2006-1411: LESSONS LEARNED FROM THE IMPLEMENTATION OF AN INTERNETWORKING REMOTE ACCESS LABORATORY

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LESSONS LEARNED FROM THE IMPLEMENTATION OF AN INTERNETWORKING REMOTE ACCESS LABORATORY

Abstract
Improving student learning outcomes in Information Technology programs often depends upon maximizing student access to technologies. Courses dealing with internetworking technologies – routing, switching, dialup – may be constrained by the use of simulation applications and their inherent functional limitations, or by the use of live equipment on-site with its inherent high cost and limited access to students. This paper describes the implementation of a remote access internetworking laboratory designed for the purpose of improving student learning outcomes through increased access to internetworking laboratory equipment. Technical planning, design, and implementation issues are examined along with the capabilities and limitations of this implementation. Student feedback from a pilot course is presented. Advantages and disadvantages of the implementation are addressed including scheduling of classes, routine maintenance, management of network topologies, and student access.

Introduction
Because of budget constraints and the difficulty of having new degree programs approved by the state governing board, the Information Technology (IT) program began as an interdisciplinary program with support from a National Science Foundation (NSF) grant, #DUE-9950085. This funding provided the required resources to establish a four-year articulated curriculum in computer networking with state community colleges.

Although funds were available to support the program, space was very limited. A 1600 sq. ft. facility was allocated to support the program; however, the space had to be used for lectures and laboratory exercises. In the process of developing the articulated curriculum, faculty identified 23 different courses that needed access to the facility. The network topology for the facility had to be highly configurable to support multiple network configurations. Figure 1 shows the design of the facility network topology using managed switches and Inter-VLAN routing.

Background
Other constraints that impacted the program were vendor specific courses that had to be articulated. Specifically, the Cisco Networking Academy Program (CNAP) had to be articulated with eight different community colleges in the state. In addition to a four course sequence offered at the community colleges, an additional four course sequence was required because the four-year IT program included the Cisco Certified Network Professional (CCNP) program. Seven out of eight Cisco courses required use of the facility. Since Cisco content required high contact hours, a significant impact on course scheduling for the facility was created. When all courses were considered, almost no open laboratory time was available for students.
For the first two years of operation, scheduling was possible with faculty teaching both day and evening courses on a Monday - Thursday schedule. Fridays and weekends were established as open laboratory times monitored by student workers. While not the best arrangement, it did allow some student access to the facility outside of normal operating hours. Figure 2 shows the initial facility layout.

In year three, additional problems were encountered. For the first two years, only the first four CCNP courses were scheduled and allowed a four-day schedule to function. When the remaining CCNP courses were incorporated into the facility schedule, it was necessary to increase to a five-day schedule with the facility only available weekends for open laboratory periods.
University administration also required higher student credit hour (SCH) production from faculty. The result was adding 12 additional seats to all courses, and a facility redesign shown in Figure 3. Lectures classes were easy to conduct in the redesigned facility, but laboratories could not be easily implemented. After one semester of operation, university administration provided adjacent space to accommodate a 20 seat laboratory similar to the layout shown in Figure 2.

Even with additional space, scheduling problems continued. With several parameters involved in scheduling, course popularity had not been considered for the first four CCNP courses. Faculty and facility limitations allowed only one 32 seat lecture and two 16 seat laboratory sections per lecture course during normal operating hours. Additional evening sections were required to accommodate student demand for the courses, but it eliminated open laboratory times for students.

Potential Solution
To overcome the continuing problem of limited laboratory access for students, faculty recommended purchase of a Cisco NetLab Server (CNLS) and Cisco Internetworking hardware to populate all pods. Table 1 describes the equipment for all pod configurations and the associated cost. The rational being that students would have 24 hour access to equipment and facility cost would be reduced by reduction of student workers needed to monitor an open laboratory. Figure 4 shows the equipment rack for the CNLS system and infrastructure hardware.

The CNLS would allow students access to equipment for six of eight CCNP courses. The first CCNP course was not included because it did not require access to internetworking technology. The last CCNP course was not included because of a large troubleshooting component requiring hands-on hardware configuration by students.
<table>
<thead>
<tr>
<th>Quantity</th>
<th>Description</th>
<th>Equipment (n)</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Basic Router Pod</td>
<td>2801 router (3)</td>
<td>$8,085.00</td>
</tr>
<tr>
<td>2</td>
<td>Basic Switch Pod</td>
<td>2801 router (1) 2950T-24 switch (2)</td>
<td>$9,085.00</td>
</tr>
<tr>
<td>1</td>
<td>Advanced Router Pod</td>
<td>550 Adtran Atlas (1) 2801 router (1) 2811 router (2) T-1 card (1)</td>
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<td>1</td>
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<td>2801 Router (3) 2950T-24 switch (4) 3560-24 switch (1)</td>
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<td></td>
<td>Total</td>
<td></td>
<td>$58,256.00</td>
</tr>
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</table>

**Table 1 - Remote Access Server and Internetworking Hardware**

**Problems Encountered**

Once the decision was made to purchase the CNLS system, delays were encountered because of state purchasing guidelines. It resulted in the hardware not arriving until December 2004 which was just in time for spring classes. With the problems encountered in obtaining the hardware, the faculty decided to limit use of the CNLS system to one course for the spring 2005 semester. This would permit faculty time to configure the system and test the operation on a pilot class before widespread operation was implemented.

The pilot class selected was the fifth of the CCNP sequence. Fifteen students participated in the pilot class and had the option of using the CNLS system or laboratory equipment. Few restrictions were implemented in the management software since it was a small group and because the software package was new to the faculty. It was assumed that students would be ethical in using the system and since it was a small group system administration would be minimal.

All students in the pilot course used the CNLS system, but usage varied greatly from a low of 13 to a maximum of 137 sessions during the semester. Faculty learned a great deal from the pilot class. The most important lesson was to limit the number of sessions any student could reserve within a specified timeframe. When a session was reserved, no other student could access that equipment pod even if it was not in use. The result was development of strict policies for the management software of the CNLS system.

Part of the original CNLS concept was to allow students’ access to online skills finals for certain classes in the CCNP sequence. The rational behind this decision was based on
limited test times at the end of term and equipment restrictions for classes. Passing the skills final is required if a student is to advance through the CCNP course sequence. Faculty apply a three “strike” rule for all skills finals in the CCNP sequence, e.g. if the third attempt is not successful the individual fails the course.

![Figure 4 – CNLS System and Infrastructure Hardware](image)

Historically, most students pass skills finals by the third attempt; however, a significant number of students, 100%, passed the skills final on their first attempt in the pilot class, even though, five different skills finals were used. This success rate had never occurred before and resulted in a policy change for future courses using the CNLS system.

The faculty decided to phase-in the CNLS system for other CCNP classes. For the fall 2005 semester, two additional courses utilized the CNLS system. Limiting the use of the CNLS system would allow additional CNLS policies to be developed, allow all faculty time to become familiar with the management software, and evaluate the CNLS system in an accelerated scheduling format, e.g. eight week term.
The major policy change implemented regarded skills finals. Faculty decided that all students would be required to take a hands-on skills final for their first attempt. Second and third attempts could utilize the CNLS system; however, the final was required to be in-person and supervised. The CNLS system was used by students for weekly laboratory exercises and additional practice sessions. Results of the skills finals are provided in Table 2.

<table>
<thead>
<tr>
<th>CCNP class</th>
<th>n =</th>
<th>Attempt 1 (%)</th>
<th>Attempt 2 (%)</th>
<th>Attempt 3 (%)</th>
<th>Failed (%)</th>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>15</td>
<td>100</td>
<td>0</td>
<td>0</td>
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<tr>
<td>6</td>
<td>15</td>
<td>40</td>
<td>46</td>
<td>7</td>
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<td>13</td>
<td>54</td>
<td>46</td>
<td>0</td>
<td>0</td>
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</table>

Table 2 – Pilot Classes Skills Finals Results

The pilot classes were instructed by the same faculty member and most but not all students were the same group of students enrolled in each class. Because of the accelerated format for pilot classes 6 and 7 and time restrictions implemented in the management software, the usage of the CNLS system changed significantly. While the number of user accounts was about the same for the CNLS system, usage ranged from a low of 4 to a maximum of 20 sessions for a course by an individual student.

Remote Access Considerations
IT students faced continued access restrictions to networking equipment to perform laboratory exercises. To overcome these restrictions, faculty implemented a remote access server and network hardware to accommodate student access. This access did not come without limitations that other IT programs should consider before implementing this type of operation.

If an IT program does not change current laboratory sizes and schedules, a completely different set of network hardware should be used with a CNLS implementation. Once hardware is allocated to CNLS pods, it is difficult to return anything to the laboratory. It is not possible for students to have a troubleshooting exercise since all hardware in the CNLS system is pre-wired and cannot be accessed by students. Topology limits the type of exercises that can be conducted, and for advanced CCNP courses student access is limited to one per session.

Student Feedback
Students that completed the three course pilot sequence were asked to evaluate their experience with the remote access server when compared to traditional laboratories. Because of the small sample size, questions were limited to a small number that could be used to improve the learning experience for other students. Each survey question was explained to the students to eliminate confusion and allow students to provide an honest evaluation of their experience. For the convenience response, students were asked to rate the user interface and their ability to access the remote server at any time. Equipment access was related to their ability to schedule an equipment pod(s) needed for a laboratory exercise. The next question was directed toward the student reservation
system, e.g. ability to reserve desired time(s) and length of a session. Laboratory practice requested student feedback on the ability to repeat a laboratory exercise. Location requested feedback on where remote lab sessions were conducted. Remote assistance asked for feedback if assistance was needed during a remote lab session. Responses to the survey are located in Table 3.

<table>
<thead>
<tr>
<th>Comment</th>
<th>Strongly Agree (%)</th>
<th>Agree (%)</th>
<th>Neutral (%)</th>
<th>Disagree (%)</th>
<th>Strongly Disagree (%)</th>
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</thead>
<tbody>
<tr>
<td>Convenience</td>
<td>77</td>
<td>15</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Equipment Access</td>
<td>62</td>
<td>30</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Reservation System</td>
<td>62</td>
<td>30</td>
<td>8</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Laboratory Practice</td>
<td>46</td>
<td>54</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Location</td>
<td>77</td>
<td>23</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Remote Assistance</td>
<td>30</td>
<td>8</td>
<td>62</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 3 - Student Satisfaction to Pilot Courses

Students were asked to make additional comments in support of the six survey questions. The majority of students liked the ability of flexible laboratory times because of work schedules, family constraints, and reduced commuting. Students liked the ability to reserve certain equipment for a certain time. Many times students arrived at an open laboratory only to find needed equipment already in use by another student. Several students liked the ability to work from their home or other quite location. Quicker setup time for labs was also noted. While this allowed students more time to correct errors in programming their network hardware, they did not obtain any experience in connecting network devices. Feedback on length of remote sessions allowed the management software to be “tuned.” In the initial deployment, all laboratory sessions were allowed equal times for sessions and available for the same number of days. From the student feedback, adjustments were made to accommodate more users in a given time period.

Future Developments and Comments

This paper describes the implementation of a CNLS system to allow 24 hour laboratory access to students in a Cisco CCNP curriculum. IT programs that are associated with the Cisco Networking Academy Program may want to consider this type of implementation if student laboratory access is a recurring problem or if a larger number of students are commuters. Overall, student feedback was very positive. More importantly, the number of student complaints related to laboratory access was reduced to zero.

If an institution considers, any type of distance learning extension, student ethics cannot be overlooked. A system of checks & balances should be incorporated to insure that students are actually performing assignments.

As seen in Table 1, significant resources are required to implement this type of remote access and may not be feasible for small IT programs. In addition to the acquisition cost
found in Table 1, a recurring cost of $4,509 is required as a maintenance contract for the CNLS system. While not the most inexpensive solution, it does provide replacement equipment, management of all equipment pods, management of student appointments, and backups of all student sessions with minimal system administration. Other alternatives would be to allow access to the CNLS system at sister CNAP institutions for a nominal fee and would reduce the recurring maintenance cost to the host institution.

In the review of literature for this paper, several in-house solutions were presented by authors from different IT programs. All solutions reviewed required development of custom software and recurring maintenance of the software by faculty. This was not feasible for the IT program discussed since faculty are teaching full loads, technical support is not available, and vendor specific hardware is required.

The next phase of the CNLS system will involve deployment to all courses in the CCNP sequence. The lessons learned during the first year of operation should reduce problems normally encountered with any large scale laboratory implementation. Presently, the IT program is restricted to the main campus of a multi-campus system. Use of this technology could allow development of off-campus offerings at significantly reduced cost. However, the hands-on nature of the IT curriculum cannot be overlooked when considering any distance learning implementation.

References


