

What Differences Does a Lab Make in Teaching TCP/IP

Chad Zeman
Student
zema0016@mrs.umn.edu

Rod Kohout
Student
rdkohout@willmar.com

A.A. Lopez
Professor of Computer Science
alopez@mrs.umn.edu

Doug Moll
Student
moll0058@mrs.umn.edu

University of Minnesota, Morris

Abstract

In this paper we contrast two offerings of a TCP/IP course. The first offering had two hands-on exercises while the second offering had eight laboratory exercises. The evidence seems to indicate that the students learned more and enjoyed the course more when they had more hands-on exercises. These laboratory exercises used computers that had been removed from service in our software design laboratory, thus they were very economical for our purpose.

Introduction

This paper discusses the advantages and disadvantages of hands-on experience in a network course such as Transport Control Protocol/ Internet Protocol (TCP/IP). The main concerns of our study are: the amount of material learned by the students, how well the material is retained, how pleasant the learning experience was for the students and faculty member, the amount of equipment and (extra) time required to support a laboratory centered class.

In this paper we will discuss two different offerings of the same course with substantially different laboratory requirements. The two offerings are also separated by a two and a half year gap. The first offering took place during the Spring semester in 2000 and the second offering was during the Fall 2002 term.

The change in emphasis came about because additional laboratory space and equipment became available for the second offering and the instructor wished to address some of the criticisms and concerns of our first offering. The second offering of the course allowed for the additional hands-on exercises that were requested in the course evaluations the first time through.

Spring 2000 Offering

The first offering of the TCP/IP course came about as we revised our computer science curriculum and switched to semesters. The TCP/IP course is a 2 semester-credit elective course in our 'systems' area. The course met for about 50 minutes twice a week. Our 2-credit electives are considered 'seminar' type classes in that the students are supposed to contribute as much to the learning experience as the instructor. In other words, the instructor may not have all the answers, but s/he is willing to work with the class to reach an ultimate learning objective. In these courses some of the students volunteer to give lectures and demonstrations, but other students have a difficult time handling this learning mode.

For the spring 2000 semester, many of the students were in need of a 'systems' elective, therefore we were able to enroll 42 students. One of the students was employed full time at a location 90 miles away from the campus while she took the course. She came to the campus for one of the two weekly lectures and attended the other weekly lecture via H.323 interactive video services over the Internet from her place of work [3].

The textbook for the course was Computer Networks and Internets by Comer [1] The prerequisite for this course was our core systems course titled Models of Computing Systems [4]. On the basis of this prerequisite, the first 13 chapters of the book were not covered. We covered most of the remaining twenty plus chapters. The students expressed concerns that the course tried to cover too much material.

The course was offered in a traditional lecture, exams and paper homework mode with a couple of laboratory assignments. Because we did not have dedicated laboratory facilities to support this course, we had to use students' computers or public lab computers. One of the easiest exercises was to sniff the network and have the students observe the network traffic. The instructor requested permission from our Computing Services to sniff the network as an exercise. The students promptly discovered that there were many vulnerabilities on the campus network. These vulnerabilities were reported to Computing Services. They promptly corrected most of these problems and the network suddenly became less interesting. The major discovery was that while the campus had deployed nice Ethernet switches throughout the campus, several of them had been configured as hubs.

The second exercise was to gather some Simple Network Management Protocol (SNMP) data. The students were given an extensive list of freeware SNMP packages and were asked to download one for testing purposes. The students had difficulties choosing and installing a suitable package. The reality of the situation is that graduates will often be asked to download and evaluate software packages. At that time, many of the campus devices did not have SNMP turned on and that made the testing even more difficult. The students were dealing with two unknowns, the SNMP software and the SNMP data coming from the devices being monitored. So this exercise frustrated a number of students.

Fall 2002 offering

The second offering of this course was similarly structured to the first. Like in the Spring, this 'systems' class met for 50 minutes on Tuesdays and Thursdays for the duration of the semester. As before, it was a 2-credit offering with a seminar style approach guiding lectures and pace. However, instead of the 42 people registered in 2000, there were only 18 in 2002. This was thought to be due to stabilization in the major's requirements over the time between offerings and the fact that another 'systems' elective was also offered the same semester. A new textbook, again written by Comer, entitled Internetworking with TCP/IP [2] was used because it was slightly newer than the old book.

The greatest differences in the Fall 2002 section from the offering in the Spring 2000 were: 1) the addition of lab work instead of the traditional paper and pencil homework, 2) the breaking up of the class in groups of three students each and 3) the systematic rotation of students in and out the groups to force them to better document their work. To solve the problem of not being able to physically work on the campus network due to security issues, a separate Local Area Network (LAN) was set up using six aging desktop computers, a Cisco 2914 switch, and a hub.

The first of eight labs consisted of the physical connection of the six computers to the switch and the installation of Red Hat 7.3. This was a new experience for many students.

Each of the six groups of three students assigned a unique Internet Protocol (IP) address and a machine name to their desktop. Minimal network tests such as pinging other computers were performed to verify that the network was correctly configured.

The second lab involved investigating the Address Resolution Protocol (ARP) tables. Students were instructed to report their results from both their home computer and computers in the lab. Many students were not familiar with these programs. The lab instructed students to use manual (man) pages for the usage details of this tool. This was many students' first introduction to locating and utilizing man and help pages. This assignment also included investigating the Reverse Address Resolution Protocol (RARP). Students found much frustration for this part of the assignment since this tool was not installed on the clients that were accessible.

The third lab focused on telnet and the Internet Gateway Protocol (IGP). The students installed and configured the telnet daemon on each of the machines to accept telnet sessions from the other computers. A new "guest" account was set up by each group to allow limited access connections. Each group was also to determine which IGP protocol was installed and running on their particular machine.

For the fourth lab, the groups were rearranged to explore the ping command and its options. One of the specific options that was investigated was the -p or pattern flag that is useful for identifying data corruption problems. Ping was also used in conjunction with tcpdump to search for Internet Control Message Protocol (ICMP) source quench packets. Lastly in this lab, groups were assigned a unique Request For Comment (RFC) document related to routing protocols to become familiar with and summarize. This was many students' first experience locating and interpreting RFCs.

The fifth lab examined the Simple Network Management Protocol (SNMP) v2 Management Information Base (MIB) that Red Hat implements. This was done by setting a few strings to configure and start the snmpd daemon. Students were then allowed to choose the tool of their choice to view and set the MIB variables. This same activity was then performed on the Cisco 2914 switch that connected our simple 6-computer network. An agreement was also worked out with the campus' Computing Services to allow the class to view the MIB tree of the router connecting the computer science lab to the Residential Network (ResNet). Students were instructed to use snmp_request and report their observations.

The sixth lab involved creating a more versatile network through the use of Dynamic Host Resolution Protocol (DHCP) and Domain Name Servers (DNS). Two separate networks were set up to each have one DHCP server, one DNS server, and one client. One group was responsible for each of the machines to ensure that each component worked correctly. The DNS was set up to resolve two hostnames in the form of groupx.com and groupx.net. The DHCP server was set up with 20 addresses available for dynamic distribution. The client group was responsible for ensuring that both of these services were correctly set up.

The seventh lab focused on the installation of mail and file transfer protocols. Simple Mail Transfer Protocol (SMTP), Post Office Protocol 3 (POP3), and Internet Message Access Protocol (IMAP) were the mail protocols selected for implementation. SMTP was set up using the sendmail program packaged with Red Hat. POP3 and IMAP were set up by installing and configuring their respective daemons in the Inetd folder and starting their services. File Transfer Protocol (FTP) and Trivial File Transfer Protocol (TFTP) were the two protocols installed for the other half of this lab. The set up for this portion was similar to implementing POP3 and IMAP, however, additional infrastructure, like folders with adjusted access permissions, was required. Each protocol was then tested from other machines to verify functionality.

The final lab involved the installation of a HyperText Transfer Protocol (HTTP) server. Apache was the recommended web server, however the choice was left up to each group. They then needed to set up two domain names in the form of `www.groupx.com` and `www.groupx.net` as well as local web spaces for each account on the machine. The goal of this lab was not to generate fancy web pages, but rather to have an in depth understanding on how domain names and web services function.

Student reactions and evaluations

After receiving feedback from several students from the Fall 2002 TCP/IP class, the authors felt that the amount of material that was learned and actually retained by the students was above average.

Many of the students felt that they could competently set up a network running TCP/IP even several months after taking the class. They were also able to recall many different acronyms used for protocols in TCP/IP and briefly describe how they work. The consensus of the students was that this was a direct result of the labs. They felt that the actual hands on experience gave them greater depth in the understanding and practical application of the material that was covered in the classroom.

The students also expressed that the extra amount of lab work that was required outside of the normal scheduled time for class was a bit overwhelming. 'Too much work outside of class for 2 credits' commented a student. Many students felt this was due to limited structure in the lab assignments. Tasks that were to be done in the labs were often vague and could have been expanded upon. 'A little more detailed instructions on assignments' commented another student.

Several students had a lack of experience in setting up networking protocols in a Linux environment. For some, this meant turning to online documentation and filtering through mass amounts of information to find appropriate answers. Less time would have been spent if more focused direction was given.

On the other hand, the students now know where to go for help if they do not know how to set something up. They will be able to solve networking problems, as well as, configure TCP/IP protocols. Through this process the students should have learned to recognize the quality of the information that they are examining when addressing a problem. For example, the information in many 'man' pages and web pages is quite out of date or inappropriate for some tasks.

The size of the groups for the labs were received well by both the students and the instructor. It was required that each student hand in a paper on their individual experience for each lab. This enforced activity and participation of all the group members. In doing this, it also helped the students learn from each other. If one of the students was lacking in knowledge in some area, many times another student in the group knew something about it and shared their knowledge with the group.

A total of three group arrangements were used. This gave the students an opportunity to interact with other students in the class. This was frustrating to some students as they had to switch to a machine that may have been set up differently. However, this reinforced the knowledge that they had because they had to verify that the machine they moved to was properly configured.

The authors felt that had the labs not been a part of the class, the amount of time spend on the material covered in the classroom would have been less meaningful. If the material was presented solely through lectures and readings, many of the students wouldn't have taken the time to immerse themselves in the subject matter that they didn't understand well. Having the labs forced them to take the time to have a better understanding of the material and thus also helped them to retain the information covered.

Faculty perceptions

Teaching a course like this with 8 or more laboratory exercises and trying to cover most of the protocols under TCP/IP in a 2-credit course is taxing. This is made possible only by excellent and dedicated students (such as my co-authors) that are willing to find me at all hours of the day and night to point out flaws in the lab instructions, hardware and software.

For the instructor the biggest challenges are:

- 1) to have well written and researched laboratory experiments for our students. The commercially available lab manuals that I have evaluated are too simplistic for our course.
- 2) convincing the students that a certain amount of uncertainty in these laboratory exercises is a good thing. My experience is that in the real world there is no such thing as well defined problem. The more that you look into a problem the more that the situation will change.
- 3) getting the students to research solutions to problems on their own. Students need to

learn that the computing world is one of continuing change and they need to learn to learn on their own. Upon graduation they will only know a very small fraction of what they will need for the rest of their career.

- 4) teaching students how to manage their frustration when things are not going well for them in the laboratory.

Adding the laboratory component to the course was relatively inexpensive. The initial hurdle had been to secure laboratory space. With the advent of a newly remodeled Science building, space became less of an issue. Our class took over the back third of one of our two computer science laboratories. We were able to reuse computers that had been replaced in our software design lab, an existing Cisco switch and a hub.

The instructor agrees with the student's comments that the laboratory exercises need to have more structure to them and that the instructor has to reduce the material that is covered in this 2-credit course.

Conclusions

The most recent offering of the course received higher student evaluations than the earlier version of the course. However, on the critical question of 'how much you learned in this course', both offerings got the exact same value 5.1 in our scale of 1 to 7.

There were a number of differences between the two offerings. The first offering had a larger enrollment (42 vs. 18) and proportionally more women (19% vs. 5%). The second offering had more access to laboratory facilities and performed several hands-on labs. These students received better grades (61% vs. 38% A's, 39% vs. 21% B's).

Having students figure out how to configure computers and protocols with minimal instructions has its benefits and its drawbacks. On the plus side the student will gain confidence that s/he can tackle any problem. On the other hand, it provides for a high level of frustration on the part of some students.

The faculty member's informal observation of students in the Fall 2002 offering indicates that the students retain the material better and enjoy the course more when several hands-on laboratories are included. But laboratory type experiences are more time consuming for both the instructor and students.

Adding laboratory experiences to this course does not need to be expensive. We were able to reuse computers for very meaningful network exercises that have benefited our students immensely.

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