A Computing Education Vision for the Sight Impaired

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Abstract

Vision is the main sensory modality employed in learning. Teaching materials in the areas of information technology and computer engineering are highly visual in nature and vision impaired students find it increasingly difficult to access and process these visuo-centric learning materials and on-line delivery.

This paper describes a research project undertaken by Curtin University in conjunction with Cisco Systems and the Association for the Blind WA to identify tools and techniques appropriate for vision-impaired students studying computing at tertiary level. It investigates considerations and learning characteristics of sight impaired students, and also describes the aims of the project, the approach being undertaken to identify and apply alternative modalities. The paper concludes with a brief discussion on progress so far including some of the teaching aids used to assist learning complex concepts usually delivered by visual means.

Keywords: Vision, computing, teaching IT, sight impaired, blind, multimodal learning.

1 Introduction

Education in information technology and engineering at tertiary level encompasses understanding and applying theory in addition to hands-on practice in order 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. The more complex the model, the more complex the visual effects used, 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 on-line learning is increasingly being used to deliver coursework in higher education and vocational training environments.

The main aim of this paper is to describe a research project currently underway to identify and apply alternative means of presenting visuo-centric engineering and information technology teaching materials to vision impaired students.

2 Vision in Learning

The concept of the traditional learning environment has existed since the 1930s (Goh & Fraser 1998), and the conventional classroom environment has been the focus of learning environment research over the past 25 years (McRobbie, Fisher & Wong 1998, Tobins & Fraser 1998). The move to research in an on-line and e-learning environment is a recent phenomenon in the quest to increase accessibility to learning materials.

Vision is the primary integrating sense within learning and development (Kelley, Sanspree & Davidson 2000, Levtzion-Korach, Tennenbaum, Schnitzen & Ornoy 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. 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 differential conceptualizations and understanding of phenomena. 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.

One of the main deprivations caused by blindness is the problem of access to information. Visualisation is an increasingly important method for people to understand complex information, and 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 users to easily comprehend instructional materials.

A research project within the Department of Electrical & Computer Engineering at Curtin University is modifying the Cisco Network Academy Program (CNAP) to develop an e-learning environment for vision impaired students. This project is being undertaken in conjunction with the Association for the Blind WA and Cisco Systems. 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.

3 The Vision-Impaired Learner

It is important to recognize that there are different forms of vision impairment, ranging from the congenitally blind, who are blind from birth or from a very early age, through to the adventitiously blind, who lose their sight in varying degrees as a result of accidents, disease or the affects of medication. Some forms of sight impairment can be treated and improved or reversed, however congenital blindness is normally permanent.

The difference between temporary and partially sighted students and permanently blind students is considerable, particularly with relation to student expectations and staff support as the two groups exhibit different study patterns and difficulties (Shepherd 2001).

Of more concern in specialist fields such as information technology and engineering are the effects of the impairment on the student's ability to comprehend essential parts of the curriculum, normally taught using visual means. Specific conditions relating to vision impairment and their effect in a visuo-centric learning environment are summarized in Table 1. Although Mann (1999) developed this list for disciplines involving fieldwork, the majority of these conditions also impact learning in a computing and engineering environment.

In general, medical conditions resulting in vision impairment are likely to affect the following visual capabilities of students (SSC, 2000):

- Ability to see details
- Contrast sensitivity
- Colour vision
- Accommodation to changing light levels
- Width of visual field
- Changing focus
- Seeing moving images
- Sensitivity to glare.

Condition	Impact
Ocular Albinism	Difficulties with scanning, tracking, depth perception, rapidly shifting visual points, reading
Cataracts	Wide variation in visual acuity (thought full visual field usually maintained) and near and far vision often adversely affected
Diabetic Retinopathy	Fluctuating visual acuity, distortion of vision, and possible impairment of visual field
Glaucoma	Progressive loss of visual field, poor visual acuity, impaired peripheral and night vision, and difficulty in adapting between light and dark
Macular Degeneration	Loss or central vision (hence reliance on eccentric or sideways looking), difficulty in discerning fine detail and reading, and problems in colour discrimination (especially reds and greens)
Nystagmus	Blurred vision, difficulty in scanning and tracking, and problems with depth perception
Optic Atrophy	Variable loss of vision and/or total blindness
Retinitis Pigmentosa	Night blindness, narrowed field of vision (resulting in tunnel vision)

Table 1: Impact of vision impairment conditions
(Mann, 1999)

The above factors will affect the vision-impaired student's ability to physically see pictorial representations presented on a computer screen.

In the experience of the authors the comprehension of visuo-spatial material by sight-impaired students in computing-related disciplines appears to be affected by a number of factors including:

- The sensory systems used to absorb the basic spatial concepts and data,
- The use of different dimensions for presentation of the data (ie 1D, 2D, 3D),
- The dynamic nature of the data and images,
- The use of symbols to represent data and concepts,
- The perspective from which pictorial data is viewed, and

- Any rotation or movement of the images, symbols or data.

This has raised the challenge to discover alternate methods of effectively presenting education material, and visuo-spatial material in particular, to blind students in the IT field.

4 Overview of the Project

In conjunction with the Association for the Blind WA and Cisco Systems, the School of Electrical & Computing Engineering have embarked upon a two-year program to investigate the needs of vision impaired students subjected to on-line education courses in computing, and develop alternate means of accessing and presenting the teaching and learning materials.

The research will focus 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 first area will investigate the use of force-feedback (haptic), 3D sound, Braille and speech output as methods to overcome access problems associated with low vision. The second area will study the comprehension of visuo-spatial concepts and images by blind students in order to identify not only those modes and representations difficult to comprehend, but also those easily assimilated. The materials posing cognitive assimilation difficulties can then be converted into formats more readily understood by blind students.

The researchers have been teaching the Cisco Networking Academy Program since 2001. This program is an e-learning model that delivers web-based educational content, online testing, student performance tracking, and instructor training and support in addition to hands-on labs. It is the result of an alliance between Cisco Systems, educators, governments, international organizations, leading technology companies and non-profit organizations to prepare graduates for the demands and opportunities of the new global economy.

The research being undertaken aims to examine both the unique accessibility requirements and the optimum learning environments for computing students with vision impairment. The research will utilize the existing, successful curriculum for the on-line Cisco Network Academy Program with the following objectives:

- Describe the difficulties that students with vision impairment face when trying to access or visualise information and concepts
- Investigate how students with severe vision impairment can utilize cognitive and perceptual properties of non-visual sensory modalities to learn (as compared to sighted students)
- Develop new visualization techniques utilizing various feedback methods to allow students with vision impairment to use and understand complex and visuo-spatial information and concepts
- Develop a novel user interface explicitly designed to deliver technological and engineering skills to students with vision impairment, and
- Investigate how these new techniques can be incorporated into future systems.

The final product will be a train-the-trainer manual, and training module, designed to assist teachers involved in the delivery of technology subjects to create accessible learning environments for students with impaired vision.

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. However, the curriculum is 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 diagram is 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.

Task analyses will be carried out individually with current students to gain an understanding of the human computer interface as it relates to students with vision impairment. The strengths and weaknesses of the existing interface are being identified and this will act as a comparison to examine and improve the current methods of e-learning in this area.

In-depth interviews and focus groups will be held with students with vision impairment to describe the difficulties they encounter when learning complex concepts without access to visual information and the strategies that they utilize (cognitive, perceptual, visualization, etc). It is estimated that a minimum of 20 students with vision impairment will be willing to participate in the program.

As the researcher is inevitably part of the research process in an project of this type, the action research methodology is proposed. 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.

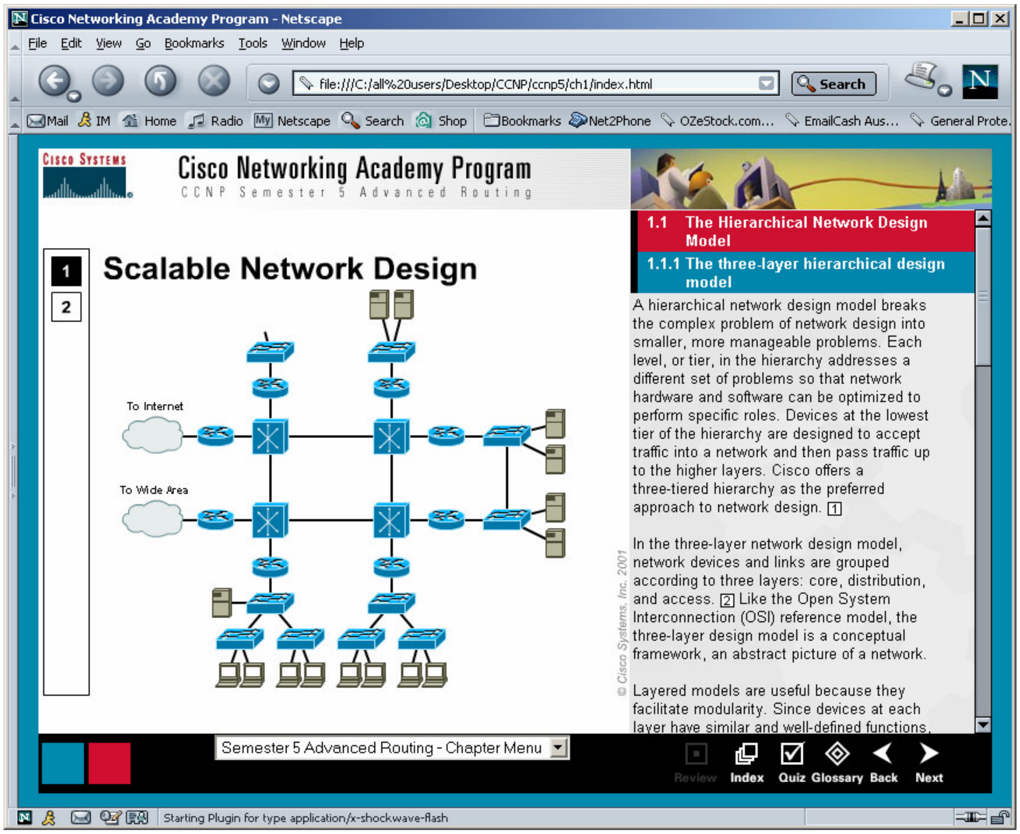

Figure 1: CNAP curriculum delivery example

5 Progress So Far

The School of Electrical & Computing Engineering has been delivering the first section of the CNAP to students with vision impairment for the past six months. Five students formed the first intake, and there are nine students currently in the second intake. Within the second intake five of the students are totally blind and four have very low vision. All participating students are legally blind (having <5% vision). There are an additional six blind students on the waiting list for the third intake.

The blind students use the same materials, assessments, laboratories, equipment and teaching staff as the sighted students. The blind 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 blind students.

In the experience of the authors, sight impaired students have not only the hurdles of impaired physical vision to contend with, but they also lack in self-confidence, resulting in a reticence to play or experiment. Students admit they fear they may 'break something'.

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.

The second serious learning obstacle observed in students with serious vision impairment is their difficulty to comprehend spatial concepts. Jacobson, Kitchin, Garling, Gollege and Blades (1998) presented the difference theory of spatial cognition, proposing that the cognitive map knowledge of adventitiously blind persons are different from sighted persons (rather than underdeveloped or used inefficiently). Individuals with no or limited vision rely on sequential learning using tactile, proprioceptive and auditory senses to construct spatial relationships and in absolute terms, limited vision leads to limited spatial knowledge (Bigelow 1996). Hence an alternate means of developing an understanding of more than two dimensions is required for those students with serious vision impairment. 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. Additional alternate methods of presentation of visuo-spatial materials will be incorporated as the research progresses.

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. Examples of both high and low technology are being used. Some simple tools used are pipe cleaners to describe syn waves, blocks of different shapes and sizes to illustrate network models such as the OSI model, peg boards for binary conversions and the use of speakers instead of oscilloscopes to define frequency and amplitude. Figures 2 and 3 illustrate two of the methods used to facilitate learning for the vision impaired students.

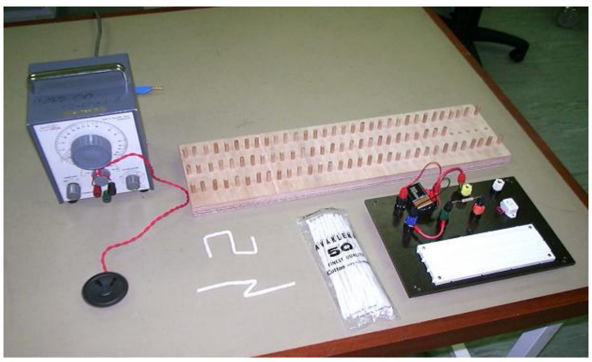

Figure 2: Pegboard for binary-hexadecimal-decimal conversion

The written explanations and instructions appearing on the right hand side of the screen display of the CNAP materials (as illustrated in Figure 1) have been converted to speech output. The vision-impaired students respond quickly to the spoken materials and move through the modules at a much faster rate than the sighted students. At times the vision impaired students play and assimilate the speech output at very fast rates to the amazement of the sighted students who have difficulty keeping up the same pace.

Figure 2 shows a very simple pegboard used to convey methods of binary-hexadecimal-decimal conversion. 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.

Complex equipment is also used to convey other graphical information. Figure 3 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.

Figure 3: A Braille display

Other devices are currently being developed within the Division of Electrical & Computer Engineering to aid the sight-impaired students. Additional devices to be investigated as part of the research include haptic interfaces (devices that allow users to interact with a computer via tactile communications), for example the PHANToM (a high performance, 3D haptic interface from SensAble Technologies), force feedback joysticks and a tactile computer mouse based upon touch.

Although it is very early in the research to identify trends, five vision-impaired students have now completed the first of four modules with grades comparable to those of their sighted peers. Tests were attempted by 24 sighted students and 5 blind students before commencement of the first module and subsequently for the first four modules in the Cisco program. The marks for the first test for sighted students ranged between 35% and 95% with an average of 52%, and the marks for blind students ranging between 7.5% and 90% with an average of 47%. Results for modules 1-4 for sighted students ranged between 83.3% and 100% compared with a range of 86% to 98% for blind students. Both groups showed an average mark of approximately 92% for modules 1-4.

The research so far has concentrated on the physical access and delivery of the Cisco materials to blind students. The second avenue of investigating the comprehension of visuo-spatial concepts and images by blind students is still in the early stages. However, the progress so far is promising, with not only encouraging academic results, but also noticeable changes in the self-confidence of the vision impaired students. An additional benefit to date has been the development of a unique program to teach the vision-impaired students general IT skills as well as an in-depth knowledge of network design.

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