

INTRODUCTION

The triple bottom line framework was developed to help organisations understand their broader impacts and consists of social, economic and environmental domains. This can be summarised by the 3 P's; People, Profit and Planet. By embracing this framework, we can move towards a more sustainable model of surgical training in order to provide excellent quality care for patients whilst minimising the environmental impact of operating theatres.

AIMS

The aim of this project was to create a sustainable surgical anatomy training platform that improves accessibility, minimises cost and environmental damage, whilst ensuring that trainees get a more immersive and tailored surgical experience, without posing harm to patients. The main aim was to incorporate the VARK model of learning which encompasses visual, auditory, reading and Kinaesthetic stimuli (Fleming et al., 1987).

We developed several new technologies including a mixed reality headset, a novel 3D printing pen and augmented reality overlay that allows participants to learn surgically relevant anatomy whilst having tactile feedback.

GLOBAL FOCUS

There is a significant challenge ahead to enable surgery to meet net zero carbon by 2045, in line with the Greener NHS strategy. We find that surgical simulation is an underutilised method for training surgeons and can bring a more sustainable future to surgical training. Our innovative surgical anatomy platform increases access to surgical training in the developing world as well as significantly reducing the global carbon footprint of operating theatres.

MATERIALS

We designed and manufactured a VR headset that could be used to create an immersive environment with rendered reconstructions of human neuroanatomy (Figure 1; A-F). We then converted patients` CT and CT Angiogram scans into 3D models and 3D printed them in mass.

We also designed and manufactured a custom 3D pen with an adjustable heated nozzle which can allow the user to extrude variable diameters of conductive thermoplastic filaments. This enables users to draw neurovascular structures in 3D space.

Figure 1 - Design of custom VR Headset

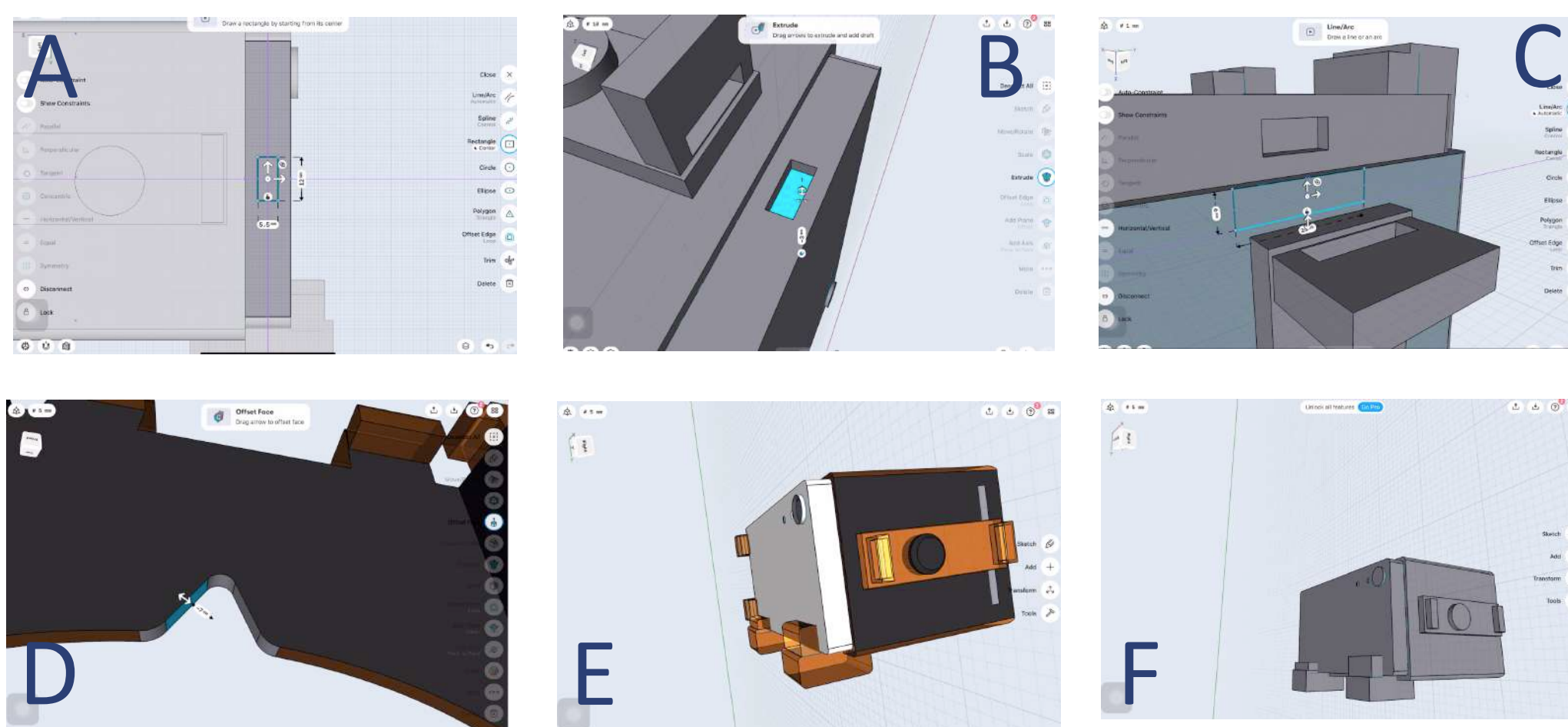


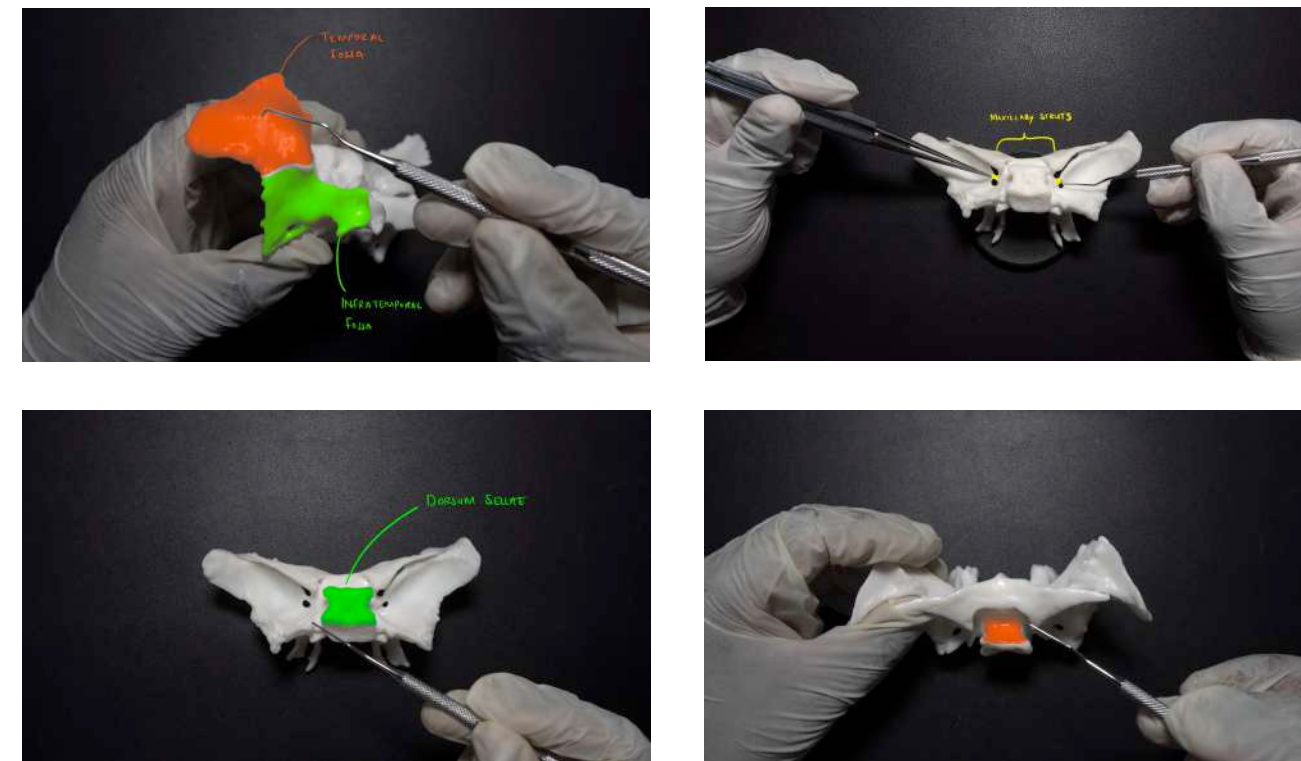
Image 1- Cadaveric dissection & prosection teaching in Shenyang, China



Instructing a Regional anatomy Class in Shenyang, China.

(Image 1) Teaching regional anatomy to medical students in Shenyang China, using cadavers. Participants were able to participate in live dissections and prosections. Cadavers were donated by Shengjing Hospital and were preserved in formaldehyde. Attendees were then assessed to determine how much they retained from these sessions and this was compared with their retention after completing our VARK-based Kinaesthetic simulation.

Figure 2 - Development of AR overlay teaching



(Figure 2) AR overlay is a novel technique that we developed to allow the VR headset user to see a coloured overlay on the specific anatomical structure being discussed.

This process helps to reinforce key concepts and enables the student to have simultaneous tactile feedback.

Figure 3 - Design & Manufacturing of Custom Neuromuscular 3D printing pen



(Figure 3) We also designed and 3D printed a customised 3D printing pen that has a unique adjustable nozzle. This allows the student to extrude thermoplastic filaments of varying thicknesses. As a result, the student can draw veins, arteries, capillaries, nerves and plexuses by altering the size of the extruder nozzle.

Image 2 - Mixed Reality & Kinaesthetic 3D Lecture



(Image 2) By combining all of these technologies, the VR headset wearer can experience a "mixed reality" whereby they can interact with a rendered 3D scan and have a truly immersive and kinaesthetic learning experience, as they draw in the structures.

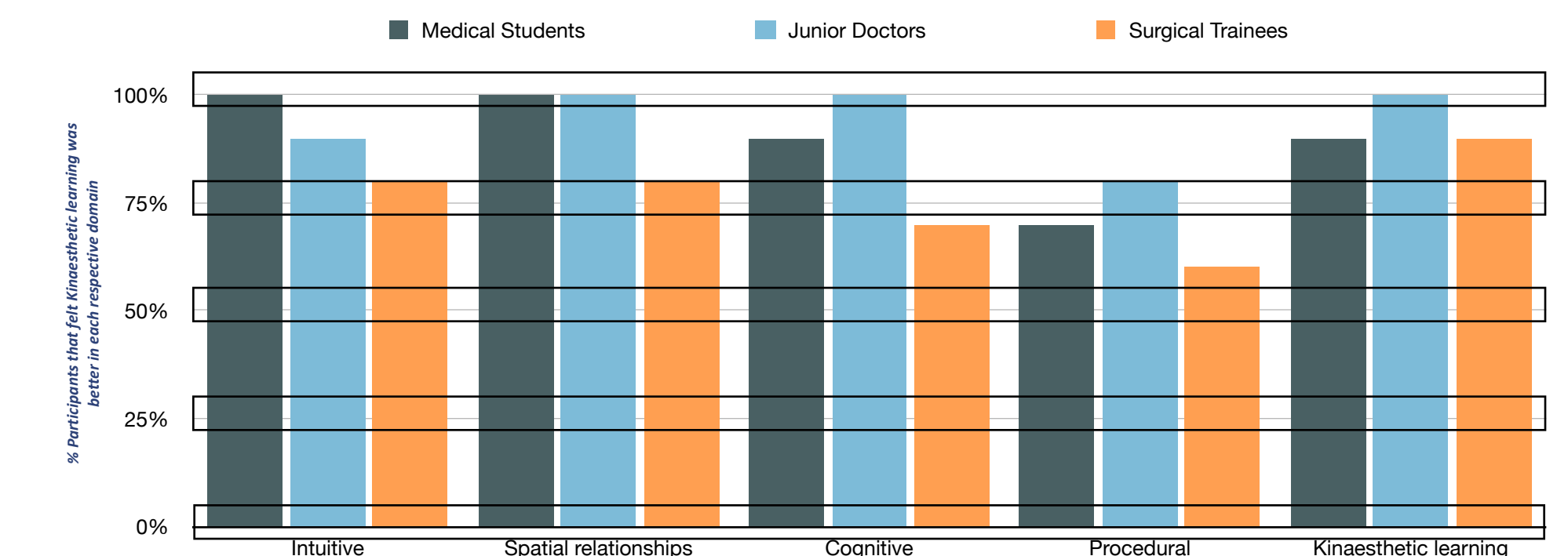
METHODS

Data was gathered from interviews with 30 participants comprised of medical students, junior doctors and surgical trainees. Participants took our neurosurgery skull-base course where they were able to explore the skull base in a mixed reality setting whilst having tactile models with pathological findings. Our students learned advanced skull-base surgical anatomy as well as procedural skills that are transferable to the operative realm. Our participants were assessed on their ability to retain knowledge of skull base anatomy. Students were given an empty cranial vault and were asked to populate the cranium by drawing in the 3D neurovascular structures.



RESULTS

Graph A - Results from Questionnaire comparing conventional Anatomy Teaching Vs VARK VR Kinaesthetic Teaching Model



CONCLUSION

Kinaesthetic learning was deemed more intuitive by 93% of participants, when compared with conventional anatomy lessons. 80% of trainees felt like they understood a more critical part of surgical anatomy, namely spatial relationships. This novel mode of training was extremely cost-effective whilst reducing solid waste and energy consumption. Equivalent operative demonstration of these principles would have caused approximately 750-1250kg CO₂e, with major procurement of anaesthetic agents. We found that surgical simulation is an underutilised teaching modality in surgical training. Furthermore, Our study showed that, on average, students retained 40% more anatomical structures when adopting our Virtual kinaesthetic approach to learning anatomy when compared with traditional cadaveric dissections.

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