Institution: Liverpool Hope University

Unit of Assessment: Computer Science and Informatics

Title of case study: MAGIC2VIP: Making Accessible Graphic Information Context to Visually Impaired People

1. Summary of the impact (indicative maximum 100 words)

This project has made a considerable impact on the teaching of Geometry to school pupils with visual impairment thus ultimately enhancing their teaching and learning experience and quality of life (pupils and teachers from schools in remote villages in the states of Tamil Nadu; Andhra Pradesh; and Kerala in India). The Tactile Graphic Tool (TGT) designed as part of this project is a device allowing hand exploratory movement in making tactile diagrams of graphical and geometrical constructions and then portable digital device (e.g. DigiMemo A402 or a tablet PC) is used to make these accessible as digital pictures through the interface of a computer. The benefits of the tools developed have been in assisting people with visual impairment to overcome the challenge of accessing graphic information contents in mathematics, including graphs, geometry and statistical representations. In particular, the case study's impact represents a practical demonstration of the potential of technology-assisted learning for visually impaired students and is aimed at enhancing their educational and workplace opportunities, as well as access to popular media.

2. Underpinning research (indicative maximum 500 words)

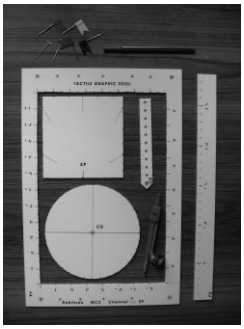
This research is in the area of Human System Interaction-design (or aka HCI) and underpinning this impact case study is a HEIF (Higher Education Innovation Funding) funded project entitled "***MAGIC2VIP: Making Accessible Graphic Information Context to Visually Impaired People***". The central motivation for the research derives from the fact that the progressive stages that are involved in teaching practical geometry, graph constructions and statistical representations include exploratory practical experience, which people with visual impairment have no direct means of acquiring during their learning process. MAGIC2VIP was, therefore, aimed to contribute to the teaching and learning of mathematics education for people with visual impairment, and enable them to draw or produce pictures, graphs and diagrams with greater accuracy and using the same pedagogical approach that a person with normal vision would adopt. Graphical information contents such as graphs, statistical representations, geometry constructions and technical, scientific on-line documents that involve mathematical and non-linear expressions pose a great challenge to '*print disabled*' people (persons who are unable to read standard printed material due to blindness, visual disability, physical limitations, dyslexia, etc.). The challenge is much greater for them while making or drawing such representations. The objective of the research work was to mainly make *assistive and adaptive devices barrier-free and inclusive* so that picture based non-linear contents become accessible for print disabled students.

While learning diagrammatic concepts (graphs, statistical representations, and geometry constructions), vision-impaired students need to understand the intermediate stages of drawing or constructions. So, the assistive device needs to provide an avenue to explore by hand the intermediate stages. Similarly, while teaching vision-impaired students geometric and diagrammatic concepts, resource teachers or special educators need to display and demonstrate the intermediate stages. Hence the need is to design an assistive device that complies with *universal design principles*. The 'Tactile Graphic Tool' (TGT) designed and developed is cost-effective, adaptive and serves as a tool for an inclusive education environment.

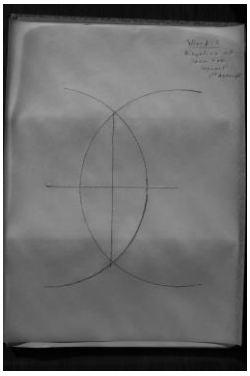
Researchers and Dates of Research: This HEIF funded project was led by Prof Atulya Nagar of CAMSS and the research was conducted between October 2009 and June 2013. It is a joint collaboration with Dr Robinson Thamburaj, who is a Visiting Senior Research Fellow at CAMSS and an Associate Professor of Mathematics at Madras Christian College (MCC-a partner HEI of Hope in India); as well as a Disability Science expert Prof Yoshiko Toriyama, who is a Professor at the University of Tsukuba, Japan. Dr Thamburaj was on leave from MCC on a Leverhulme Trust Visiting Fellowship at CAMSS from 12th October 2009 to 11th October 2010 and Prof Toriyama visited the CAMSS during that period. Dr Thamburaj has been associated with Prof Nagar since 2005/06 and works in the area of Theoretical Computer Science (P-systems) as well as Disability Science and Assistive Technology. Since 2010, Dr Thamburaj visits the CAMSS at least twice annually and has been working with Prof Nagar (and other members of CAMSS in general) on this and other project. The impact of this work took place during April 2010 to June 2013.

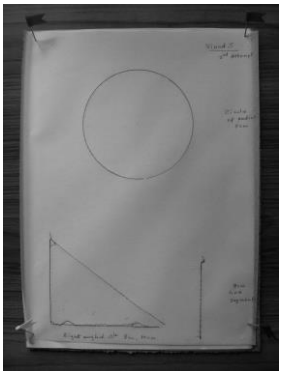
Brief description of Tactile Graphic Tool (TGT) and its modification: TGT is a set of templates

and frames of 2 mm size white acrylic sheet with v-notches and black tactile markings placed at specific positions. The templates include a rectangle perforated reversible tactile grid plate; a tactile scale, a tactile circular disc, a tactile square protractor and a tactile compass scale (as shown in the Figure). There are pinholes with tactile indications and v-notches at specific positions. TGT provided a suitable avenue for exploratory hand movements in the making of tactile diagrams. This tool is also mountable on a portable digital pad and makes the picture or graph drawn as a digital file simultaneously. For this purpose an A4 sized digital pad '**DigiMemoA402**' was identified and used. The DigiMemoA402 is a device with storage capability that captures the scripts written or diagrams drawn on its surface using ink. The content written or drawn thus is transferred, organised or edited when connected to a computer. The storage capacity for number of pages varies depending on the memory storage device. The annular template (of dimensions 295 mm X 200 mm) with its annular frame is modified to fit on the A4 size area of the digital pad. A cork sheet of 5 mm thickness is used as for the pad to sense the inking pen there is a limitation of 14 mm proximity. Apart from flat headed pins, folded pins are used to mark coordinate positions of the annular frame. The picture drawn by TGT is simultaneously stored in Digimemo. Then the picture content is imported as an e-book file through pre-installed manager software in the PC. The picture thus saved can further be edited, resized or saved as image file type.



Working principle of TGT: TGT works on a simple principle that *when a stylus or sharp pen is pressed on a 'German film' placed on a soft rubber backing pad, raised lines are produced*. ('*German Film*' is a translucent and lightly textured polymer sheet. A touch-detectable raised line forms when drawn upon with a simple scriber or ballpoint pen on a soft rubber-backing pad). TGT is best utilised when the subject is taught geometrical and diagrams using the technique of 'progressive step method' for teaching the concepts.





Special features of the tool: TGT is a classroom device for students with special needs, especially those print disabled as well as other students (from specialist secondary schools), thus making it an inclusive educational geometry drawing kit. As described above, TGT is a collection of 2mm thick acrylic templates. The contrast black coloured Braille, tactile indicators and v-notches provide easy identification of measurements for people with low-vision or partial sight and the vision impaired. The templates, backing rubber pad etc. are packed in an A4 sized box, making the kit handy and compact. Safety is considered by using flat-headed pins, and the edges of the box are curved. TGT is mountable on a digital note taker (DigiMemo), hence making digital conversion of hand-drawn diagrams possible. In the pictures (with permission from the student) above a fifteen year old 'X^{th}-standard (year 10)' totally blind student is shown using the TGT tool (from St. Louis School for the Blind, Adyar, Chennai, India– which is a specialist blind school in a remote and hard to reach village in India whose pupils are usually from poor and under privileged families). The initial orientation and first two sessions took 20 minutes each. After the third session he handled the tool with ease and was quicker in drawing basic shapes and plotting and drawing graphs of linear equations.

3. References to the research (indicative maximum of six references)

The research from this project was presented in a specialist conference entitled *International Conference on Computers Helping People with Special Needs* (ICCHP), which is a series of biannual conferences in the area of ICT/Assistive Technologies (AT) for people with disabilities and the aging population. The conference has a tradition over 22 years of supporting people with disabilities, run in co-operation with the Johannes Kepler University, Linz; and the Austrian Computer Society. The conference proceedings are published in *Lecture Notes in Computer Science* (LNCS), Springer, where output [1] was published. The extended version of the work was subsequently published [2] in an Open Access journal entitled: *International Journal of Computer*

and Electronics Research (IJCER).
1. Thamburaj, R. and Nagar, A. K. (2010). *Tactile Graphic Tool for Portable Digital Pad*, In: Proceedings of the 12th international conference on Computers Helping People with Special Needs, Lecture Notes in Computer Science (LNCS), Vol. 6180, Springer-Verlag Berlin, page 403. DOI: 10.1007/978-3-642-14100-3_60.
2. Thamburaj, R. and Nagar, A. K. (June 2013). *Adapting Tactile Graphic Tool for Portable Digital Pads and Tablet PCs*. International Journal of Computer and Electronics Research (IJCER), Vol. 2, Issue 3, page 33. ISSN: 2278-5795.

The research was done during Dr Robinson Thamburaj's visit to CAMSS on a Leverhulme Trust Visiting Fellowship from 12th October 2009 to 11th October 2010 and then work continued until June 2013. HEIF funding was used for the development of the TGT took-kit (including the purchase of materials etc) and participation in the ICCHP conference (output [1]).

4. Details of the impact (indicative maximum 750 words)

Prior to the experience of using TGT, students were only using a *Taylor frame* for making basic shapes while studying geometry. The procedure of geometric constructions was dictated by the class teacher and was written as Braille notes; the students memorised those procedures. In the examination, the students used to narrate the memorised procedure of the constructions and the scribing sighted volunteers did the actual drawing of the construction. In the experiment using 'Tactile Graphic Tool' as part of this project, the students made the tactile geometrical pictures of polygons and lines by themselves. They could also draw geometrical constructions by themselves with this assistive device. *The students were excited that it was their first ever experience of drawing tactile diagrams*. The orientation session was time consuming, as the subjects had to familiarise with the templates and learn the hand and finger coordination of holding the templates and drawing. The tactile drawings of shapes on microcapsule (swell) paper were found to be essential in the initial sessions. The quality of the drawings improved significantly after the subjects learned to apply less pressure and coordinate the hand accordingly. *With TGT, these print disabled students were able to make tactile (raised line) diagrams of graphs, geometrical shapes and statistical diagrams as any normal student would do in mainstream regular classes*. This enhanced the understanding of drawing mathematical diagrams. The TGT tool was used with students of specialist Blind schools (e.g. St. Louis School for the Blind, Adyar, Chennai, India) which are in remote, hard to reach, village areas and the students themselves are from poor and underprivileged families.

The impact of the research on improving the teaching and learning processes of visually impaired students has been acknowledged by special education centres for the blind in India and the UK, such as: St Vincent's specialist school for sensory impairment and other needs at Liverpool; specialist blind schools in India; UNESCO India; and the Government of India/Tamil Nadu in India. The impact of this research has been well demonstrated at an internationally recognised centre committed to supporting blind and partially sighted people, namely the *National Institute of Visually Handicapped* (NIVH) at Chennai (India). The NIVH is a leading charity offering information, support and advice to almost two million people with sight loss and visual impairment, and are passionately committed to providing technological support to enable the blind and partially sighted to live an independent and fulfilled life. NIVH is a premier Institute in the field of visual disability, working under the administrative control of the *Ministry of Social Justice and Empowerment of the Government of India*. The Institute is concerned with the task of empowering the visually handicapped by encouraging and supporting the development of innovative technologies. The choice of NIVH to deliver this strategic vision of Hope was on the basis that NIVH is a leading organisation for blind and visually impaired people, and shares the same vision of empowering the visually handicapped through the use of innovative technologies centred on people-oriented requirements. This ensures that the MAGIC2VIP research has had a significant and broad impact, across geographies, on the educational empowerment of the blind and partially sighted people. As mentioned above, this project on the use of TGT was piloted with St. Louie's School for the Blind in Chennai, including tools to teach Kolam patterns and play Sudoku. Staff and students of NIVH and St. Louie's School were involved in all stages of the design and development of the TGT tool to ensure that usability issues were adequately met. Each aspect of the tool has been tied into current knowledge of geometry and technology-supported learning for the visual impaired. At NIVH specific activities were used to broaden the reach of the MAGIV2VIP, which highlighted particular impacts as detailed below:

1. The Government of India through the National Institute for Visually Handicapped (NIVH) conducts human resource development programmes for special educators and resource teachers of blind schools. The Rehabilitation Council of India (RCI), the nodal agency that regulates and monitors the services given to persons with disability in India, approves these programmes. The southern Regional Centre of NIVH at Chennai conducted training programmes for resource teachers and special educators of schools from rural districts of the southern states Tamil Nadu, Kerala, Andhra Pradesh during 2012 and 2013. The techniques and tools developed and modified through MAGIC2VIP at Liverpool Hope University were introduced and demonstrated at the training programme on "*Teaching Algebra and Geometry at Post-primary level*" (10 – 14 December 2012) and a refresher course on "*Teaching Arithmetic at Primary level*" (28 January – 1 February 2013). The students and teachers who had the hands-on experience felt they had benefitted and gave their feedback, some of which is given below (some of the feedback sheets are in Tamil language and can be obtained from the HEI):

(a) "it is much better than the existing tool because of its simple method with very few steps to draw tactile pictures"; **(b)** "Yes, In a single board students can learn graph, geometry, drawing any shapes"; **(c)** "It will be easy to learn and draw by the visually impaired & totally blind"; **(d)** "measurements can be drawn precisely" (translated from Tamil); **(e)** "it is better to handle than wooden models" (translated from Tamil); **(f)** "It is easy to handle for the visually impaired children"; **(g)** "I can teach the steps better to my students through this tool" (translated from Tamil); **(h)** "better than existing device, very clear methods"; **(i)** "it is totally different from ordinary tools"; **(j)** "looking nice, attractive and weightless also".

2. The TGT tool (geometry kit) has become a key resource for teaching mathematics and tactile geometry in many of the government sponsored workshops conducted by NIVH.
3. Potential avenues for patenting the TGT tool have been highlighted in discussions with interested stakeholders concerned with supporting the visually impaired, and are being pursed. In a letter from the Regional Director of NIVH, he noted that he would be delighted to see any concrete steps taken towards making the TGT tools available for the need and benefit of students in blind schools.
4. During the workshop at Hope, Prof Toriyama demonstrated tools for teaching Science in general and Geometry in particular; she did a public demonstration so that participants from local schools could see and consider the work being done and the philosophy. This workshop was very well received and some very valuable feedback was collated. The feasibility of using the TGT tool kit as inclusive, cost effective and portable make this relevant for math and statistical education in any developing nation.

This work continues to progress as a joint project between MCC (India) and Hope, with on-going discussions about a joint spin-off company for mass production and supply of the Geometry toolkit to specialist schools in India and outside India, including Africa and the UK; discussions are also on-going with the St Vincent's school in Liverpool.

5. Sources to corroborate the impact (indicative maximum of 10 references)

The sources (available from the HEI) for corroborating the impact of the MAGIC2VIP project include:

- Letter from the Regional Director, NIVH - **named contact details have been provided**; NIVH has compiled the feedback from the participants of the programme and refresher course, acknowledged the contributions of MAGIC2VIP and recommended suggestions for the future work too.
- UNESCO Invitation Letter – confirming the usefulness of the toolbox.
- Feedback from Students and Teachers (i.e. special educators and resource teachers); this feedback was collected using a questionnaire (approx. 60 respondents) after the TGT tool-box was used with the specialist blind school pupils and teachers.
- Email/letter from Ms Marie Quinn, Sensory officer of RNIB; Expression of interest and feedback email(s) from meetings/demos with officials of RNIB, London; St Vincent's School at Liverpool.

Additional evidence in the form of posters, letter of appreciation and awards:

Evidence of a workshop organised at Hope - Prof Toriyama presented a workshop on teaching science to visually impaired students and the toolbox was used as a demo. Letter of evidence from the President's Office, Indian Government and letter of appreciation/award by the Tamil Nadu Government given to Dr Thamburaj.