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Abstract

Teaching Information and Communications Technology (ICT) to Information Systems (IS) students has too often drawn its pedagogy from Computer Science Education. This paper illustrates by way of a case study a set of very successful techniques and a philosophy of, perhaps, an IS pedagogy. We show that it is possible to expose IS students to some quite rigorous educational experiences that are particularly well suited in preparing them for their future employment and their careers as IS professionals. This paper discusses the use of portable and removable hard disks as "virtual computers" and "virtual servers", as an aide in the pursuit of providing practice of the ICT theory.

Keywords

IS pedagogy; virtual servers; virtual computers; portable hard disks; removable hard disks; protected laboratories; system administration; networking; information systems

INTRODUCTION

To quote Sun Microsystems' slogan: "Everyone and everything connected to the network" (Sun, 2005). Most computers today are connected to the internet and corporate information systems are built on servers, use databases and rely on networks. An understanding of fundamental information communication technologies (ICT) such as operating systems, networks and databases is essential to Information Systems professionals and students.

Adams (1993) quotes an old Chinese proverb,

> *I hear and I forget.*
>
> *I see and I remember.*
>
> *I do and I understand.*

The primary goal of undergraduate education is to teach students the underlying concepts and theories of the discipline. Just as important, however, is to prepare students with the skills and knowledge they need to gain employment in industry. "One factor that often seems to be lost in the process of designing IS curricula is that success for the graduate begins with being hired." (Crockett et al., 1993). The field of information systems itself is one of applying information theories and technology to solve practical business problems - a combination of theory and practice. Shackelford et al (2005) go on to describe IS graduates as needing the ability to "Define, design and implement" information systems. This includes coverage of components such as the desired operating systems, networks, database management systems and so forth.

Our goal, then, is to discuss what we have found to be a most effective and useful way of achieving these goals - define, design and implement.

Given the important role that IS professionals play in business, the researchers feel that this work is important in equipping IS students with invaluable skills that will serve them well, firstly in their early careers, then later on as they rise in the management ranks.

BACKGROUND

When it comes to teaching ICT topics such as operating systems and networks to Information Systems students, deciding what practical tasks to give the students can be difficult. Theoretically any task that expands on theories taught is useful, but consideration must be given to what skills the students already have and also what skills are likely to be useful to them when they graduate.

Most of the literature on this topic relates to computer science students and usually involves programming at a system level. Some researchers describe getting students to build operating systems from scratch (Reek, 1990), alter existing operating systems (Claypool et al., 2001, Perez-Davila, 1995, Shub, 1990) or alter educational operating systems (Tanenbaum, 1987, Comer and Fossum, 1988). Others describe getting students to write various system level programs (eg: process monitoring, producer-consumer problem) (Ramakrishnan and Lancaster, 1993). Withers (1992) even describes attempting all of the above in a course.

These approaches are not suited to information systems students, however. IS students usually do not possess the requisite low level programming skills (eg: knowledge of C or C++). More importantly, very few IS graduates would seek employment in roles where they would be altering core elements of an operating system or writing network packet drivers.

We believe that the appropriate approach for IS students is to give them experience as users and managers of operating systems and networks, rather than as builders of such. The skills IS students need are more aligned to the skills of system and network designers and administrators than those of system programmers.

This is easier said than done. The idea of giving students total administrative control of a university server or network to experiment with would horrify any technical support person. There have been a number of recent reports describing attempts at solving this problem. Corbesero (2003) reports using dedicated, on campus computers for this purpose. This approach works with small student numbers but when the students number in the hundreds it is not possible to provide each with a machine. Davoli (2004) describes teaching system administration using User Mode Linux which is a virtual machine approach, however it provides a limited operating system environment. Adams (2000) describes installing a cut down version of Linux on zip disks. This also works, but is limited to the capacity of the disk (100Mb) so a full size commercial operating system cannot be used.

The rest of this paper describes the approach that we have successfully been using since 1995. It is presented as a case study, describing our experiences and the challenges we have faced. We hope to encourage others that such an approach is possible and viable. Although some investment of time and money is required, we believe the outcome for the students is well worth the effort.

MANY STUDENTS ON ONE SERVER, OR ONE SERVER PER STUDENT?

Universities have never had the ability to provide each student their own personal equipment, like say a server. It is, however, interesting that what makes a server a “server” is that the machine boots and loads a given operating system and applications. A given machine might have the ability to dual or even multi-boot, allowing a variety of operating systems and applications to be loaded at boot time.

So the real key here was to understand that a “server” is actually those parts of the computer that define what the booted computer will do. And that is essentially the operating system and any applications that need to be loaded and run after that operating system has loaded. These components can be all contained on a single hard disk. If the computer had a removable hard disk that could be moved from one machine to another, then you effectively have a portable server. The only other aspect of note is the ability to leave the computer that is hosting these moving hard disks, intact. This means that we need the ability to dual or multi-boot the “server”.

For the past 10 years, students doing any one of four different courses related to operating systems, networks and databases have been using a special lab for all their practical work. At the start of semester, each student is issued with their own ‘disk unit’ or portable storage device. In the special lab, the disk unit plugs into a compatible drive bay on the PC and becomes just another hard disk. Depending on the course being taken, the student may install, onto their disk, a copy of Linux, Windows Server, Novell Netware or Oracle (on either a host Linux or Windows server).

The student keeps the disk unit for the entire semester and it becomes their own ‘server’. They bring their disk to each weekly tutorial class. They turn the computer off, insert their disk and then reboot with a floppy boot disk. The PC then becomes a server, running off the student’s disk. All class work done by students and all changes made are done to their server only. These changes are cumulative and reflect the student’s semester work effort. The laboratory PC itself remains unchanged and can still be used as a normal PC when the disk unit is removed.

This case study reports on the success story in an Australian University Information Systems department embedded in the University's Business Faculty. The IS undergraduate student count at early second year varies between 100 and 200 (a peak year).

A Brief History

Like many other initiatives, it took a disaster to prompt us to go down this path. In 1995 an attempt was made to give students an educational experience with Novell Netware. Students installed Novell servers on normal lab PCs. Chaos resulted in two specific areas. Firstly, as students returned after periods of time to their allocated computers in the labs, it quickly became apparent that their work (installation of Novell, and various configurations) was readily compromised by students who "had no idea" of what was going on. Many of these "servers' were regularly damaged or even fully rebuilt by technical staff. Secondly, Novell Netware is very "conscious" of servers on its physical network and havoc was wreaked with the university's primary Novell servers.

In 1996 we discovered removable hard disk technology (IDE caddy and frame) and found cheap 300mb laptop (2½") hard disks. University management were convinced to allow us one lab of 24 workstations dedicated for teaching operating systems and networking (the prior unfortunate Novell experience may have swayed them). The lab was set up with the caddies and a local network that was isolated from the rest of the university. This isolation was effected by introducing a NAT[1] Router and allocating private[2] IP address within this lab. We are eternally grateful to our very smart technical guru who went by the pseudonym of "Zen". Both Novell and Linux were taught using the same platform.

1997 saw the introduction of two more courses to the lab – one teaching Windows NT and another based on Database administration using SQL Server (later to change to Oracle). In the case of the Windows NT course, it was created due to demand from students that enjoyed the experience with Linux and wanted more. We purchased more hard disks (500mb) to cater for the increased student numbers.

In 1999 the disks were becoming too small for newer versions of the operating systems, so we purchased a number of 2Gb drives. These were full size (3½") drives to try to keep the cost down. They worked well initially but soon started developing errors and failing. We concluded that standard hard disks were not built to be thrown in and out of school bags and occasionally used as weapons by exuberant students.

We changed to Castlewood ORB technology in mid 2000. ORB disks promised to be similar to ZIP disks but could store 2Gb on each disk, were as fast as hard disks and much cheaper. The ORB disks did indeed prove to be all these things, when they worked. After a short while, there were a high number of errors occurring on the ORB disks and with the ORB drives. We were unable to determine the cause of these high error rates.

In 2002 we discarded the ORB technology and went back to the caddy platform. We purchased a large number of 10Gb (2½") laptop hard disks, having learnt from our previous mistakes. These disks are still serving us well to this day.

COURSES TAUGHT / TYPES OF BUSINESS PROBLEMS ADDRESSED

Currently, four different courses have adopted the use of portable storage devices to enhance their practical components. All the courses are part of an information systems undergraduate degree – one is compulsory for all students and the others are electives. The use of portable storage devices has allowed the students to gain an increased understanding of the concepts being taught, therefore enhancing the pedagogy of these courses.

The following discussion will focus on the aspects of each course that used the portable storage devices and what information systems components that are investigated by students during a semester made up of 13 weeks. Each of the courses described below have practical assessment tasks, evaluated using a face-to-face demonstration by the student to their tutor. The face to face demonstrations enable questioning and evaluation of student knowledge and enables tutors to provide instant feedback and rectification of any misunderstandings the student may have with the material. This manner of student evaluation, although quite time consuming, appears to also have the effect of deterring simple plagiarism. Although having said that it acts as a deterrent, plagiarism can never be totally eliminated.

[1] NAT: Network Address Translation Router. This is a normal router that does network address translation – translates a single normal IP address into a private IP address range. This router allows traffic out of the lab and prevents incoming traffic unless configured to do so.
[2] Private IP addresses are non-routable addresses. We used a class "C" address range – 192.168.x.x.

Novell Netware course

This was the first course developed to use the idea of giving students "real world experience". After the first false start in 1995 we deployed the portable hard disks in the isolated private IP laboratory and asked students to install the operating system, create users and demonstrate their use of the security mechanisms available under this network operating system. Students also delved into the complexities of NDS partitions, replication, Novell GroupWise, and the use of the management tool kits available.

The Novell Corporation were extremely supportive of our venture and supplied the software we needed. Our relationship with the company is still quite productive.

This elective[3] course proved very popular with students, many of them taking their work integrated learning year[4] as trainee network administrators within small to very large organisations.

Over the years we have been able to "keep up" with the various releases and patches for Novell Netware and have introduced students to the wonders of bug fixes and patches.

The value proposition in the use of the Novell Netware environment is that students can actually experience a genuine network operating system that is a viable alternative in business to providing key communication services, such as file and print sharing.

Linux and network course

This core[5] course provides students with concepts and practical knowledge of one of the key components of an information system, i.e. communication services. In order to provide the practice, an open source network operating system was used with the portable storage devices.

We started using Slackware Linux in 1996 as our preferred distribution because of the availability of a reasonable text with software included. Subsequently we moved across to the Red Hat distribution and are currently using the Red Hat Fedora Core 4 release.

The students start the course by investigating the configuration of the laboratory environment they will be working in, the portable devices being used, the setup of the routers, and the location of the resources required for the semester. The assessment criterion is discussed, focusing on the bi-weekly evaluation of the server setup of each student in relation to the practical exercises performed in the tutorials.

The portable storage devices are provided to the students in week 3 of the semester. At this time the students are required to partition the disk and install the Linux open source operating system.

The initial concepts covered with the installed operating system is the creation of user accounts, with discussion on the various aspects of a user account, such as the home directory, template used, expiry date and passwords.

The security permissions of files are discussed and implemented, from a Linux perspective. This includes the type of permissions, eg. rwx – read, write, and execute and scope of permissions, eg. owner, group and other. The setting up of groups is covered, with discussion on advantages of providing permissions based on groups rather than individual user accounts.

Students manually configure the network settings of their server with a fixed (private) IP address they are given, and also a couple of predetermined domain names using the local hosts file.. All students are within the same subnet (usually 192.168.8.x is used). They perform networking exercises involving accessing each other's server via telnet and ftp.

The mail server is configured to receive and send mail on the domain name provided to each student. IMAP and POP3 services are setup to allow clients to check mail on the student's server. File sharing is also configured, including a windows file share server (samba), NET BIOS, and the Linux file share service, NFS. Students test their file servers using both windows clients and other Linux computers.

They also configure a Web Server using the Apache web service. Virtual hosting is configured to allow the server to handle multiple domain names and websites on the single server, as done on commercial web servers. The web pages created include static and dynamic pages. The dynamic pages are generated using Perl scripts, using a back end database (PostgreSQL) to access data from a set of tables. The students need to configure and

[3] An elective course is a non-compulsory course designed to allow individual students to specialise or follow a chosen educational path.
[4] Our Information Systems undergraduate degree requires students to undertake a 12 month work integrated learning experience in industry. Our School assists in identifying suitable jobs, handles the placement of students, then engages in a supportive mentoring and ongoing contact with placements.
[5] A core course is compulsory for all undergraduate degree IS students.

start the database service and then create and execute SQL statements to create the database objects, i.e. tables and data. CGI[6] is extensively used.

Each of the above activities is performed individually by each student, on their own portable storage device, and every second week of the semester an evaluation, by the tutor, of successful completion of activities is done. Students need to perform commands and answer questions about the activity being evaluated. Students usually test each task performed each week from other student's servers or a second computer (if available) that has a Windows operating system on the internal hard drive (rather than boot the portable storage device).

The final assessment task requires a business server to be setup and configured which builds on all activities performed during the semester, in each tutorial, based on a business problem specification. Their final presentation is in effect a complete business server – configured with user accounts, security permissions, and network settings, running as a file server, web server and mail server.

In conclusion, students can find the work load heavy, with each of the week to week laboratory tutorials (2 hours) covering and performing the various business communication services. The students need to spend considerable time outside tutorial times to complete or revise the material. The practical material may be redone by students multiple times in order to get it working or reinforce how it was done. The theoretical content (lectures) is also intense, with a two hour lecture each week.

The value proposition in selecting Linux as the vehicle for a core course in the curriculum is manifold. Firstly, all students essentially start from the same base line – having little or no exposure to Linux. The second value issue is that they receive a very good grounding in an environment that offers an alternative to the traditional Microsoft Windows and Novell NetWare. Students are also made aware of the variety of systems administration tools available under Linux, including the "Webmin" product. They are helped to discover the vast array of available Open Source applications such as Open Office.

Because of the ease with which Linux can (now) be variously configured, students acquire deep knowledge of how IP ports operate, user accounts, security and the delights of encountering "kernel panics".

Windows Server course

This elective course provides some more advanced networking issues not covered in the core Linux course. This provides students interested in expanding their knowledge of networking concepts an opportunity to continue to do so using the same pedagogy as in the previous courses. The good experiences during the preliminary course usually lead to a large number of students choosing this elective.

This course was first introduced because of student demand for a mainstream networking environment that Microsoft Windows NT Server represented. The Microsoft Corporation was extremely helpful with software licences and we were able to successfully use the "time bombed" versions over the period of a semester. We are currently using Microsoft Windows Server 2003 as the platform for this course.

Students perform the same basic network operations as in Linux and Novell, creating users, groups, setting up file security, creating web servers, and dealing with email (Microsoft Exchange Server).

Advance networking services are configured, such as DHCP, DNS, and WINS. Active directory services are enabled. Server performance monitoring and network bandwidth monitoring are performed. In addition, this course also allows students the opportunity to investigate "packet sniffing" using the tools available.

Of interest in this course is that students are encouraged to spend time on the Microsoft web site investigating its knowledge base and reading up on recent vulnerabilities and their mitigation.

The value proposition of this course is that it effectively completes a very comprehensive exposure of students to three different operating systems and their respective ways of connecting and dealing with users.

Numerous students have since moved on to take up roles as network administrators as their early career choices.

Advanced Database course

This course is divided into roughly two equal parts. The first part involves a complete coverage of SQL, including PL/SQL, stored procedures and triggers. The practical work for this part is performed by the students on a shared oracle server. The second part focuses on database administration. It is the second part that makes use of the networking lab and the portable storage devices.

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[6] CGI. Common Gateway Interface is a standard way of transferring data between a client web browser and a web server. It illustrates a contemporary way of interacting with a remote database or Information System.

The students are provided with a portable disk with an operating system pre-installed. We have used both Windows server and Linux over the years. The students are then required to install Oracle, after having planned the storage requirements of the DBMS.

The students, with full administrator access to the server and database management system, can now perform database administrator activities. This begins with creating database users and setting permissions to database objects using roles. They go on to configure networking settings so their database servers can connect to each other, and then use this to set up replication between their servers. They also perform backups and restores, using simulated crashes. The students would never be given permission to do this on centrally run database servers.

Other advanced database programming is performed through constraints, referential constraints, triggers and stored procedures. An appropriate case study is used to enable a highly complex set of business rules to be implemented. They also examine performance issues with the database management system configuration and query execution.

The students work in groups of two for the last half of the semester. This allows them to have two servers where they can implement some of the distributed database concepts discussed in lectures. This involves performance of additional modelling exercises to make due consideration for the distributed environment. The students then set up appropriate replication between their databases.

The students perform some web programming by creating static web pages which are updated by triggers when data changes. The case study also requires them to create some code that performs some sort of process. For example, one year the students had a company's share registry management system to develop. One aspect of the case study required details of a company announcement to be transmitted to clients based on the advice provided by clients. This transmission included email, SMS, letter and/or fax. The email was done through the email server installed on the portable storage device, the fax was stored in a text file, the SMS was put into another text file, and the letter details was put into a CSV[7] file to be used with a mail merge document. The announcement was also placed on the company website via the creation of a static webpage and the updating of the index page to reference this new announcement page.

The final assignment resulted in a business case study with various requirements, including complex business rules, distributed database environment, emailing, processes and web site. The solving of this business case was done on two separate servers connected over a network utilising the database management system.

The value proposition of this course is that it allows practice and demonstration of database topics that could only be otherwise discussed theoretically: remote database connections, replication and backup/recovery. Numerous students have since moved on to take up roles as database administrators (DBA) as their early career choices.

SETTING UP THE SPECIALISED LABORATORY

Our University (RMIT) has allowed a single laboratory to be setup without their secure Standard Operating Environment (SOE) being installed. This allows each workstation to be a free standing independent machine with students logging in as administrative users. This would normally send a chill through IT support people but surprisingly, the sort of events that most would dread are very rare indeed. Students are cautioned about altering the desktop to suit their personal tastes; do not change the language from English, and resist the urge to anonymously connect to their favourite web sites.

We use Ghost to maintain the images in the lab and are able to resurrect a compromised machine in 15 minutes. The whole lab is "ghosted" once a week. The image is "ghosted" more regularly during the week when the portable storage devices are partitioned and formatted. Accidents do happen, but this is part of the learning experience.

The lab has all UTP wiring exposed and terminated in a Krone distribution panel. Students use a fly lead to connect their workstation to one of two switch banks. One accesses the internal Windows and Linux network and the University network (and consequently the Internet) and the other accessing an internal closed Novell Netware specific environment. In the ten years of operating in such an open manner we have not once been compromised by any significant vandalism or major theft.

The computer hardware provided in this lab by the university is updated every three years. The other aspect to the hardware that contributes to the success of the portable storage device server arrangement is that they are of

[7] CSV. Comma Separated Variable file. This is a file standard that allows delimited data to be stored in a standard text file and accessed and manipulated by spreadsheets and word processors.

the same configuration. This reduces the frustration of the portable server detecting changes in hardware each time it is booted.

The laboratory gateway is controlled by a Microsoft ISA server (proxy engine, firewall etc) that acts as a NAT router and distributes private (192.168.1.x) addresses as a DHCP server. The ISA server is useful in making sure that students do not become too enthusiastic about their access to such a fast pipe onto the Internet (Kazaa, eDonkey, bittorrent etc). The Novell Netware network has no access outside of the laboratory so that it is possible to run numerous NDS networks without the broadcasts spreading throughout the University. We have successfully managed to run 25 Microsoft Windows Server 2003 Active Directory servers without difficulty and without enraging our local network administrators. This is a very satisfactory outcome, especially when considering that students are required to setup their own DHCP servers and verify their effectiveness.

We are a bit lucky in one sense that our Department has several academics that are technically able enough to have designed and helped set up all of this. It would be a challenge to those Universities where the academics are not so technically proficient. In those cases it will be critical to have on side a technical guru who can understand and deploy this style of infrastructure. We have found that maintaining close relationships with technical staff to be a critical success factor in our endeavours.

MANAGING THE SOFTWARE

Both Microsoft and Novell Netware software is available in "time-bombed" versions that expire in 180 days. Some texts come with the software on CDROM in the inside cover. Both companies have been extremely supportive of our endeavours and have always been forthcoming with arrangements to use their software.

The use of Oracle and Linux is even simpler with both available on the Internet as free downloads as well as some availability in text books.

We store the main software images on a separate partition on the workstation so that in the event of a student forgetting their books or CDs the software is there.

The researchers have found a very unpleasant trap in all this. Even though all the software we use is thoroughly tested (sic), we always come up against undocumented features and special bugs designed to destroy everything we touch. These only surface when in the laboratory and never on our own office or home desktops. Thus we try to make sure that everything works like in previous semesters, in the lab. All assignments and laboratory tasks are verified by either the academic concerned or (if lucky) by a volunteer student.

When a student destroys their server they enjoy the experience of a complete re-installation from scratch, including the ghosting of the lab image. Lectures on backups always draw sighs of relief as they realise that a good backup strategy can save hours of time rebuilding damaged machines. In addition, having such a safe laboratory environment allows detailed and repeatable examination of such phenomena as "Blue Screens of Death", "Kernel Panics", frozen screens, non responsive mice and the ever present "I didn't do nothing – it just went like that, honest!".

We are finding that software release cycles (eg Linux Fedora Project) are quite fast, forcing us to keep on our toes. Each semester we need to retest all tasks and assignments and just make sure that everything still works the same way and that class notes are still valid and accurate. This is a hidden problem that should never be underestimated.

ACQUIRING THE HARDWARE

Dealing with University administrators and bureaucrats can be a challenge that can disenchant even the most ardent of zealots. Fortunately, most Universities follow the same bureaucratic and financial procedures, so by falling into step with their own processes and procedures it is possible to engineer oneself into a winning position.

The researchers have found the following steps work…

- Articulate your needs – number of disks, caddies etc (allow at least 15% for loss etc), and the number of students who will be participating in this new initiative.
- Add this initiative to your local strategic ICT five year plan. If there is no plan then start one.
- Once the plan is endorsed by your School/Department broadcast its acceptance and applaud the visionary leadership that supported it.
- Add the costs into the building of next year's budget, citing the endorsement of the strategic initiative.

- Once the figures are a part of the budgetary process commence a forward planning cycle for the following 2-3 years.
- When the initial capital expenditure has been done (equipment has arrived), convert the maintenance expenditure requests into recurrent funds. This will dramatically reduce the annual running costs to cover losses and breakages.
- Prepare for the next technology barriers and start the ground work for the next round of capital expenditure bids.

There is little hope in expecting any University to be able to come up with $100k for capital expenditure on the spur of the moment. However, when this sort of figure is woven into a long term strategic plan and appropriate budget processes endorsed by all the important people in the "food chain", there is every reason to expect it to work.

The next and possibly most important step is to get management buy-in for the proposal. This is exactly the same sort of buy-in we all expect when a large IT/IS project is underway in any organisation. We get this sort of support from at least our Heads of Schools or Department by making them part of our innovative and far-sighted planning process. This management-level ownership will help shepherd the proposal in places where ordinary academics just don't go. This support has to be appreciated publicly at every available opportunity.

This sort of technology commitment is a long term proposition. The disks and portable devices will break and will get lost. As one student explained to the researchers recently…

> *"When I reversed the car I had forgotten I had left it on the roof until I saw it slide down the back window and onto the ground, when I felt the car run over it. Then I went into drive to find out what I had run over, going over it again…"*

We budget for between 10-15% replacements each year. This allows a little slack in that there will be few devices that wear out that early in their lives, but as the years elapse, the number will increase. The researchers have found that natural (sic) obsolescence of technology also occurs with better, cheaper and faster devices becoming available. We have also encountered the "bloatware[8]" effect with the software increasing in footprint size as it matures. Students are advised of their personal responsibility for the hardware and they sign an acknowledgement attesting to that fact. If they lose the hard disk, they have to replace it and its caddy at their own expense or their results are withheld.

Technology barriers will occur from time to time. We find that every 3-4 years we are either forced into or voluntarily decide to review our hardware and software. This year we have been confronted with the standard laboratory workstation unable to accommodate both our internal IDE caddies and their native SATA hard disk because of BIOS limitations. The workstation suppliers were and still are unwilling to address that issue. We have now been forced into re-entering the capital expenditure cycle prematurely.

TECHNICAL ISSUES

In our ten year experience we have become quite educated about the technical issues that will help this style of teaching become a success.

Given that a specialised laboratory can be acquired and fitted with a suitable NAT router that does DHCP, the rest is all about the computer itself and its BIOS.

We used small laptop computer hard disks because of their lightweight profile and their resilience to being carried around, and in a lot of cases, being able to survive drops. The caddy and frame are the way that these disks are inserted into the computer. We found that some caddy/frame combinations were simply too large for a given case's dimensions. In some cases, the caddy and frame were too flimsy and felt like their longevity at the hands of students would be limited.

The target computer motherboard and BIOS must support an IDE device being connected to the secondary IDE controller.

If all these conditions are OK then it will be smooth sailing. All three environments allow selective booting into the target environment. Windows and Linux use a boot floppy configured with a suitable boot loader.

Unfortunately, as mentioned earlier, our current machines' BIOS do not support an IDE device on the same motherboard as their standard SATA devices. The plugs are there but the BIOS just will not recognise the IDE device. The manufacturer is not in a position to rectify the issue. Our solution then is to split our energies into two solutions.

[8] Bloatware: A word used to describe the sheer size of a piece of computer software that is to be installed where only a very small percentage of the total product is to ever used.

The first path is to satisfy the Linux requirements. The current Fedora Project Core 4 product will allow an installation onto a “removable” USB2 device. We have been able to install this Linux onto a USB2 hard disk using the same drives as before and to optionally boot from a floppy disk. This is a major win for us. We only have to acquire 200 USB2 enclosures. These are relatively cheap coming in at around $AUD15.

Neither Microsoft Windows Server nor Novell Netware will allow an installation to proceed onto a known “removable” device such as the USB2 external disk. The only way out of this problem is to acquire SATA caddy and frame devices and to use them in these courses. Unfortunately, the SATA hard disks are quite heavy, but appear to have good shock resistant properties. Only time will tell. The hunt for a caddy and frame combination that fitted into the existing cases was quite extensive. The actual SATA interface appears flimsy and at least one researcher has doubts about its longevity.

We look forward to encountering computers that can have their BIOS configured to accept the external USB2 disk drive as being effectively “non-removable” so that Microsoft and Novell products can be used with USB2 devices. The problem described is current, but it serves as an excellent example of the types of issues that have occurred as the software and hardware has changed over the past 10 years that we have invested in this real world practical approach.

OBSERVED BENEFITS

Although we have not conducted any formal research measurements, we have collected considerable anecdotal evidence over the years that lead us to believe the use of the portable storage devices has produced many benefits for the students. The following points are based on our own observations of students working, as well as talking to students, both informally and formally (eg: student staff consultative committee meetings), and also from end of semester course review surveys that students complete anonymously.

Use of multiple, commercial operating systems

One of the primary reasons we chose this approach was that it allows us to teach different operating systems and packages for different courses. Also, because the disks are a useful size, it is possible to use full versions of commercial operating systems – exactly the same software the students will use in industry. Most of the other approaches usually require a restricted version of an operating system to be used.

Students get networking and system administration jobs

We consider the skills our students gain from these courses to be a major contribution to gaining employment. Our work integrated learning (industry placement) students as well as our graduates regularly get jobs as systems and network administrators for both small and large companies, including high profile networking companies and internet providers. For some students, the initial experience of these practical lab sessions sparks an interest in a field of IS they never previously considered. Such students regularly go on to do all the networking electives and seek employment in that field. Something they may never have done if not given the opportunity to experience a real world network configuration.

Students “own” their server

A major advantage of each student having their own disk is that they feel a sense of “ownership”. For some students this becomes a very powerful force, generating a lot of enthusiasm. They personalise their server as much as they would their own computer at home. They spend a great deal of time working on their server and some are even reluctant to hand it back at the end of semester.

Tutorials can build on previous work

As each student keeps their server and takes their server with them, any work they do one week is still there the following week. Each tutorial is designed to build on the work of the previous week, culminating in a fully configured server running services relevant to the particular course. There are several pedagogical benefits to this. One is that students are forced to complete each tutorial before moving on to the next. The other is that they can see their practical work as being part of a whole, rather than fragmented pieces that do not relate to each other.

Students can safely make errors, crash and rebuild their servers

As each student is running their own private server, any error they make will only impact on them. Indeed, we consider it part of their learning process to seriously crash their server and then to be forced to re-install it a number of times. This kind of experience can only be gained in such a protected environment – making serious errors with a commercial server would not be taken lightly. Our students gain valuable experience in disaster recovery, sometimes without planning to.

Students can work at home

For very little cost students can purchase a compatible caddy unit and install it at home. This allows them to reboot their server on their home computer and continue working.

Students come from far and wide

One interesting trend we have observed is that students from other parts of the university come to study the networking courses we offer. Many of these are from engineering and computer science disciplines that have heard about our particular approach from their friends doing Information Systems. We also regularly have international exchange students choosing to do one or more of these courses because they realise they cannot get the same type of experience at their home university.

CONCLUSIONS

We believe that the use of portable storage devices has provided our IS students with a valuable experience and enabled them to gain a strong understanding of ICT concepts. By providing students a server that they ‘own’, students are motivated to excel. By using full size commercial operating systems, the students gain practical skills that are immediately applicable in the workplace. These skills lead directly to employment opportunities.

A specialised laboratory with appropriate hardware configuration and security measures is essential. Support from knowledgeable ICT technicians is a critical success factor and needs to be carefully nurtured. IS academics need to leverage their understanding of the IS project cycles in obtaining the funding and support for these types of projects.

FUTURE RESEARCH

This case study can be further enhanced by performing a longitudinal survey of the effectiveness of this pedagogy. This would involve evaluating student performance over a number of semesters as we make changes to the teaching environment. Another avenue for investigation is surveying how this problem is addressed by others.

There have been times when we have considered using the same platform for other types of courses. For example, we have several courses that involve building complex applications using ASP.NET and also the enterprise java platform. Both courses have problems in normal labs due to requiring more permissions and security access than students are generally allowed to have. There would be scope, therefore, to use the portable disk platform to enable students to work on software construction assignments that required a server platform. We also have courses involving major projects. These projects require software configurations that are different to the standard lab platforms; the portable devices may be useful in this case.

We are also constantly looking out for better alternatives. For example, can requiring students to have a laptop enable this practical approach to be utilised with a multi-boot setup. Some secondary schools require all students to have a laptop. The same requirement could be imposed at a tertiary level for IS degrees. A practical approach to network operating systems could be envisaged by appropriately partitioning the internal hard disk and enable a multi-boot loader on the laptop. The possible use of virtual machines (such as VMware or Virtual PC) is also something we are currently investigating. Although these technologies have existed for some time, it is only now that the size and power of standard hardware has reached a level where it may be possible to run an entire server in a virtual image on a PC.

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