TEACHING SIGHT IMPAIRED IT STUDENTS

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ABSTRACT

This paper describes a research project to convert Cisco network administration e-learning education materials to a format that can be accessed and undertaken by sight impaired students. The changing nature of educational materials and the associated problems faced by vision impaired students are discussed. A description of both the high-tech and low-tech solutions applied to this unique teaching environment is presented. Results so far are reported together with a discussion of future plans for the project.

1 INTRODUCTION

The delivery of educational content is changing. E-learning encompasses not only the on-line presentation of core and supplemental materials but also tutorials and self-paced learning materials for distance learning. The opportunities for education have expanded both laterally (reaching a greater distance) as well as vertically (reaching a wider variety of students). Graphical user interfaces have become the norm in the teaching of IT (information technology). Computers are visio-centric as they rely predominantly on computer displays to present information and the learner's sense of sight to observe this information. Researchers have found that vision is the primary integrating sense within learning and development (Kelley, Sanspree & Davidson 2000). Vision utilizes nearly half the human brain and approximately 70% of its sensory capacity is dedicated to processing visual information (Shepherd 2001). Traditional teaching methods have moved from a predominance of textual material to visual content and modes of delivery. With the increase in e-learning comes a greater dependence on computers for access, content and presentation of educational materials. The computer has also become an extended learning and teaching tool. As up to 80% of traditional education is presented in a visual format, students with vision impairment are unable to access information that is common to other students (Levtzion-Korach, Tennenbaum, Schnitzen & Ornoy 2000, Ross, Lipper, Abramson & Preiser 2001), leading to different conceptualizations and understanding of phenomena.

Visualisation is an increasingly important method for people to understand complex information which is presented using tables, graphs, diagrams and images. Visual techniques are also used to navigate around structured information. Computer-based visualization techniques, however, depend almost entirely on high-resolution graphics and for vision-impaired users the problems of using complex visual displays are great. There are currently only limited methods for presenting information non-visually and these do not provide an equivalent speed and ease of use to their graphical counterparts. This means it is impossible for blind people to use visualization techniques, depriving them even further. Hence techniques and technologies need to be developed to aid sight-impaired students to easily comprehend instructional materials.

This paper describes a teaching and research project undertaken at Curtin University in conjunction with Cisco Systems and the Association for the Blind Western Australia to identify tools and techniques appropriate for vision-impaired students studying computing at tertiary level. The project aims to identify and apply alternative means of presenting visuo-centric engineering and information technology teaching materials to vision impaired students in an e-learning environment. It investigates considerations and learning characteristics of sight impaired students, and also the approach being undertaken to identify and apply alternative modalities in an e-learning environment.

2 DISCUSSION

2.1 THE NATURE OF COMPUTING EDUCATION MATERIALS

Education in information technology and computer engineering at tertiary level involves understanding and applying theory and hands-on practice to develop advanced knowledge and skills involving specialist equipment. Computing theory is a combination of logical and physical abstractions, invariably taught to students using conceptual diagrams or figures containing shapes of different sizes together with other visual effects such as shading, colour and sequence. Tables are also used frequently in computing; to illustrate rules in router tables and firewall tables, hexadecimal to decimal conversions, and the like. Drag and drop, pop-up menus and windows have become the norm in software products. Graphics and images are also used extensively to illustrate logical concepts such as theories, patterns, models, flows and topographies, as well as more physical facets including architectures, cabling and devices. The more complex the model, the more complex the visual effects used, with the most sophisticated requiring spatial abilities to interpret motion and 3D images. Sight-impaired students are at a severe disadvantage in this type of learning environment, particularly those who have been blind from birth or an early age.

Compounding this problem is that e-learning is increasingly being used to deliver coursework in higher education environments. While computer-based learning has opened opportunities for many students with disabilities, it remains primarily vision dependent. Students or potential students with vision impairment are thus doubly disadvantaged, as even programs taught in traditional face-to-face mode use computer-based information as an adjunct to teaching and learning. Sight impaired students are disadvantaged, not only due to their vision impairment, but also by limitations in their access to electronic teaching information.

2.2 CAVI RESEARCH PROJECT

The Cisco Access for the Vision Impaired (CAVI) program investigates the needs of vision impaired students embarking on e-learning education in computing within the School of Electrical & Computing Engineering at Curtin University of Technology. Two other key partners are also involved in the program, the Association for the Blind Western Australia and Cisco Systems. This research involves not only identifying the needs of vision impaired students but also developing alternate means of accessing and presenting the teaching and learning materials. The CAVI project forms part of a much larger project in assistive technologies at Curtin University aiming to develop systems and methodologies to assist people with sensory disabilities to gain access to education and technology.

The CAVI research utilises Cisco e-learning programs in computer networking and internet technology. The project focuses on two main areas; firstly the physical access and delivery of materials, and secondly, alternate methods of embodying and presenting the required technical content. The project investigates the use of screen enlargement, tactile graphics, force-feedback (haptic), 3D sound, and Braille and speech output as methods to overcome access problems associated with low vision. The Research identifies not only those modes and representations difficult to comprehend, but also those easily assimilated.

One of the main drivers for the research was the recognition that vision impaired students in the tertiary education sector in Western Australia were failing to achieve certification in their chosen course of study, due to an inability of the sector to adapt the training and assessment framework to meet their needs. Although students with vision impairment appeared to be equitably represented in the tertiary education sector in Western Australia, lack of staff awareness of issues related to vision impairment and difficulties in adapting the training directly have hampered completion rates (Dept Training & Employment, 2000). Recommendations for improvement included the need for professional development for lecturers and improved student access to electronic educational materials.

2.3 CATERING FOR SIGHT IMPAIRED STUDENTS

There are more than 8,800 legally blind people in Western Australia, with approximately 2,400 under the age of 65. The Association for the Blind in Western Australia reports they gather 75 new clients per month and in 2001 there were more than 400 blind students in technology training (ABWA, 2001).

Each sight impaired student in the learning environment under study has different requirements, based upon their unique situation. Some students have been blind since birth, some since an early age, and these students have an immense disadvantage as they have no recollection of seeing objects, no memories from sight to aid their comprehension. Students who have lost their sight later in life, or who have been able to see for a short period, are able to remember and assimilate the knowledge more easily.

In the experience of the authors, all the sight impaired students commencing the program generally lack confidence and are afraid to experiment. This appears to be the result of past life experiences where the impacts of previous actions have been physically or psychologically painful. Students are made familiar with the physical building and laboratory environment and are encouraged to be as independent as possible. As the students learn to use the multi-modal computer interfaces their confidence grows. The need to play and experiment in order to learn in a computer engineering environment is vital to the learning process. Practical application assists in the assimilation of new knowledge (supporting Piaget's theory of cognitive development) thus solidifying learning. As students with vision impairment tend to have more highly developed memory capacity than their sighted counterparts, the importance of practical experience is raised even more. Students learn by processing materials via different lanes to the brain (Sprenger 1999). Experimenting in a familiar and trusted environment allows vision-impaired students to use multiple lanes to the brain, and thus will learn more quickly.

In order to address the learning needs of sight impaired students the aim of the research is to discover alternate methods of effectively presenting computing education materials, specifically the CISCO CNAP (Cisco Networking Academy Program) to blind students. An additional aim of the CAVI project is to advance a number of the vision impaired participants to the level of certified Cisco instructors, who can, in turn, teach other vision impaired students. This means that the sight impaired instructors can more easily understand the difficulties faced by the students and develop alternate and innovative methods of teaching the materials.

2.4 TRANSFORMING THE CISCO CURRICULUM

The Cisco Network Academy Program (CNAP) is a comprehensive educational program designed to teach students computer, internet and networking technology skills. Its e-learning format delivers web-based educational content, on-line testing, student performance tracking, and instructor training and support, as well as hands-on laboratory exercises. CNAP is the result of an alliance between Cisco Systems, educators, governments, international organizations, technology companies and non-profit organizations to prepare graduates for the demands and opportunities of the new global economy (Cisco, 2002).

The Department of Electrical and Computer Engineering at Curtin University is a recognized Cisco Academy, having taught CNAP for the past four years. The Cisco program is well accepted by industry and educators as an effective and worthwhile certification at high school, technical and vocational education and university levels. At present there are more than 10,000 Cisco Academies world-wide across 162 countries. Current student numbers are just less than 500,000, with only 14 vision impaired students; all of them in Perth, Western Australia, participating in the CAVI project.

Cisco offers a number of programs as part of the CNAP, however the current CAVI research covers only the CCNA (Cisco Certified Network Administrator) and ITE (IT Essentials) programs. There are several reasons for choosing this particular program for the vision impaired but the most important is that network administration does not require mobility, and physical orientation and mobility training is time consuming and expensive. This research program also offers sight impaired students qualifications in a high-tech field and provides new employment opportunities.

Unfortunately, the Cisco curriculum is traditionally delivered as Flash web pages, as illustrated in Figure 1. This style of delivery is unsuitable for visually impaired persons. The arrangement of frames is unsuitable for screen review applications (speech output), but more importantly the curriculum relies heavily on visual keys to illustrate learning objectives.

Several problems, not apparent to most sighted users, are also inherent in the curriculum design. The first problem is that the diagrams are extremely difficult to access or even explain to a person who has been blind since birth. The second problem is that the arrangement of frames and the lack of correct ALT labels (text equivalent buttons) add to the complexity of the presented material.

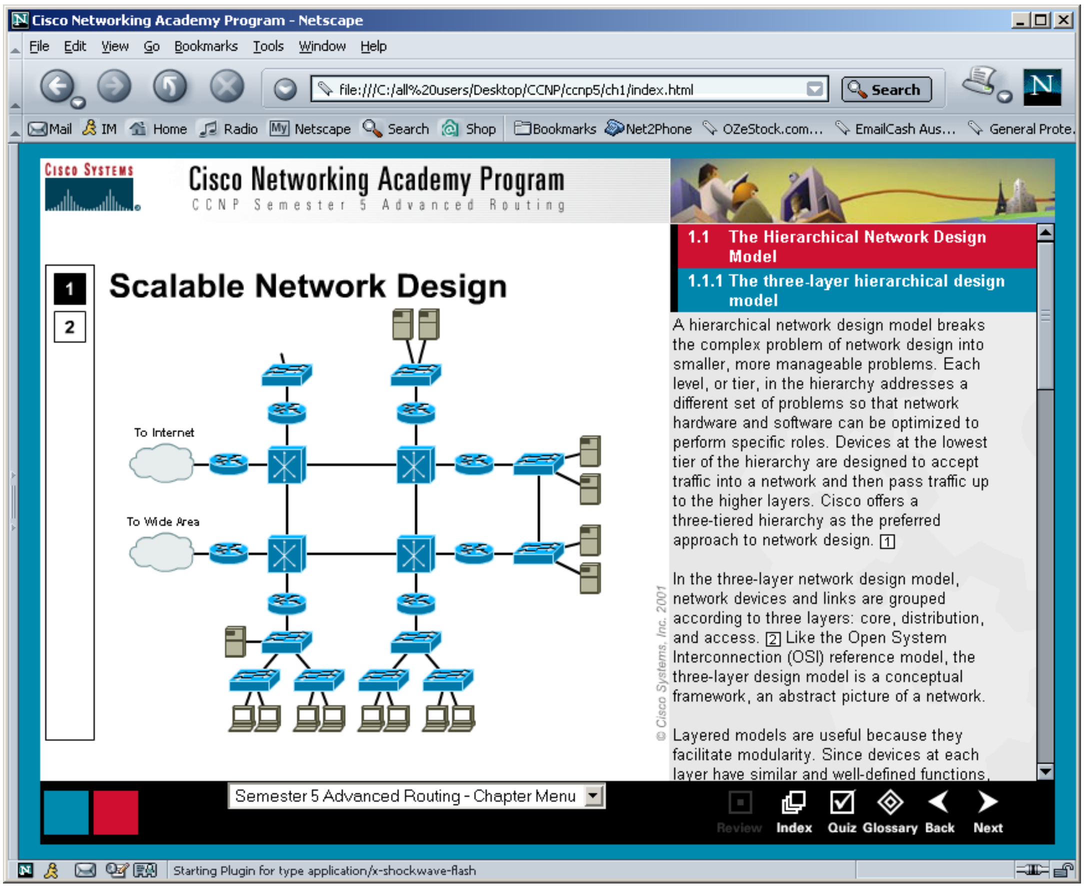


Figure 1: CNAP curriculum delivery example

2.4.1 EVOLUTIONARY RESEARCH METHOD

The research methodology used in this project is a combination of the evolutionary method and action research. Darwin proposed the evolutionary research method as the basis for his theories in the 1850s. It is the random combination of elements in a given environment (ie trial and error) to find the most efficient and robust combinations. The evolutionary method is used by nature, ie those combinations which do not work do not survive, ie natural selection. As there is little prior research on the effects of sight impairment and the assimilation of information in adult e-learning environments, there are few proven combinations. The evolutionary method will allow the combination of different elements, the testing of these combinations, and modifications based upon feedback. Those methods that fail will be discarded.

As the researcher is inevitably part of the research process in an project of this type, the research becomes action research. The situation calls for lateral thinking in the extrapolation and illustration of complex concepts, and immediate evaluation and feedback is required to ensure students' understanding of the curriculum material. Action research also involves a series of iterative loops involving planning, action, feedback and review. As each new technique or method is devised, evaluation is carried out by both students and academics. The results of the evaluation then feeds into the planning phase of the next cycle, allowing alternate methods to be devised, or previously successful or partially successful methods to be enhanced.

2.4.2 THE VISION IMPAIRED STUDENTS

There are currently 14 vision impaired students involved in the CAVI program. All participating students are legally blind (having <5% vision). Some of the sight impaired students have medical conditions such as retinitis pigmentosa which results in tunnel vision. Others have conditions such as optic atrophy or diabetic retinopathy which can result in distortion or impairment of the visual field and total blindness. Others have blindness caused by cancer, glaucoma, inter-cranial hypertension and other medical conditions resulting in a variety of impairments. Accidents have also resulted in blindness for some of the students. One of the first tasks in the learning environment under research is to determine each student's sight impairment, and the underlying medical condition, as this will be a guide in determining the most appropriate assistive technologies for that student.

The students range in age from 18 to 55 and have a variety of technical ability and prior experience. Five of the group have no useful vision at all and require Braille and screen reader access, three have such limited vision they also require screen reader software, five can access a computer with screen enhancement software, and one student is deaf and blind requiring screen enhancement and Auslan sign language.

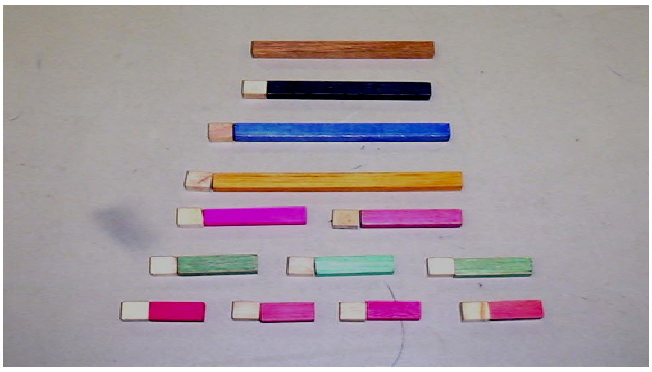
The vision impaired students use the same materials, assessments, laboratories, equipment and teaching staff as the sighted students. These students attend separately scheduled laboratory classes due to the high levels of noise generated by sighted groups. This noise competes with the speech output modules used by the vision impaired students.

2.4.3 TEACHING TOOLS AND AIDS USED

The loss of vision is often accompanied by an increased development of other senses including touch, hearing, memory and intuition and the research aims to tap into those enhanced abilities. The human computer interface of the Cisco curriculum has been altered to incorporate unique visualization strategies to aid conceptualization and these are being monitored on an ongoing basis.

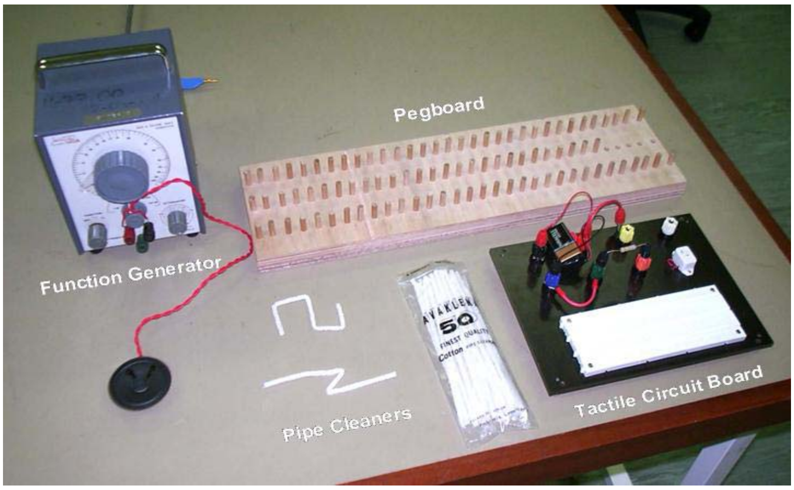
A flexible and practical approach has proven successful so far in the current delivery of the CNAP material, with a number of strategies already developed to assist students to acquire, explore and manipulate complex technical and engineering related concepts. The most common access methods used by the vision impaired students are screen enlargement applications (e.g. Zoomtext and Magic), screen review programs to output text into speech and Braille (e.g. Jaws, Slimware, Artic), tactile graphics (e.g. PIAF), and printed Braille and audio recordings.

Examples of both high and low technology are being used. Some simple tools used are illustrated in the photographs below. Blocks of different shapes and sizes are used to illustrate network models such as the OSI model and the breakdown of packets (see Photograph 1). Students can feel the size of the blocks and their positions. Photograph 1 illustrates the decomposition of messages into packets of data (the coloured or non-white larger blocks) and the addition of packet headers (the smaller white blocks). The packets are then broken down into frames, then bits, represented by smaller blocks with headers attached.



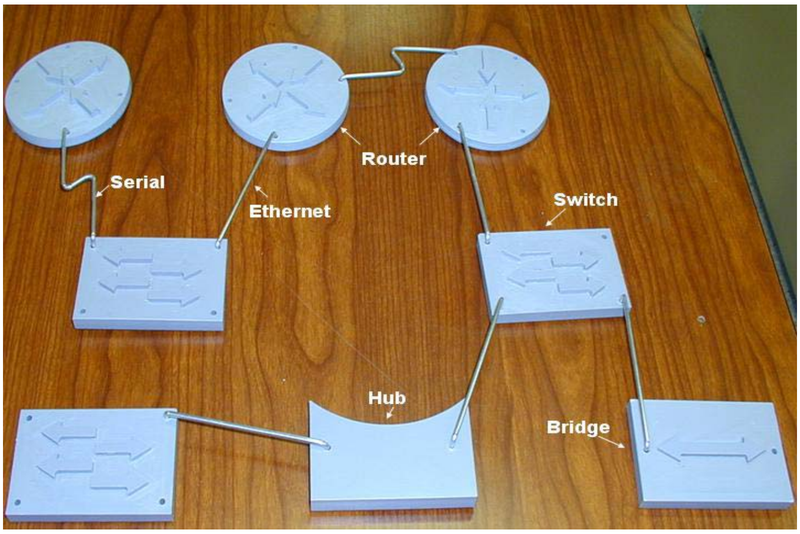
Photograph 1: Blocks of different shapes and sizes illustrating the packetisation of data

Several other aids used are illustrated in Photograph 2. A simple peg board is used for binary conversions. Students place a peg in the hole to represent “1” and no peg for “0”. Once familiar with the concept of different numbering systems, the pegboard assists the vision impaired students to grasp and assimilate the conversion process. Pipe cleaners are used to describe wave forms such as syn waves. A function generator attached to a vibrating speaker is used as a tactile oscilloscope to define frequency and amplitude. Students can feel the vibration and hear the sounds associated with a given frequency. A tactile circuit board consisting of a buzzer instead of a light globe, plus enlarged ports and plugs is used to teach logic gates and wiring.



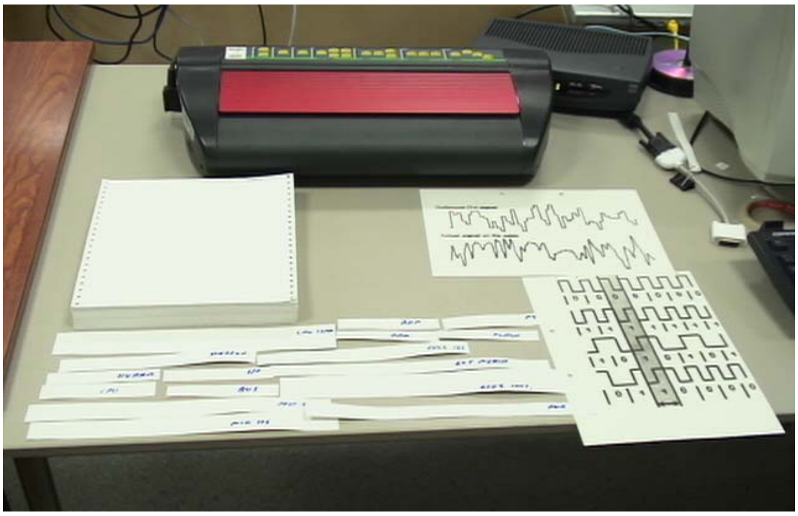
Photograph 2: Function generator attached to a vibrating speaker for frequency and amplitude, Pegboard for binary-hexadecimal-decimal conversion, Pipe cleaners to show wave forms, and a Tactile circuit board with enlarged ports and plugs

Network dominos are combined to produce tactile diagrams. These consist of blocks representing network components and devices which are shaped to match those in the Cisco diagrams (see Photograph 3). For example, the round shapes represent routers, the rectangular shapes with four arrows represent switches, the rectangle with a single arrow is a bridge, and so forth. The blocks are manufactured on-site in the teaching and research engineering workshops.



Photograph 3: Network dominos producing tactile representations of network diagrams

Another effective tool is tactile graphics printing producing raised-surfaced diagrams. The PIAF tactile graphics printer illustrated in Photograph 4 applies heat to special capsule paper causing the capsules to expand, raising the printed surface. By running their hands over the surface vision impaired students can feel the raised area on the paper.



Photograph 4: Tactile graphics producing printed diagrams with raised print, Braille printouts and Braille labels

Complex equipment is also used to convey other graphical information. Photograph 5 illustrates a Braille display translating numerical and textual data displayed on the screen. This device allows students to read the content of each screen display. Textual and sequential information is easily converted, however the Braille display is poor at interpreting 3D images.

Photograph 5: Braille display located between the keyboard and screen

2.5 PROGRESS AND THE FUTURE

The written explanations and instructions on the Cisco CNAP screen displays have been converted to speech output. The tables, diagrams and graphics have also been converted to text and also speech output. Although the conversion of the written explanations has been fairly straightforward, the conversion of the illustrations has necessitated the use of the tools discussed above to supplement the vision impaired students' learning. The vision-impaired students respond quickly to the spoken materials and other teaching tools and move through the modules at a faster rate than the sighted students. At times the vision impaired students play and assimilate the speech output at very fast rates and the sighted students have difficulty keeping up the same pace. One of the notable differences in the learning styles of the vision impaired students is their need to repeat playing the modules several times to fully grasp what is being taught. The sighted students are able to remember the content more easily due to the visual clues.

The educational materials are being converted in line with the progress of the first intake of students. This intake has completed the CCNA1 program and are mid-way through the CCNA2. The second intake of students are part-way through the modified CCNA1 and are progressing at a much more rapid rate than the first intake. Members of the first group are showing improved self confidence in the use of the equipment and the teaching materials. Modifications to the CCNA1 program are currently being finalized ready for ‘boxed’ release by Cisco internationally for those Cisco Academies wishing to teach vision impaired students.

Although it was expected that the sight impaired students would achieve lower grades than the sighted students, this has not been the case. Prior to the commencement of the Cisco modules sighted students generally achieve slightly higher grades than the vision impaired students. The researchers have found that once the vision impaired students undertake the modified Cisco curriculum there is no discernable difference in the marks between the two groups. The average marks gained by the sight impaired students in both intakes so far (utilizing the modified teaching materials) do not differ significantly from those achieved by the sighted students using the traditional Cisco materials.

Two of the students from the first intake have now progressed to instructor stage and have successfully completed the Cisco Instructor certification for CCNA1. Both now teach the vision impaired students in the second CCNA1 intake. This is proving highly beneficial as the new intake students are responding well to instructors with similar disabilities and are moving quickly through the learning materials.

As the teaching materials for the vision impaired students have been in a constant state of change it has not been appropriate to compare the time taken by the sight impaired students to complete modules with those for the sighted students. Once the curriculum has been finalized it will be possible to do such comparisons.

Devices being evaluated for inclusion in the Cisco teaching materials for the vision impaired include further sound and speech devices, haptic and tactile interfaces. Sound devices include Earcons which produces different tones for different commands providing audio clues on top of speech; AsTeR (Audio system for Technical Readings developed by T.V. Raman) which provides rendering of technical documents and formula, and other devices providing pitched tones to indicate shading, superscript and subscripted information. Haptic and tactile devices (devices that allow users to interact with a computer via touch and other senses) include a force feedback pen, haptic mouse, force feedback joysticks and a tactile computer mouse. These devices and tools are being tested and used by the CAVI students and modifications made based upon their feedback, and successful tools will eventually be incorporated into the Cisco teaching programs.

Other devices are currently being developed within the Division of Electrical & Computer Engineering to aid the sight-impaired students. Some of the current research projects include a speech friendly packet sniffer, router simulator, XML to descriptive text, computer-based Brailler, Braille scanner to convert Braille into expanded text in real time, wireless stereo headset, screen reader for Mac OS X operating system, currency identifier, Auslan to text converter, and an ultrasonic white cane.

3 CONCLUSIONS

The CAVI program has enabled the Cisco e-learning curriculum to be modified for vision impaired students. Although only partially completed the project is providing positive results. The conversion of the CCNA1 program has been successful granting vision impaired students access to the modified e-learning material using multi-model interfaces and other high and low tech tools. Conversion of the Cisco CCNA2 and ITE programs are progressing at a much faster rate than the CCNA1 due to the consolidation of the successful methods of presentation to non-sighted students in the first phase.

Although the vision impaired students use the same laboratory and materials for their courses they have as a minimum an additional one hour scheduled per week in the lab to their sighted counterparts. They also have extra time to complete the on-line tests. It is rewarding to see that the vision impaired students are achieving comparable results with sighted students in the Cisco test modules.

In general the vision impaired students are more dedicated to learning and spend more time outside the classroom studying the material. As many of the CAVI students are already employed full-time the opportunity to become Cisco certified is important to them as an aid to their current jobs or to move to IT-related jobs.

Cisco has recognised Curtin University as the first vision impaired Cisco Academy in the world. The first two vision impaired Cisco Instructors are teaching other vision impaired classes. When sufficient vision impaired instructors obtain certification and the conversion of the CCNA and ITE materials is completed the Cisco Academy for the Vision Impaired will move to the Association for the Blind Western Australia, allowing the researchers to convert the remaining Cisco e-learning courses as well as focus on other research projects for the vision impaired.

Teaching vision impaired students requires non-traditional methods, particularly in an e-learning environment. The CAVI project is currently testing devices and methods developed by other researchers internationally. By working together the development of assistive technologies for the disabled, particularly the sight impaired, will progress much faster.

4 ACKNOWLEDGEMENTS

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