitator for each remote site. Some issues to be explored with respect to facilitation include tailoring the role of the facilitator to take into account the cultural differences between the students, the facilitators and the university. The online program also needs to model the knowledge domain into levels of expertise from novice, beginner to expert and identify the key problem solving strategies that must be imparted by the RSF and the LSF in order to ensure student transition from novice to experts in the duration of the course. The long-term goal of the program is to study the feasibility of laboratory access from the student’s home and study how the remote site facilitation process will have to be modified to accommodate a purely online facilitation scenario.

8. Conclusion

This paper described a pilot online remote interactive laboratory (RIL) environment used to deliver remote internetworking laboratory experience by allowing students at geographically remote sites to access and utilize devices including routers, switches, LAN analyzers, and simulators located at Halifax. The RIL course content, instructional design and multimedia delivery mechanism were tailored to model a synchronous, constructivist, collaborative, directed learning environment that meet the unique educational challenges of the Internetworking program. The RIL system design ensures an accessible, reliable, easy-to-use and responsive remote laboratory environment that supports multiple simultaneous real-time interactions and effective information transfer between the remote site and the equipment at the Halifax equipment facility. The RIL limits individual access to laboratory resources only to authenticated students using an access control server. The RIL uses de-facto networking standards, free software and commercial Internet browser for connecting remote students to the laboratory at Halifax. While course content, delivery style and laboratory development are the primary responsibility of the faculty member delivering the course, the online laboratory format presented here has a uniform approach to meeting instructional objectives of the Internetworking program. The RIL employs multi-media including streaming video/audio to provide unambiguous equipment cabling and wiring information to multiple concurrent users; and video-conferencing to provide remedial laboratory instruction enhancing the remote laboratory learning experience, increasing student learning and retention of Internetworking concepts. The RIL uses effective student interaction with remote equipment and simulations that employ multimedia to create an engaging environment that enhances problem-solving skills. The RIL incorporates a 4-tier role architecture consisting of faculty and local site facilitators at Halifax; remote site facilitators and remote students at the remote site whose roles/duties are very well defined that ensure the same quality of interaction with the laboratory that the current onsite program offers. The RIL role architecture design provides for continuous assessment and real-time feedback to track student performance and maintains the academic integrity of the program.

9. References