SPANNING THE DIGITAL DIVIDE: A REMOTE IT LEARNING ENVIRONMENT FOR THE VISION IMPAIRED

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ABSTRACT

People who are vision impaired continue to experience difficulty in accessing tertiary education relevant to their disability due to inaccessible learning environments. The nature of acute vision disabilities requires access via assistive technologies; however these aids provide only limited access to educational materials designed for sighted students. An e-learning environment designed specifically for students with vision and print disabilities has been designed by the authors and implemented by the Cisco Academy for the Vision Impaired (CAVI) for delivery of accessible Cisco certification courses to provide the vision impaired with the skills to design and maintain computer networks. This accessible e-learning environment comprises two main sections, the accessible curriculum and the collaborative e-learning environment. This paper describes the virtual classroom and remote laboratory that comprise the collaborative e-learning environment. Other educational institutions wishing to develop similar environments may benefit from this environment in their quest to deliver education to meet the special needs of the adult vision impaired learner.

1. INTRODUCTION

Disabilities inhibit many from obtaining gainful employment and the building of skills in IT enables those with a vision disability to be better equipped to take on employment in the IT industry. With an unemployment rate of more than 60% in Australia, the vision impaired battle to compete for employment with those who are sighted (Vision Australia, 2007). Technology has become an integral part of the business world with little being achieved without some use of information and communication technologies. In many cases organizations use technology to gain a competitive advantage, hence the need for IT skills is paramount for employment in today's business world. Education courses in introductory skills in computing are offered by many disability support organizations to their members, however very few advance beyond the basics of how to use email, Word, and how to search the Internet. A scan of the literature on accessible e-learning environments results in little in the way of new developments.

People who are blind rely on computers and the Internet for information essential to their lives, availability of goods and services, directions to get from one location to another, pay bills and do their banking, communications with other people, transferring information and documents to businesses, family and friends. The ability to set up their own home computers and networks is a great advantage to them. With advanced IT skills they can also troubleshoot problems and fix their own systems when they fail. They can also do this for their employer, making IT help desk and network administration a relevant employment role for people with vision impairments.

E-learning environments suitable for remote delivery of accessible IT curriculum have been a long time emerging. The needs of those with vision disabilities are specialized, requiring assistive technologies to access the information technology and curriculum. Research and reporting of advances in this area have not been forthcoming, with pockets of work on accessible teaching methods and curriculum, but little spans the digital divide between sighted and vision impaired students in the area of information technology and network administration education. Employing an e-learning environment consisting of a virtual classroom, remote laboratories and curriculum fully accessible to the vision impaired, the Cisco Academy for the Vision

Impaired (CAVI) delivers advanced IT network education to students situated around the world. Students access the learning system via the Internet, enabling those in remote locations to work through the courses at their own pace and within their own time zones. This paper describes the remote e-learning environment designed for the delivery of advanced IT networking to vision impaired students so that others may benefit from the low-cost and effective design. The paper first discusses the needs of vision impaired students and the benefits of virtual and remote learning environments. Details of the environment components are then presented and the methods of user access are described. The learning environment described in this paper offers vision impaired students and others with print disabilities, the opportunity to gain advanced IT skills without leaving their home computers. The architecture presented is appropriate for other types of remote technology training for vision impaired learners.

2. NEEDS OF LEARNERS WITH VISION DISABILITIES

Many of the problems with inaccessible teaching environments have been presented in prior research (Arrigo 2005). Mobility can be a problem for those with a vision disability and often educational courses are offered at locations that are not physically accessible. Courses are seldom offered within easy travel distance for the vision impaired to attend physical classes. Harper et al. (2001) describe the problems associated with diagrams, images and visual cues, and the difficulties these pose to vision impaired users. Much of the learning materials in e-learning environments assume the user is sighted, incorporating highly sophisticated visual features not accessible by the assistive technologies used for translation of the materials into audio and haptic output. Instructors are rarely cognizant of the problems faced by learners with a vision impediment and do not know how to make their materials accessible. Awareness of the need to make web sites accessible is generally rising with guidelines and standards now available, the most prominent emerging from W3.org (Kelly et al. 2005, W3C 1999, 2006). Many large organizations now have accessibility guidelines for web-based information however accessibility is still overlooked by prominent bodies. Several Olympic websites have been inaccessible to the vision impaired, including the Sydney, Beijing and Vancouver Olympics (Carter 2000, Sloan 2001, Worthington 2003). Bruce Maguire, a blind web user who took legal action against the Sydney Organizing Committee for the Olympic Games for discrimination, was awarded $20,000 AUD (Carter 2000, W3.org).

The use of visual features in e-learning environments alienates students with vision disabilities. The use of photographs, images, colour, animation and interactive multi-media are ignored by the assistive technologies currently available and this places these students at a distinct disadvantage. In most cases there are no accompanying explanations as 'a picture paints a thousand words' and the meaning is assumed to be clearly portrayed by the image. Although the insertion of html tags on images is recommended, very few developers of web materials actually insert meaningful labels to images and seldom include descriptions of the image or explanation of the Flash image progressions. However, access to web-based materials is not the only concern. It is argued that while learners who are blind can 'access' e-learning material, even if it is designed carefully there may be a danger of excluding them from the learning experience (Evans 2009). Evans differentiates between *accessing, using* and *doing* in her research into e-learning strategies for the blind and observes that specialist skills and technology are needed for supporting learners who are blind. One of the problems identified during a pilot project working with vision impaired students was that sighted instructors were not fully cognizant of the needs of vision impaired students with relation to the presentation of concepts and materials (Armstrong & Murray 2007). As the study progressed it was found that the vision impaired students at a more advanced level were able to explain these concepts in a manner the less technically adept students could assimilate more easily. This resulted in the training of totally blind instructors and the subsequent delivery of the IT courses by these vision impaired teachers.

Once enrolled in a course, blind students in a traditional learning environment have difficulty just reaching a starting point equivalent to their fellow sighted students. Vision impaired students still have to attend classes, take notes, get audio copies of textbooks, have diagrams and tables explained to them and sit assessments with the aid of a student disability support officer. Students with a vision disability rely predominantly on memory to store knowledge and then make links as new knowledge is presented. They need to revisit the same materials several times before it can become clearly understood. Evans (2009) reported that blind students required twice as much time to complete tasks. Due to this need for repetition

vision impaired learners need accessible learning materials available 24 hours per day, every day of the week electronically. This would provide them with the ability to access the learning materials as many times and as often as they need. Like other students the vision impaired need contact with the lecturer and other students. Whilst the physical classroom provides this, an electronic and/or remote facility must provide a similar capability. They also need the opportunity to ask questions and have concepts explained by instructors as the lectures and tutorials progress.

3. VIRTUAL AND REMOTE LEARNING ENVIRONMENTS

E-learning environments provide an effective alternative to the traditional learning environments. The ability for students to gather in a virtual classroom for the broadcast of lectures and undertake practical exercises in a remotely accessible laboratory provide numerous advantages. Auer and Gallent (2000) believe that remote laboratories provide the following benefits:
1. Students can carry out experiments from anywhere in the world.
2. Extended access is provided to expensive and highly specialized devices.
3. Provide a real lab experience when compared to simulations.
4. Remote laboratory experience is an advantage for future engineering jobs.

The reporting of virtual and remote learning environments appear to be dominated by ICT, Science and Engineering education applications as laboratory work is an essential part of the learning process in those disciplines. In their comparison between hands-on, simulation and remote laboratories Jang and Nickerson (2006) discovered that in addition to remote labs being a more popular medium, this option for laboratory teaching provides more flexibility due to the extended accessibility, the times and places the student can interact and the cost-effectiveness of these solutions. There are also cultural and social advantages to remote learning environments that have global accessibility. In a study of adult learners in rural South Africa Henning and van der Westhuizer (2004) reported that the support of peers was the main contributing factor to entry into e-learning. Their findings were that the social context provided more facilitation than the technology. Although the resistance to technology was identified in their chosen student sample, this is not characteristic of all e-learning student groups. Buzzetto-More (2005) claims that technology-facilitated global education provides social benefits including unique insights through exposure to global perspectives and the development of skills that facilitate student collaboration in addition to the building of necessary technology skills.

Virtual and remote learning environments provide numerous advantages to the vision impaired in particular. Most vision impaired students use computers and the Internet on a regular basis, and as such have skills in the use of basic assistive technologies that convert the output into some accessible form. Flexible learning permits students to access the materials when they can or choose to, and progress at their own pace. Due to the nature of their disability virtual and remote learning environments are ideal for the vision impaired. They interact with computer systems via voice over applications that read the text as audio output. As they cannot see the screen display or the whiteboard there is nothing a teacher can do more than explain in words, or teach by other sense such as touch. Hence there is no compelling reason for them to be physically situated in the classroom, provided they have electronic access to the instructor and other students. Some courses will need access to equipment in order to build and test designs, particularly in the ICT, science and engineering disciplines. Remote access is needed so that students located anywhere can log in. Access to equipment that can be configured and tested is also required. Ideally this needs to be available via the Internet for easy global access. An environment such as the one described in this paper can be used and adapted for delivering many types of courses remotely to vision impaired students. The design presented is based upon education in advanced IT, however the environment can be used for mathematics, engineering, etc. by inserting the desired accessible learning materials in to the course management system.

4. THE CAVI COLLABORATIVE E-LEARNING ENVIRONMENT

The CAVI accessible e-learning environment was established to deliver advanced IT networking courses to vision impaired students situated in different parts of the world. The authors designed and implemented an

accessible e-learning environment for the delivery of Cisco IT networking courses. The Cisco courses were also redesigned to ensure the teaching and learning materials were accessible, however the environment structure can be applied to any learning environment that has accessible educational materials. The learners in the CAVI environment are vision impaired students located across the globe and the curriculum presented is comprised of the Discovery courses (previously CCNA courses) that form part of the Cisco Networking Academy Program. "Networking Academy utilizes a blended learning model that combines face-to-face teaching with engaging online content and hands-on learning activities to help students prepare for industry-standard certifications, entry-level and advanced careers, and higher education in engineering, computer science, information systems, and related fields." (Cisco 2010). The Cisco courses are taught as stand-alone industry certification courses as well as forming part of undergraduate curriculum. As the chosen Cisco courses chosen for inclusion in bachelor programs were not accessible by vision impaired students, the first phase of the project was to redesign and rebuild the curriculum to ensure its accessibility. More details on the curriculum can be found in Armstrong & Murray (2007). The Cisco courses require students to design and build IT networks, and trouble-shoot these networks. This means the vision impaired students must have access to network equipment they can configure and test, hence the need for an accessible remote laboratory facility.
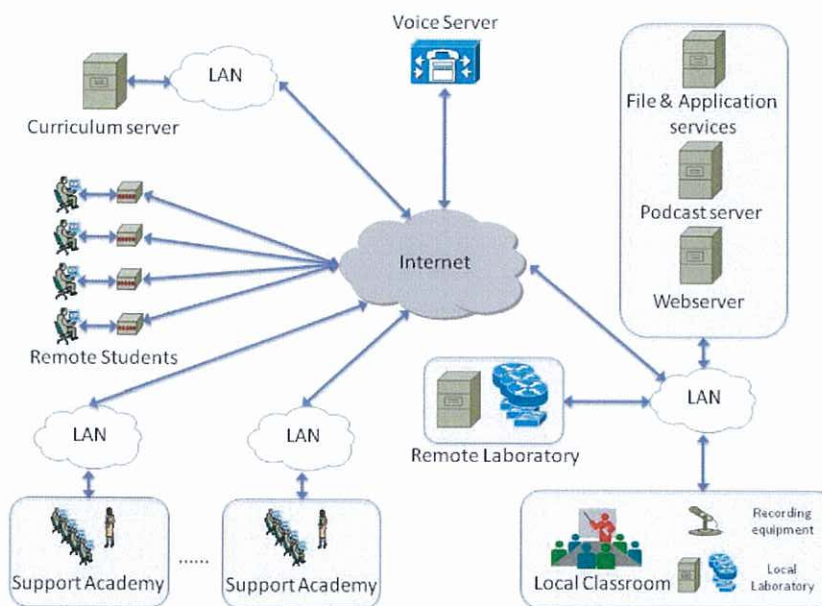

Figure 1. The CAVI accessible e-learning environment.

The CAVI e-learning environment is illustrated in Figure 1 and comprises:

1. a local classroom where local vision impaired students can attend and where lectures and tutorials are broadcast for the virtual classroom,

2. support academies situated at other remote locations providing local vision impaired tutors,

3. direct access via the Internet for remote learners at home,

4. a curriculum server housing the Cisco e-learning materials and a file and applications server housing the course management system plus additional accessible teaching materials and applications,

5. a local laboratory where local students can carry out their laboratory exercises,

6. a virtual classroom consisting of a voice server, webserver, and podcast server,

7. a remote laboratory where students can configure the network equipment and test their configurations.

Vision impaired instructors deliver the lectures and tutorials in the local classroom and these are broadcast to the support academies and remote students. Vision impaired tutors provide a one-on-one capacity with students to further explain and walk through concepts and exercises. The lectures and tutorials are recorded and the audio files are stored for later access by the students on demand. The virtual classroom

enables the students to interact with the instructors and other students during the broadcasts. The virtual classroom also provides the opportunity for lectures and tutorials to be delivered by lecturers in remote locations, as the physical location of the teaching staff is flexible. Assessing assignments can also take place electronically. Students can complete and submit their work electronically, and lecturers in any location can grade the students' work. One-on-one communication between instructors, tutors and remote students is carried out via Skype.

The above components allow the vision impaired students to login and hear broadcast lectures and tutorials, and then work through the accessible curriculum at their own pace. The curriculum and applications enable the students to design network architectures, then implement and test these in the remote laboratory which is a real networked environment. The Network Academy program places great importance on "hands on" experiences in the laboratory sessions. The program does offer an advanced network simulator in Packet Tracer, however this is inaccessible to low vision and blind students and is also not intended as a replacement for exposure to genuine hardware.

5. THE REMOTE LABORATORY CONFIGURATION

Commercial systems that facilitate remote connection to networking hardware do exist. Netlab is a common solution utilized in mainstream academies. Developed and distributed by NDG (http://www.netdevgroup.com/) the cost of this system is a major factor hindering its adoption. Additionally, the java based applications in Netlab, including the booking system, telnet client to interact with the network hardware and server system are not accessible by screen reader software utilized by blind computer users to convert on-screen information to audio or Braille output. The system developed for the CAVI environment costs significantly less than the Academy Edition of Netlab. Whilst it does not offer advanced features such as equipment booking it performs all the required functions for the vision impaired class applications. In its most simple form, it consists of 3 routers and 2 switches, with several virtualized Linux PC servers running FTP, HTTP, Telnet and other associated services. However, a problem exists when attempting to allow remote students access to "real" routing hardware. The routers may not be placed on production networks for obvious reasons and initial configurations must be entered via the console connection. Therefore requirements for a remote lab must allow students to perform initial configuration via the console cable, remote power cycling of network equipment and workstations, connectivity tests, and advanced router and switch configuration. The remote laboratory configuration is illustrated in Figure 2 and consists of the following:

1.   16-port "out of band" management switch that allows access via telnet to the serial console ports of the attached equipment,
2.   16-port remote power switch controlled via serial in order to cycle device and workstation power as necessary,
3.   Three Routers Cisco 2821 routers,
4.   Three servers that host two virtual Linux workstations each,
5.   Three wireless access points,
6.   Three USB to serial converters, one per virtual server box to allow virtual workstations command line access,
7.   One VPN control box: a dual homed Linux workstation to provide VPN access to the web interfaces of the wireless access points and other virtual workstations when necessary,
8.   One eagle server host that simulates an internet cloud for student labs.

The remote laboratory environment had to satisfy a number of operational and administrative requirements. It was imperative that the networking equipment be isolated from any production networks in such a way that student exercises would not disrupt network operation or risk compromising security. The use of out of band management switches facilitates the segregation of laboratory and production networks. Additionally and most importantly, the full environment must be accessible and compatible with assistive technologies used by the blind and vision impaired students. As many potential students reside in developing countries with limited access to communications technology the interface and access methods should require a minimal bandwidth so as to allow connections to be made via dialup modem. As a result of these considerations, the use of screen sharing technologies (e.g. remote desktop and virtual network computing)

was not considered. In order to reduce the machine count and therefore space and power considerations, all workstations were virtualized. Workstations also had to be controlled remotely with the ability to reconfigure network hardware on demand without losing connectivity to the systems themselves. For example, if the network interface was utilized for workstation configuration and the IP address altered, the student would immediately lose access to that workstation thus rendering the system inaccessible. As students are required to reconfigure the network hardware on the virtual workstations methods of interacting with the virtualized operation systems was researched. It was found that using a virtual serial port on the workstation would satisfy the requirements. Serial connections may also work on low bandwidth links.
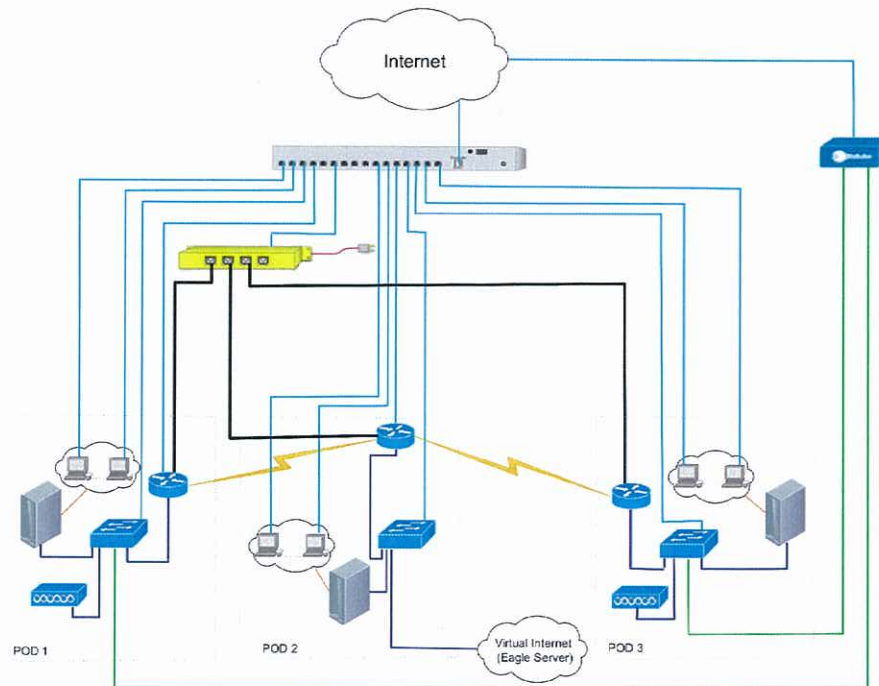

Figure 2. Remote laboratory configuration

As can be seen in Figure 2 the remote laboratory environment is separated into 3 "pods" with each pod containing two workstations, a router, a switch and a wireless access point. One serial port is required for each device within a pod with the exception of the wireless access point. The 16-port "out of band" management switch was segmented to provide 4 ports for each of the 3 pods, one port for management of the switch itself and a port for the remote control power switch. The remote power switch has 16 IEC power ports, which may be used to cycle power on workstations, routers and switches. This is required in several laboratory scenarios including when password recovery is required on the routers. As cost was a consideration in the construction of this laboratory environment, free software was utilized wherever possible. The decision was taken to base the virtualized workstations on Ubuntu 9.10 running under VMware server 2.0.1. Although several difficulties arose in recompiling the kernel, a review of the documentation led to a solution.

The testing of a prototype virtual machine containing a basic set of networking utilities and serial interface configured as its primary console was undertaken and once stable, cloned to produce the other workstation images. New machine profiles were created in VMware server and virtual machine images were then copied from the prototype machine. Once booted, the hostname was changed along with the mapping for the serial port with Com1 on the virtual machine mapped to ttyUSB0 or ttyUSB2 depending if it was the first or second virtual machine on the host hardware. All virtual machines had their Ethernet interfaces bridged to the Ethernet interface on the host server in order that they could communicate with equipment in each pod.

6. USER ACCESS TO THE REMOTE LABORATORY

To gain access to the remote laboratory students Telnet into the "out of band" management switch accessing the routers, switches and Linux servers from any locality worldwide. Users may then connect to the virtual machines and access the command line via the screen reader. This approach was taken as virtualized GUI based operating systems are not easily accessible to the assistive technology when installed behind the console switch. As the routers are on their own network, with remote access attaching only to the serial ports, this system does not offer any security risk to the institution utilizing it. Once the student has authenticated with the console switch (simple plain text password) a list of available equipment is displayed.

As the booking system was incomplete at the time of writing, a virtual classroom was used as a method of ensuring students knew if the equipment was in use. When undertaking a laboratory, students logged into the Ventrilo server (a voice communication application designed for on-line gamers) and entered the appropriate channel. In this way students can not only tell if a particular bundle is in use but may also conduct laboratory sessions collaboratively with other students.

Power cycling of equipment is undertaken by authenticating first to the console switch and connecting to the remote power switch. The power switch may then be used to power down individual devices within the bundle. This is usually done with a secondary telnet session, allowing access to the router/switch to be power cycled and therefore the boot process to be interrupted (as in the case of password recovery laboratories). Each device may be powered on, off or rebooted.

Once connected via Telnet, students may configure routers, switches and workstations in the same manner as if physically present. Although this system allows laboratories to be completed, including e-Labs it has several shortcomings. These include the lack of a formal booking system, leading to students attempting to access the limited resources while others are engaged in laboratory sessions and it does not give students experience with the physical cabling of network systems. To assist students with understanding the physical aspects of cabling, recorded audio demonstrations of the physical features of cables, connectors and their locations on switch and router hardware are conducted. In these demonstrations, a local vision impaired student conducts a supervised cable lab, describing in detail what they "feel" and how connections are made, in much the same manner as video is utilized for sighted students.

7. CONCLUSION

The CAVI Collaborative E-learning Environment was designed specifically to address the problems faced by vision impaired students in a learning environment studying advanced ICT networks. This environment has also been used with success for delivering introductory IT courses to both sighted students as well as the vision impaired. Many of the teaching aids and techniques designed for the vision impaired students have been helpful for sighted students. Not only does the environment allow students located anywhere in the world to access a fully accessible education courses, it also provides the infrastructure to enable the students to converse and the instructors and each other to discuss the course materials and walk through lectures and tutorials. The remote laboratory solves the problems of accessibility to live networks to test the design and configuration of networks from remote locations. The CAVI accessible e-learning environment has been in operation since 2003, and is regularly being updated. At present there are approximately 140 totally blind and acutely vision impaired students enrolled in the course worldwide.

Although this environment is developed specifically for the training of vision impaired students in advanced IT networking, the remote accessible environment can be implemented for other IT-related education. This paper has described the technical environment enabling the vision impaired students to access the remote classrooms and laboratory to carry out the learning tasks and meet the same learning outcomes as the sighted students. The authors welcome the application of any ideas from this environment for employment in the remote education of vision impaired students in other contexts. In order for the environment to be most effective, instructors need to ensure the learning materials are totally accessible before deploying into the accessible physical and virtual networking environment described above. The electronically accessible learning materials need to include lectures, tutorial exercises, lab exercises, quizzes and examinations as a minimum. An accessible course management system is also needed to act as a repository and an aid for the continued management of the students progress.

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