UTJMS 2026 February 16, 15(S1):e1-e7 doi:10.46570/utjms-2026-1906

Engaging Minds: A Brain Cutting Experience for Undergraduate and Pre-Medical Students

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Received 12/17/2025

Accepted for publication 12/22/2025

Published 2/16/2026

Abstract

Brain anatomy is notoriously difficult to teach and visualize to first-time learners. To make neuroanatomy more digestible, our group designed an educational brain-cutting experience that used gross dissection of a cadaver brain alongside digital dissection through the Anatomage Table technology to elucidate more difficult structures in three dimensions. A slide presentation was also prepared to help guide the learners through the dissection and to teach structure, function, and pathology. Two sessions with undergraduate learners were performed, with the first having four learners and the second having eight. Pacing and improper cutting technique were the main obstacles encountered in the first session; however, this was remedied by proper communication, teaching, and changing the format of the visual presentation. We feel that Anatomage helped the learners better visualize each structure in three dimensions, which aided in understanding the content. Early exposure to anatomy and pathology can inspire students to pursue careers in medicine, so we hope that this experience inspires others to develop their own neuroanatomy program.

Keywords: Neuroanatomy,Education,Anatomage

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1. Introduction

Anatomy is considered the building block of medical education (1). Anatomical knowledge is essential for patient examination, correct diagnosis, and all medical specialties (2). Hands-on experience and, more recently, digital models of anatomy are crucial for medical education. Given this importance in medical education, beginning anatomical study as an undergraduate may have positive consequences. As one example, an observational study examined the impact of hands-on workshops on future medical students' motivation, confidence, and career aspirations (3). They reported an increase in median scores for motivation to pursue a medical career, theoretical, and practical knowledge. In addition, motivation to pursue a career in medicine increased after a workshop on any medical subject, regardless of the information presented (3). Reasons for learning anatomy can also extend beyond just passing a test. One study of undergraduate science students found that intrinsic interest in anatomy was a reported motivation among most of the students surveyed (4). These studies highlight the importance of incorporating hands-on experiences early in pre-medical education and the objective of this paper.

Neuroanatomy poses a unique challenge in medical education. Obtaining donated human specimens/cadavers for dissection is difficult, and it is often less expensive to use digital models of anatomical figures (5). As a result, 3D tools like Anatomage (a virtual dissection table), as well as Primal VR (a virtual reality environment for teaching and learning human anatomy), have been developed and used to fill this gap (6-7). Various studies have been conducted on the use of these virtual resources in neuroanatomy education (5-8). For example, one study assessed the effectiveness of Anatomage as a teaching tool for neuroanatomy for third-year physiotherapy students (8). The study found that those assigned to using only Anatomage for dissection had increased post-test results compared to those assigned to using only the cadaver (8). Nonetheless, there has not been a study that used a brain dissection and Anatomage simultaneously. We aimed to bridge the gap in the literature with this experience.
We designed a hands-on didactic experience to help teach neuroanatomy using an interactive, mixed-media approach that integrated cadaver and traditional presentation slides. This experience was designed to introduce brain physiology and highlight the anatomical structures that result in some vital disease pathologies. In addition, this experience was meant to inspire and motivate pre-medical students to pursue a career in medicine. There was a broad distribution of academic majors among the learners, ranging from neuroscience to electrical engineering, and only a small percentage of learners had prior neuroanatomy education.

2. Methods

Overview and objectives. Our main objective was to provide learners with a detailed understanding of neuroanatomy in three dimensions. To achieve this objective, we incorporated the Anatomage Table virtual dissection technology into a clinical dissection. Anatomical structures were first found via gross dissection; then visualized in three dimensions using the Anatomage table; then discussed in relation to function and pathology. We aimed to cultivate a positive and inviting environment for learners to ask questions and engage at their own pace. In addition, we aimed to provide a hands-on experience for pre-medical/undergraduate students.

Learning outcomes. We established three major learning outcomes for this didactic experience. At the end of this experience, learners should be able to (1) understand the three-dimensional structure and organization of the brain; (2) relate neuroanatomy to regional brain function and common medical disorders of the brain; and (3) perform a dissection of a cadaveric human brain and use digital dissection technology to identify the structures.

Equipment and supplies. This educational experience used a total of three cadaveric human brains, one per four learners, which were provided by the University of Toledo College of Medicine's Anatomy Laboratory, as originally sourced through the Anatomical Donation Program. Prior to use, each cadaveric brain was soaked in 1% saline for at least 24 hours, then transferred to fresh 1% saline for at least another 24 hours, to minimize the scent of preservative. The cadaveric brain dissection was performed on a clean, empty cadaver table with a plastic dissection platter. The tools used included a large cutting knife, a metal probe, and a scalpel. The digital dissection was performed using an Anatomage Table Clinical model (Anatomage, Santa Clara, CA) running Anatomage Table EDU version 11.0.1. The slide presentation was displayed on multiple large external monitors throughout the lab that were connected to a standard desktop computer. Appropriate disposable personal protective equipment was provided to all learners and educators.

Educational content. We designed the experience to be as interactive as possible. The sessions were held in an anatomical laboratory within the medical school (Figure 1). We allocated one brain per four students, with one medical student guiding the cutting as a proctor. The Anatomage Table was positioned in front of the cadaver tables and was set to display the brain (see Anatomage Guide). We projected a slide presentation for the session using a central monitor, which connected to multiple TV screens in the lab that the learners could view as the session proceeded. The slide presentation included relevant anatomy, pathology, and pictures of previously cut brain slices with the anatomy labeled.

The sessions began with a slide presentation of the external brain, throughout which an external examination of the brain was performed, highlighting sulci, gyri, and meninges. We decided that making coronal slices of the brain, anterior to posterior, was the best method to view the relevant anatomical structures. Each learner took turns cutting the brain by placing the brain on its side (lying on either temporal lobe) and slicing downward in the coronal plane, and each slice was examined afterwards. The slide presentation was set up in such a way that structures would be seen and discussed in the same order as they appeared in the dissection. On the Anatomage Table, the Clipping Planes tool selected, and the Clipping Plane Slider Bar was toggled to coronally "shave" the brain to mimic the cuts being made by the learners. After we reached a structure of interest, we highlighted it on Anatomage, discussed its functions, and presented an associated pathology. The dissection proceeded from anterior to posterior, stopping in the forebrain at the level of the atrium of the lateral ventricles, and in the hindbrain at the cerebellum just behind the fourth ventricle. After the whole brain was sectioned, the tissue was placed back in its container.

Sessions. Two sessions were held. The first session was performed with four learners and one brain. The second session included eight learners, with two groups of four cutting one brain each. Figures 2-10 depict the flow of sectioning performed during the sessions, alongside anatomical structures and pathologies discussed.

3. Results

Session 1

During our first session, we found that taking a slow approach, allowing learners to ask questions and look at the brain slices, worked best. By following the pace of the learners, a better learning environment was attained as the learners had time to ask questions. Using the Anatomage Table also helped to visualize the internal structures of the brain (basal ganglia, ventricles, etc.) in three dimensions more easily than pictures or dissection alone. The Anatomage Table also has the added benefit of being able to color-code different structures and/or eliminate outer structures from the view, which helped to differentiate them for the learners. Using the Anatomage Table to remove the outer cortex from one side of the brain (leaving it intact on the other side), and simultaneously to color-code the structures of the basal ganglia, greatly enhanced the visualization of their three-dimensional structure. We found that concurrently seeing the structures in an actual brain, visualizing it on the Anatomage Table, and discussing function/pathology via a presentation made for a memorable and enlightening experience that integrated anatomy and pathology.

One limitation we noted was the consistency with cutting the brain. Since it was the learners' first time cutting a brain, it was difficult to get consistently small, even slices that mimicked the slices in the presentation. Sometimes slices were too big, and a structure was missed (i.e., amygdala) or too small, in which the slices were uneven and made future slices more difficult.

Although we dedicated a slide in the presentation to instructions on how to cut, we decided that a more involved teaching process needed to take place during the next session to ensure quality cuts. The inconsistency of cuts also led to pacing issues with the presentation. Sometimes, the presentation discussed structures we had not gotten to on the actual brain, which interrupted the workflow.

Session 2

After addressing the issues in Session 1, we doubled the class size to eight people. Figure 1 depicts the setup of Session 2 to account for more learners. This led to new challenges. For Session 2, we retained the group size of four learners per brain/table. This group size allowed the proctors to have a more personalized approach to teaching, and it encouraged an environment in which the learners felt comfortable asking questions. Having two brains also allowed room for error in case one group missed a structure. For example, one group accidentally missed the amygdala in their cut, but the other group didn't; therefore, everyone still had an opportunity to see it. We also devoted more time in Session 2 to teaching the learners how to cut correctly. In addition, each proctor made the first cut to demonstrate proper technique. This ultimately allowed for better cuts to be made by the learners compared to Session 1. Furthermore, we addressed the pacing issue from Session 1 by adding a master structure list slide in the presentation deck. Once we reached a structure of interest, we would click on its name on the master slide, which would take us to the slides associated with that structure. This ensured that we could focus more on the brain itself than attempting to keep the same pace as the slides during the dissection.

We did encounter some limitations with the larger class size. While the pacing of the presentation was fixed, it was difficult to maintain a similar pace between proctors. There were times when one proctor would be on a future structure that the other had not reached yet. This occasionally led to confusion between each proctor and the person running the Anatomage Table. In future sessions, proper communication should be emphasized so that this does not happen. Another drawback to using more than one brain is inconsistent anatomy. One group's brain was much larger than the others, which made cutting more difficult and varied pacing to a minor degree, as they saw structures before the other group did. However, this can be remedied by attempting to select brains that are similar in size.

For both sessions, one drawback was the lack of depiction of brain pathologies on the Anatomage Table. Being able to show a normal vs. an abnormal brain on the Anatomage Table would help the learners in visualizing and understanding brain pathologies. Unfortunately, this is not a current feature of the Anatomage Table.

Hopefully, this feature will be added in a future update.

4. Discussion

Incorporating the study of anatomy into undergraduate education can help motivate students to pursue careers in medicine; this was the primary goal of the brain cutting experience. Both sessions used cadaveric human brains and Anatomage Tables. Two medical students presented specific neuroanatomical structures of the brain to undergraduate learners as they were revealed via coronal sectioning. In addition, explanations of pathologies that may arise when those structures are damaged were also presented. The Anatomage was used to showcase brain structures in three dimensions, which aided in understanding the anatomy and pathology in a more meaningful way compared to gross dissection alone. While difficulties did arise in terms of presentation pacing and cutting technique, these were addressed by the second session. In future sessions, we will address the issue of differing anatomy when using more than one brain.

5. Future Endeavors

Our future endeavors are to continue to teach medicine-inspired students about basic brain regions and functions through our guided brain cutting experience. We hope to continually improve our experience in hopes of perfecting the process. Additionally, we hope that the Anatomage program gets updated with increased detail in the brain. Currently, Anatomage seems to be more suited for learning about the whole body rather than solely the brain. An updated Anatomage would allow us to show every region of the brain that we find in our dissection. This would not only help learners identify brain regions but would also help us demonstrate certain brain regions that are difficult to see on gross dissection. Finally, an update allowing Anatomage to replicate disease states in the simulated brain would be extremely useful. This would allow learners to get a better understanding of what brain regions are affected by each disease, as well as the extent of the damage/distortion. Ultimately, our final goal is to pass our polished program onto future medical students, preserving its impact and inspiring future students to lead and expand this interactive teaching opportunity.

Acknowledgements

Thank you to the generous body donors, their families, and the Anatomical Donation Program of the University of Toledo College of Medicine, who granted us the privilege to conduct the brain cutting experience. We are honoring the donors' final wishes by using their bodies for medical education. We also acknowledge the University of Toledo Interprofessional Immersive Simulation Center for providing the Anatomage Tables used in this experience, as well as providing training and technical support.

Supplementary Information

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Figure 1: Session Setup. Representation of the brain cutting experience setup. For session 2, we had 2 groups of 4, each with a dissection table and a brain. We had multiple screens for the presentation, as well as the Anatomage and the Anatomage Navigator.

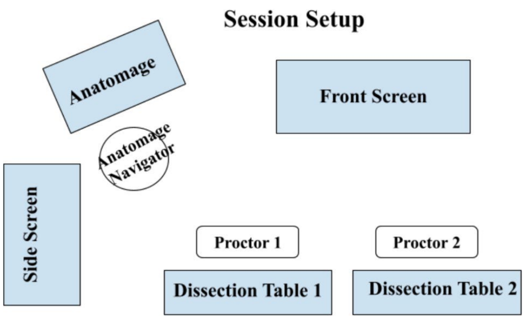

Figure 2: Whole Brain. Shows a whole brain with the arachnoid mater still attached to half of the brain. Discussed the normal structure and function of the various brain lobes, the pre- and post-central gyri, visible cranial nerves, visible arteries within the Circle of Willis, brainstem structures (midbrain, pons, medulla, and cerebellum), and meninges. Also discussed Gerstmann Syndrome and hemispatial neglect.

Figure 3: First coronal cut. Shows white and grey matter. Discussed how the structure of neurons is correlated with white/grey matter.

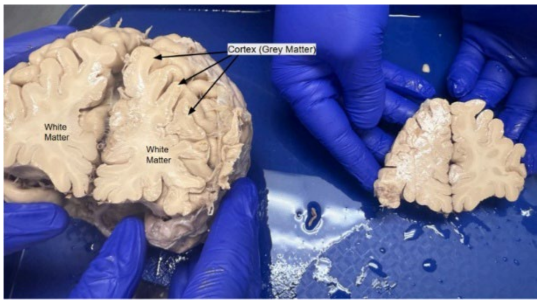

Figure 4: Second coronal cut. Showed/discussed the normal structure and function of the head of the caudate and lateral ventricles. Also explained the function of cerebrospinal fluid and the pathophysiology of hydrocephalus, specifically normal pressure hydrocephalus.

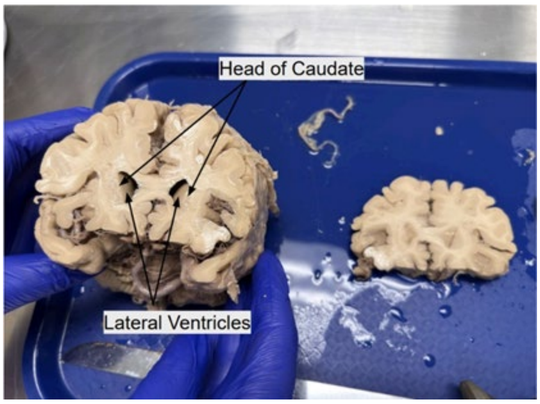

Figure 5: Third coronal cut. Showed/discussed the normal structure and function of the caudate, putamen, internal capsule, corpus callosum, and the basal ganglia. Discussed Huntington's Disease.

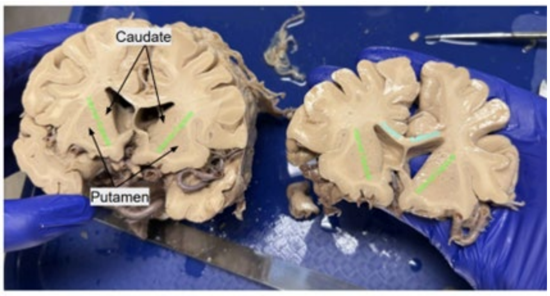

Figure 6: Fourth coronal cut. Showed/discussed normal structure and function of the 3rd ventricle, pituitary gland, anterior commissure, septum pellucidum, and amygdala. Discussed Kluver-Bucy Syndrome.

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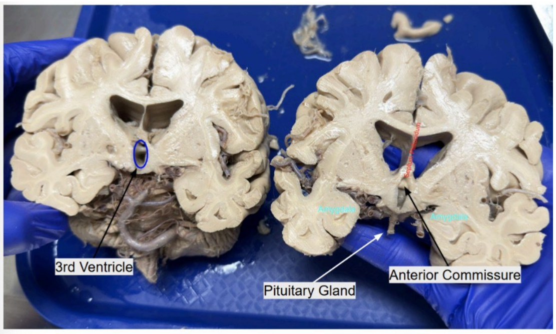


Figure 7: Fifth coronal cut. Showed/discussed normal structure and function of choroid plexus, thalamus, substantia nigra, midbrain, pons, medulla, putamen, globus pallidus, and mammillary bodies. Discussed Parkinson's Disease and Wernicke-Korsakoff Syndrome.'

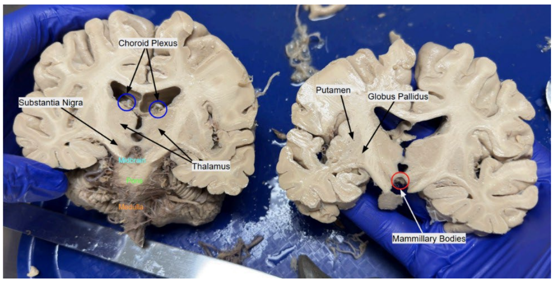


Figure 8: Sixth coronal cut. Showed/discussed the normal structure and function of the cerebral aqueduct and hippocampus. Discussed Alzheimer's Disease.

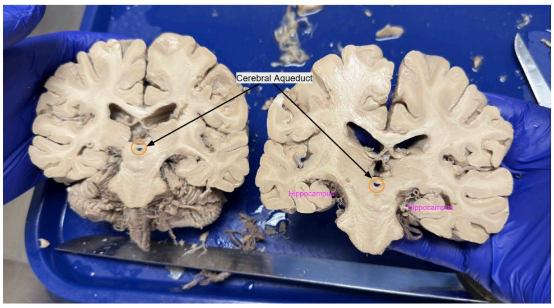
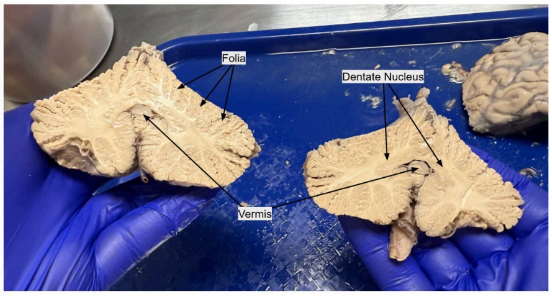


Figure 9: Seventh coronal cut. Showed/discussed the normal structure and function of the 4th ventricle.

a,

Figure 10: Coronal cut through cerebellum. Showed/discussed the normal structure and function of the cerebellum and its structures (folia, dentate nucleus, and vermis). Discussed Chiari II malformation.



Additional Files

Anatomage Guide

Author Disclosure:

The authors declare no conflicts of interest.

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