Enhancing neuroanatomy education with augmented reality

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What problems were addressed? Ongoing curricular enhancements aiming to integrate foundational science and clinical knowledge have introduced the need for just-in-time and asynchronous modalities for teaching anatomy. Although some institutions and education collaboratives have designed online resources that allow for the active manipulation and exploration of body systems, these have limited capacity to simulate the three-dimensional anatomic relationships fundamental to radiographic interpretation and procedural reasoning.

Augmented reality (AR) and virtual reality solutions close this gap by projecting anatomical models in true space filling three dimensions, clearly visualising the layout and organisation of complex organ systems. These teaching tools may be deployed nimbly in integrated curricula. Augmented reality, where users look through a clear screen overlaying information onto the physical world, has the additional benefit of allowing for direct student-to-instructor interactions.

What was tried? A collaborative, student-led team, including faculty members, simulation professionals and software developers, offered optional 1-hour neuroanatomy AR-enhanced teaching sessions to a group of 16 first-year medical students. Neuroanatomy was selected because of its complex 3-D form and its form-to-function relationship. There were two embedded modules: the first walked through the touch-stimulus pathway from the peripheral nerves of the index finger through the medial lemniscal path to the primary somatosensory cortex, and the second traced the flow of cerebral spinal fluid from the choroid plexus through the ventricular system to the subarachnoid space. Students were also permitted 30 minutes of free exploration using the headsets to enlarge, dissect, sort and identify sub-parts inside the model.

The protocol was approved by the Columbia University Medical Center Institutional Review Board. Students completed a multiple-choice neuroanatomy test (five multiple-choice questions) before and after the session and provided detailed feedback through structured and free-response questions. The sessions were taught by a fourth-year medical student teaching assistant. A rising fourth-year teaching assistant was trained before the outgoing student graduated.

Mean score increased significantly between the pre and post quizzes (paired sample *t*-test; $p = 0.00053$). Student rating of their examination readiness increased significantly (p of 0.00354). The average rating of AR as compared with other resources was 4.21 (4 = better than other resources; 5 = best resource I've used). All students agreed AR is 'high yield' and 14/16 agreed AR anatomy modules should be formally incorporated into the curriculum.

What lessons were learned? Major positive themes included the benefit of the 'immersive', 'clear' and 'step-inside 3D' experience, the helpfulness of guided exploration and modules, and memorability. Negative themes included the small field of vision, fine motor control problems and desire for a more detailed anatomical model. A student who self-identified as 'having more difficulty with special intelligence' reported that AR was the 'single most helpful anatomical learning tool I have used'.

In this limited and uncontrolled sample, AR-enhanced teaching of neuroanatomy increased student knowledge and was highly popular. Major challenges for sustaining the project include identifying dedicated space for AR education, supporting educational and IT staffing for these sessions, and scaling up capacity by identifying capital for the devices and software. Based on these preliminary data, AR could become a useful supplementary resource for neuroanatomy students.

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