Institution: The Glasgow School of Art
Unit of Assessment: 34 Art and Design: History, Practice and Theory
Title of case study: Virtual anatomy for innovative teaching and learning

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

This case study describes the innovative 3D Head and Neck learning tool and its impact on teaching in both academic and clinical settings. Since its inception, the 3D Head and Neck project has developed an innovative and rigorous workflow and a learning tool which has had immediate impact on education and training within the NHS and academic sectors in Scotland, directly benefitting dentists, doctors, nurses, surgeons and the full range of allied health professionals underpinning high quality, safe clinical care. This innovative learning technology continues to be vigorously adopted within Scotland and the research methodology developed has led to significant follow-on research.

2. Underpinning research (indicative maximum 500 words)

Between 1996 and 2003 the Digital Design Studio (DDS) was undertaking research into realtime 3D and haptics for Ford Motor Company. Professor Paul Anderson, Director of the DDS, saw the potential of these types of interfaces in medicine, particularly for teaching and training purposes using immersive virtual models to complement the resource-intensive and limited traditional cadaveric methods of teaching anatomy with a risk-free, repeatable, truly interactive way of learning. In 2006, the DDS was awarded £95k by the Scottish Funding Council to perform a feasibility study into medical visualisation. As part of this study, the DDS convened a Scottish Medical Visualisation Network (MVN) which was supported by the Royal College of Surgeons of Edinburgh and the Royal College of Physicians and Surgeons of Glasgow. This collaborative initiative brought together 22 different medical disciplines and allied healthcare professionals across 44 organisations in Scotland to pursue excellence in medical visualisation. Through this network, the DDS created 3D digital models of selected anatomy that have been used to educate health professionals and have also been used to support activities such as pre-operative planning, risk reduction, surgical simulation and increased patient safety [1][2][3][4].The feasibility study published several case studies and ran workshops and symposia to explore the issues in depth. Whilst commercial digital anatomy tools did exist, they were assessed by anatomy specialists as lacking accuracy, realism and failing to deliver meaningful interaction. Most are based on reproduction, repetition and reliance upon low-res MRI/CT scans or traditional Gray's Anatomy or Netter-type illustrations which (although interesting) are static, inaccurate, locked in non-interactive 2D formats and punctuated with continued anatomical errors. A demonstrable need was identified for a learning tool based on an efficient workflow that produced accurate, realistic, and most importantly *clinically verified* data. A Final Report of this activity was published in 2008, containing the findings of the study and all publications [1] Bertie Wood, HM Inspector of Anatomy for Scotland stated in the report's introduction "*In the short time since the MVN came into existence, it has proved that a technological approach to anatomy teaching enables more rapid learning and superior comprehension."*

In establishing further underlying research foundations for 3D virtual anatomy, Prof Paul Anderson (in partnership with Dr Paul Rea, Licensed Anatomist, Glasgow University) developed a joint institutional small scale grant (£5k) to investigate the opportunities for 3D data acquisition through topographical laser scanning of anatomical skeletal specimens (male pelvis). Subsequent funding was then received from the Chief Medical Officer, Scottish Government (£30k), The Royal College of Surgeons, Edinburgh (£30k) and NHS Education Scotland (NES) (£20k) in order to expand research development and innovation into interactive high-resolution 3D models for medical teaching derived from 3D laser-scanned data. The research broadened considerably when The Royal College of Physicians and Surgeons funded research (£600k) into developing 3D data sets for surgical simulation built from the methodology and workflow established within initial pilot studies [1][2][3][4]. The quality and innovation of this research is evidenced by wide publication and presentation to date and significant recognition from the research and clinical sectors e.g. [6] and recent major publications such as the RCUK report Big Ideas for the Future (June 2012) [5].The DDS has also secured a Fulbright Visiting Professorship in Medical Visualisation from the US Fulbright Commission – a world first in medical visualisation.

The networks, collaborations, research projects and cadaveric laser-scanning workflow development described above led directly to a major multi-year research initiative funded by NHS Education Scotland (NES) resulting in the successful development of the definitive, clinically verified dataset for

3D Head and Neck anatomy for teaching across dental schools and universities across Scotland and NES Medical Visualisation labs.

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

[1] Anderson, P. & Charissis, V. (2008) *Medical Visualisation Feasibility Study Final Report* (Scottish Funding Council, June 2008)

[2] Anderson, Paul, Ward, B, Charissis, V, Sakellariou, S and Chanock, D (2009) Design and Implementation of Augmented Reality Environment for Complex Anatomy Training: Inguinal Canal Case Study. In: *Human-Computer Interaction. Virtual and Mixed Reality, Lecture Notes in Computer Science*, 5622 . Springer Berlin / Heidelberg, United Kingdom, pp. 605-614

[3] Sakellariou, S, Charissis, V, Anderson, P, Ward, B M and Channock, D (2009) *A Novel Approach to CT Scans' Interpretation via Incorporation into a VR Human Model. In: Digital Human Modeling*: Lecture Notes in Computer Science. Springer, pp. 550-559.

[4] B Ward, P Anderson, V Charissis, D Rowley. L Brady 'An Evaluation of Prototype VR Medical Training Environment: Applied Surgical Anatomy Training for Malignant Breast Disease' *International Conference of Medicine Meets Virtual Reality* 16th (MMVR 16th), 30 Jan - 01 Feb 2008, California, USA.

[5] "*Big Ideas for the Future* is a new report from Research Councils UK (RCUK) and Universities UK that explores the excellent research taking place in UK higher education at the moment and what it will mean for us in 20 years time. […] *Big Ideas for the Future* demonstrates the value of public investment in higher education and research and the positive impact this has on economic growth and the social wellbeing of the UK." http://www.rcuk.ac.uk/Publications/reports/Pages/BigIdeas.aspx

[6] Prof Anderson was invited to give the RCPSG MacEwen lecture: 'Developing 3D Interactive Anatomy' *(International Surgical Congress of the Association of Surgeons of Great Britain and Ireland*, Glasgow 2009.)

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

A major impact from DDS' underpinning research in medical visualisation was the development of the 3D Head and Neck innovative learning tool. In 2009, after an open competitive tender, the DDS was selected to deliver the £2m 'NHS Education Scotland: 2D/3D Digital Visualisation Supporting Interactive Educational Content' project (PI: Prof Anderson). This four-strand project researched and developed digital content for interactive Head and Neck anatomy, instrument decontamination, virtual patients and common disease processes for dentistry. This was a complex project relying on the high levels of interaction across multidisciplinary development partners developed in the underpinning research. The major output from this project was a training tool comprising an anatomical dataset and interface for the human head and neck representing a world-first in resolution, accuracy, and realism. Whilst most teachers of anatomy would agree that dissection remains a critical activity there are inherent limitations centred on the cost, accessibility and potential health and safety issues which have been challenges for decades. The newly available 3D Head and Neck model provides an outstanding additional tool for trainee doctors and dentists to learn the detailed anatomy of this complex region. This innovative learning technology is a key part of the overall strategy of NHS Education for Scotland to provide leading edge support for the education and training of dentists, doctors, nurses, surgeons and the full range of allied health professionals in all biomedical sciences that underpin high quality, safe clinical care.

Engagement with policy-makers and the medical community

On Wednesday 24 April 2013 DDS hosted a major launch event for the 3D Head and Neck project showcasing the project outputs and DDS in general. The event was attended by around 50 expert delegates including First Minister Alex Salmond and Dr David Felix, NES Dean for Dental Education, including c.35 members of the European Dental Council Directorate, who extended an international conference in order to spend a day at DDS using the 3D Head and Neck. In an interview First Minister Alex Salmond noted : "*This is a fantastic example of how [the research] can benefit patients in Scotland*" [7][8] and the training tool has received extremely positive reactions from the clinical, academic, and industrial sectors based on both existing and potential impacts [9][10].. Prof. Anderson was invited to speak about the 3D Head and Neck at the Royal Society of Medicine Innovation Day [11]to an audience of around 200 clinicians and academics.

Educational impacts (direct from project outputs)

The four main project outputs (the 3D Head and and Neck model and software, the infection control online resource, the virtual patient interactive scenarios, and the disease process animations) are already having significant impact in education across the NHS and universities. The 3D Head and

Neck is used for anatomical teaching for undergraduate students at the University of the Highlands and Islands in Inverness, Stornoway and Dumfries. (Reaching students in rural and remote areas who do not have access to traditional anatomical teaching methods was a core outcome of the research). There are 14 students in each year (It should be borne in mind that the software has only just been released and this number will grow significantly in the future and have international reach as the model is leased elsewhere and commercialised). The infection control online resource is available to all NHS staff registered with the NES Portal; around 27,000 potential users. The recently-released Virtual Patients for Training software (which includes four pharmacy-related scenarios) has already been licensed 88 times by users from NES, the NHS more widely, Boots, and independent pharmacies [14].

In Scotland alone there are 20,000 undergraduate students working within healthcare disciplines in addition to over 100,000 clinical staff who undertake continuing professional development. Already, around two hundred assorted viewers/trainees have had thousands of successful interactions with the dataset. Feedback from NES indicates that clinical uptake is predicted to be rapid and comprehensive across Scotland. Initial evaluation and feedback from the Post-Graduate Dental Dean for NES is extremely positive with trainees and clinicians vigorously adopting the anatomical model [8][14]. Once the planned schedule of installations of the model across Scotland is completed, then tens of thousands of meaningful interactions with the model are expected annually.

Other educational impacts

The development of a critical mass of expertise in medical visualisation led to the establishing of the innovative MSc in Medical Visualisation and Human Anatomy designed and delivered by the DDS in partnership with the University of Glasgow's College of Medicine, Veterinary and Life Sciences (http://www.gsa.ac.uk/study/graduate-degrees/medical-visualisation-human-anatomy/). This year's cohort is 23 students. Collaboration on this project also led to a co-supervised PhD between DDS and the University of Glasgow Dental School in Paediatric Dentistry.

Economic impacts

During the lifetime of the 3D Head and Neck project, NES invested over £750,000 in the creation of 3D visualisation labs in Inverness, Stornoway, Edinburgh, and Glasgow (with two more planned in Dundee and Dumfries). These permanent facilities were designed and are managed by DDS in partnership with NES. The labs provide direct access to the project's outputs for medical postgraduate trainees and clinicians, using the 3D Definitive Head and Neck, virtual haptic injection simulation, haptic lumbar puncture simulation, and thoracic and lower abdominal anatomy models for anatomical learning, as an aid to pre-operative planning, and as a basis for charting the progression and treatment of dental disease. A full time Educational Technician permanent post has been created to manage the DDS/NES network of labs - an investment of more than £150k in salary alone. The project itself employed 2 full time 3D modellers and 2 programmers at DDS. 2 FTEs have been retained on an ongoing basis, increasing DDS' capacity to capitalise on the success of the research with further research or commercial projects. DDS has received to date £192k in additional funding from NES to expand the Virtual Patients for Training tool to cover drug use, maternity, child protection, and psychological intervention scenarios. An additional £100k was also granted by NES in April 2013 to extend the functionality of the 3D Head and Neck. DDS has received 12 requests to license the tool on a commercial basis for use in other teaching and training situations including hospitals. It is envisaged that this will create an income stream for DDS and NES in the near future.

Evaluation/early results

3D digital model development process (including data acquisition, model construction, interface design and implementation) were positively evaluated and validated by multi-disciplinary experts in the fields of medicine and computing science [13]. A preliminary (small scale) evaluation of one of the learning tools (with pharmacy scenarios on alcohol misuse, healthy eating, patient rights, and smoking reduction) was conducted with very positive user feedback and showing an increase in learning outcomes [14]. Full evaluations are planned for all work packages in both undergraduate and postgraduate spheres, including at investigation into where the resources fit best into curricula.

Public awareness and engagement

The 3D Head and Neck received considerable media interest, increasing public awareness of the potential of digital teaching tools and contributing to ongoing debates on the role of 3D technology as a pedagogical tool [12].

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

[7] *"I am delighted to be launching this hugely exciting venture that could transform medical and dental training by giving students an opportunity to learn about human anatomy using virtual reality tools. Scotland is leading the way when it comes to 3D visualisation, [...]the 3D Digital Head and Neck being launched today will keep Scotland at the forefront of clinical technology and training, opening up opportunities for these techniques to be used in other medical disciplines.This project is an excellent example of partnership working, with the clinical expertise of the NHS and University of Glasgow working in tandem with the Digital Design Studio at Glasgow School of Art to produce a truly ground-breaking clinical training tool."* First Minister Alex Salmond, http://www.scotland.gov.uk/News/Releases/2013/04/3D24042013

[8] *"This is a fantastic example of effective partnership working. The project has produced user friendly resources which put Scotland at the forefront of education and training internationally, not just within dentistry but also for healthcare professionals in other disciplines."* Dr David Felix, NES Dean for Dental Education, http://www.scotland.gov.uk/News/Releases/2013/04/3D24042013

[9] Anonymous Wellcome Trust Reviewer, "*There is a real need for [extending the scope of the tool]. Not only in terms of providing a 3D model of anatomy but in terms of providing a 3D model of anatomy that is incredibly accurate and explorable. Audiences - whether a GCSE biologist, medical student, GP or simply a person with an interest - will be able to learn to their level.*"

[10] The collective view of industrial viewers has been best summed up by GlaxoSmithKline, Dr Malcolm Skingle CBE DSc PhD, Director, Academic Liaison :- "*We think this is the best thing available to train the next cadre of medics and biological scientists…we support the project and very much value its potential contribution to the area of learning and teaching of anatomy.*"

[11] Royal Society of Medicine event: http://www.rsm.ac.uk/innovations/programme2013.php

[12] Selected publicity includes: BBC TV and online http://www.bbc.co.uk/news/uk-scotland-22279395; STV TV and online http://news.stv.tv/scotland/222758-glasgow-art-school-designs-virtual-head-for-medical-students/; Scottish Government Press Release http://www.scotland.gov.uk/News/Releases/2013/04/3D24042013; Los Angeles Times http://framework.latimes.com/2013/04/24/pictures-in-the-news-651/#/12, and also The Times (picture story), The Scotsman (picture story), The Telegraph (picture story), Press and Journal (long article with two pictures), Metro (page lead with two pictures) and online, Dundee Courier (picture story), and the Evening Times (page lead, picture), as well as the Medical Student Union homepage. International news coverage included BBC International (Brazil), BBC Arabic Service (4Tech), the Los Angeles Times, Connecticut Post, photo of the week in Australian Doctor Magazine and as one of the "Week's Greatest Moments" on Mashable.com

[13] Anderson, Paul, Chapman, Paul, Ma, Minhua and Rea, Paul (2013) *Real-time Medical Visualization of Human Head and Neck Anatomy and its Applications for Dental Training and Simulation*. Current Medical Imaging Reviews . ISSN 1573-4056 (In Press)

[14] Usage statistics and figures provided within this case study were provided by Andrew Forgie, Linda Gunn, and David Felix of NHS Education for Scotland.