Tackling Inclusive Education Through Innovations in Accessible Graphics

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Abstract
Difficulties obtaining and understanding alternate formats of graphical information serve as a barrier to success for those with a vision impairment. Emerging technologies such as 3D printers and low-cost electronics, however, can afford new ways to create and present graphical information. We have conducted a number of exploratory studies investigating the use of new technologies for accessible graphics with promising results. We will discuss the potential for implementation in the classroom and barriers to be overcome.

Author Keywords
Accessibility; Blindness; Mapping; Orientation and mobility training; 3D Printing; Vision impairment

ACM Classification Keywords
H.5.2. [Information Interfaces and Presentation]: User Interfaces - Input Devices and Strategies Human Factors, Experimentation

Introduction
Access to graphical information is vital in education and for day-to-day living. Maps, plans, tables and diagrams are ubiquitous, providing key information and informing our world view. The provision of graphics that are accessible to people with a vision impairment presents significant challenges in terms of cost, timeliness, effectiveness and ex-

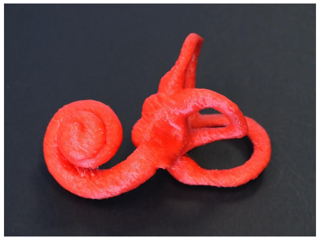

Figure 1: 3D printed model of the inner ear, obtained through free open source library Thingiverse.

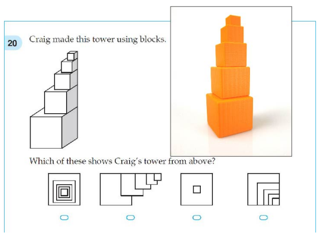

Figure 2: Simple 3D print to support numeracy test materials.

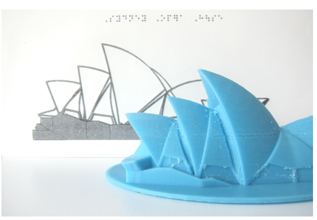

Figure 3: 3D model of the Sydney Opera House with corresponding tactile graphic, used to teach projection.

pertise. The resultant paucity of accessible graphics has implications for access to information and experience necessary for skills in understanding graphics.

Currently, one of the most common formats for accessible graphics is tactile diagrams/raised line drawings. Swell paper or embossed diagrams are relatively fast to produce but require a skilled transcriber to modify the original image to suit the new format, as well as specialist printing equipment and paper. The graphic itself also has limitations, for example in the number of areas that can be distinguished and the representation of 3D objects using only two dimensions.

The emergence and widespread adoption of new consumer level technologies, such as 3D printing, opens up the possibility of new forms of accessible graphics. In this position paper we present an overview of our work exploring the use of new technologies for the provision of accessible graphics in education and beyond.

Emerging Technologies

Computer-mediated technologies have been a key area of accessible graphics research during the past decade. These include: sonification, e.g. [1]; haptic feedback, e.g. [7, 3] and combined audio and haptic feedback, e.g. [4]. However, the technology that could have the biggest impact on the future of accessible graphics provision may be 3D printing. 3D printing allows the quick and affordable creation of accessible 3D models in the school, workplace or home. Models are specified digitally and can be distributed and stored electronically. Importantly, the cost of 3D models is in line with that of tactile graphics.

Technologies underlying audio and haptic feedback are now freely and cheaply available as part of the "maker movement". Capacitive touch sensors to trigger audio, and haptic motors to provide feedback, open up a range of possibilities for augmenting 3D printed objects.

Applications for 3D Printing in Education Accessibility

In a recent survey of over 70 vision impaired students in Australian Higher Education, 94% felt that the provision of graphical information could be improved. Key issues included timeliness, difficulties collaborating with others, and impact on choice of study area. Over 80% of students reported missing out on content because it was inaccessible. Technology-related solutions such as 3D printing and software solutions were rarely used but were wanted. [2].

We conducted a number of pilot studies with educators in vision impairment, blind adults and accessible formats producers to identify the key areas in which 3D printing could meet an unmet demand for access to graphics [5]. We also worked closely with staff at the Insight Education Centre for the Vision Impaired. We then went on to explore these areas in greater detail in a series of projects.

Curriculum materials - STEM and Geography

Perhaps the most obvious application for 3D printing in the classroom is the representation of inherently 3D objects taught as part of the curriculum. Common examples include 3-dimensional shapes in mathematics and physics; anatomy, biology and chemistry models (Figure 1); and geographical landforms. While some such objects can (and should) be easily sourced elsewhere, many can most quickly and cheaply be created using 3D printing. As a case study, we examined the occurrence of complex 3-dimensional shapes represented in national test materials. At present, some questions are removed due to difficulty in representation using a tactile graphic. Work undertaken to date has been successful in demonstrating that these questions can be supported using 3D-printed models (Figure 2).

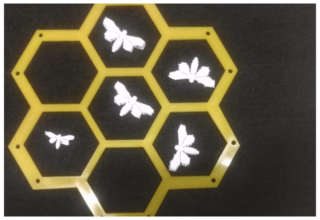

Figure 4: E-textiles playmat with buzzing 3D printed bees and laser cut beehive.

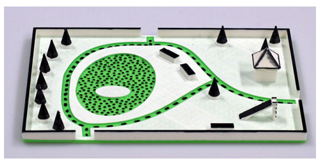

Figure 5: 3D printed representation of a park, used to determining the efficacy of 3D printing for accessible maps.

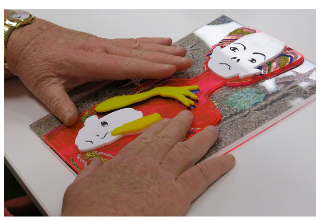

Figure 6: Layered laser cut representation of the painting "i ate the rainbow up..." by Del Kathryn Barton (2008).

Tactile Literacy

One of the disadvantages of tactile graphics is the level of tactile literacy required for their understanding and use. Students must be taught how to navigate the page and build up an understanding of the conventions used to represent a 3D object as lines and textures. We have found evidence that 3D models provide a more intuitive interface that better mimics the way blind people understand with their environment [5]. Furthermore, we would argue that 3D models can be used alongside corresponding tactile graphics to teach concepts of visual representation such as outlines, occlusion and projection. For example, the Sydney Opera House is a complex building that most blind adults have been unable to understand through description or tactile representation, however exposure to a 3D model provided their first meaningful insight into its structure. Additionally, the 3D model provided a means of understanding the conventions used in a tactile representation when provided alongside a tactile graphic. (Figure 3).

For early childhood, we have explored technology solutions for creating fun interactive story book materials to encourage tactile exploration and develop tactile literacy. For example, we created of an e-textiles playmat with vibrating, buzzing 3D printed bees to accompany a poem (Figure 4).

Orientation and Mobility (O&M)

Educators and O&M specialists agree that 3D maps could be valuable to support vision impaired students learn about their often complex environments. We explored the use of 3D printed maps for conveying O&M information (Figure 5). In a direct comparison with equivalent tactile graphics, it was found that 3D models were preferred, facilitated better recall and resulted in more accurate route-finding [5].

Art and Design

Extending beyond the realm of information to participation in culture and society, 3D printing and other emerging technologies offer new opportunities for students to participate in culture and society through creation and access. We partnered with the world-renowned Bendigo Art Gallery to explore low-cost technology solutions to provide access to their artworks for vision impaired visitors. Techniques used include 3D printing, laser cutting (Figure 6) and touch screens with audio feedback.

Classroom Adaptations

One of the advantages of 3D printing is that it is a mainstream solution, with accompanying low costs and a large community of users. A 3D printer in a classroom would not be used solely for the creation of accessible materials as it has many other potential applications. Among these are the creation of tools to assist with adaptions for the classroom such as the creation of a magnifier stand, sturdy braille signage, or personalised name stamps for a pottery class. Such uses add value to the acquisition and support of a 3D printer in the classsroom.

Audio Enhancement

One limitation of 3D printing is the reduced ability to provide additional contextual information via braille and braille keys. The use of Arduino-based boards in combination with capacitive touch points is being explored to augment 3D maps with detailed audio information. For example, we created a University Campus map (Figure 7) with touch points on the main buildings to convey different levels of audio information using taps, double taps and holds [5]. Similarly, the use of RFID tags attached to a 3D model, which when tapped on a receiver can "tell" the user about itself, is proving to be a simple yet effective way to tackle the issues as well.

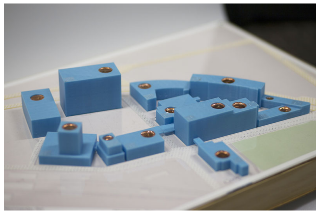

Figure 7: Audio-augmented 3D printed map of the Monash University Caulfield Campus

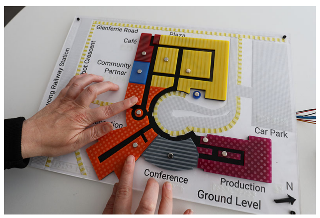

Figure 8: Audio augmented laser cut acrylic floor plan of the Vision Australia Kooyong office.

Key Challenges and Future Directions

Work to date suggests that the use of 3D printing and other emerging technologies offer much for the continual improvement of the provision of accessible graphics and inclusive education in general. We see the following as key priorities in continuing this work:

- Continue formal comparisons of 3D printed objects with tactile diagrams.
- Develop evidence-based guidelines for the design and production of 3D printed accessible objects: Clear guidelines for the design and teaching of tactile graphics have been developed through years of experience, e.g. [6]. Similar guidelines are required for the use of accessible 3D models and interactive labels to assist creators in making optimal design decisions and ensure that best practice is attained.
- Develop guidelines for tactile literacy: This includes both how 3D models can be used to assist in an understanding of tactile graphics, and study of the differences in tactile exploration techniques required for 3D models compared with tactile graphics.
- Support implementation: 3D printing demands new technical skills both for the design/modification of 3D models and the use/maintenance of 3D printers.

Collaborative support for educators from researchers, the maker community and accessible formats standards bodies will be vital for implementation of new technologies in schools. In 2018 we will partner with the Victorian Department of Education Department to pursue these issues.

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