A Computing Education Vision for the Sight Impaired

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Abstract

Vision is the main sensory modality employed in learning. Vision impaired students thus find it increasingly difficult to access and process visuocentric 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 the learning characteristics of sight impaired students, and also describes the aims of the project, the approach taken in identifying and applying alternative modalities, and 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 visuocentric 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 in particular (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). Where there is conflict between several sensory inputs vision either dominates or modifies the percept from other modalities (Shore et al. 2000). 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 allow users to feel and hear instructional materials (GIST, 2000).

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). The area of information technology was singled out as being problematic and recommendations included the need for professional development for lecturers and development of improved access to information technology and electronic educational materials.

3 The Vision Impaired Learner

It is important to recognize that there are different forms of vision impairment, ranging from the congenially 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 the congenial 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). Table 1 is a useful guide to the differences between totally blind and partially sighted students.

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 visuocentric learning environment are summarized in Table 2. Although Mann (1999) developed this list for disciplines involving fieldwork, the majority of these conditions also impact learning in a computing and engineering environment.

Blind	Partially Sighted
Unlikely to be able to use print without some adaptation	Can see in certain conditions
Unlikely to be able to produce handwritten work	May be able to cope with print but take longer to read it
Likely to have difficulty in note-taking	May be able to produce handwritten work
Likely to have difficulty producing written assignments	Has probably been educated in mainstream schools
Likely to have particular mobility difficulties	May be able to use low-vision aids in classroom settings
Likely to have to rely on listening rather than watching	Will probably not use Braille
May have problems with spelling and specialist vocabulary	
May have problems in group discussions	
May use Braille	

Table 1: Differences between blind and partially sighted students (Adapted from University of Edinburgh handout on student disability, cited in Shepherd, 2001)

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 2: Impact of vision impairment conditions (Mann, 1999)

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.

4 Overview of the Project

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 existing, successful curriculum for the on-line Cisco Network Academy Program (CNAP) 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 information
- 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.

As the researcher is inevitably part of the research process in an undertaking 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.

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 the teaching and learning materials.

Force-feedback (haptic), 3D sound, Braille and speech output are being investigated as methods to overcome access problems associated with low vision.

The researchers have been teaching the Cisco Networking Academy Program since 2001. The CNAP 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 nonprofit organizations to prepares graduates for the demands and opportunities of the new global economy.

The course 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 webpages, 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.

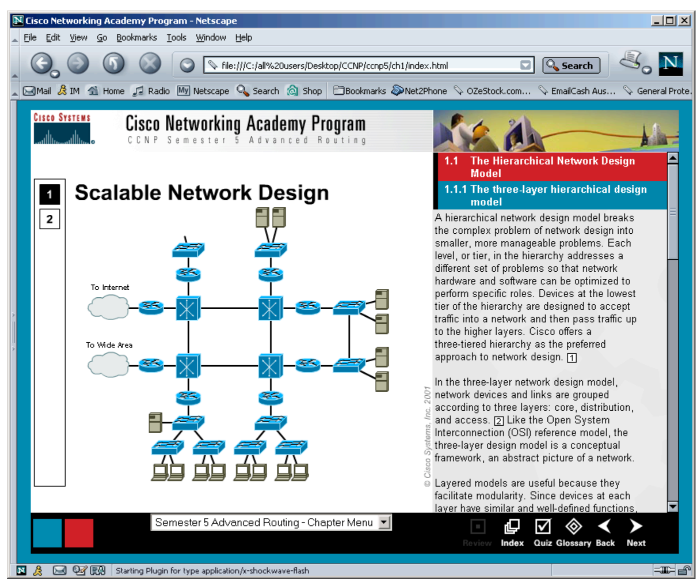

Figure 1:

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.

5 Progress so Far

In conjunction with the Association for the Blind WA and Cisco Systems, the School of Electrical & Computing Engineering has been delivering the CCNA course to students with vision impairment for the past six months.
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 in case they break something. The need to ‘play’ 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.
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 CCNA 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. These strategies include the use of force-feedback (haptic), 3D sound, braille and speech output.
Examples of both high and low technology are being used. Figure 2 shows a very simple pegboard used to convey methods of binary-hexadecimal-decimal conversion.

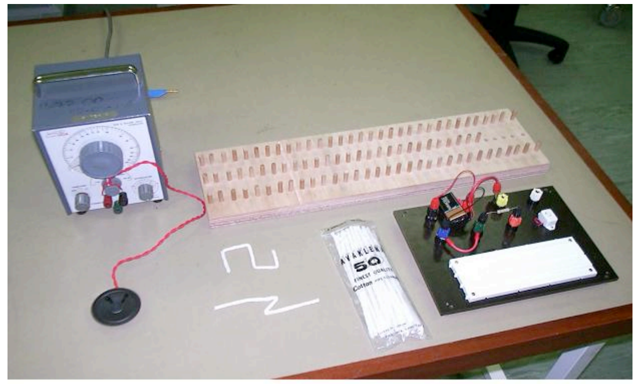

Figure 2: Pegboard for binary-hexadecimal-decimal conversion

Students place a peg in the hole to represent “1” and no peg for “0”. 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. Other devices are currently being developed to aid the sight impaired students. Additional devices to be investigated include devices similar to the PHANToM (a high performance, 3D haptic interface from SensAble Technologies), force feedback joysticks and a tactile computer mouse based upon touch.

Figure 3: a Braille display

Three vision impaired students have now completed the first of four modules with grades exceeding those of their sighted peers. Another five students are currently enrolled.

6 Conclusion

An additional benefit so far 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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