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RESEARCH ARTICLE

A Practical Examination and Feedback Survey Evaluating Learners Taught Using Physical Prosections vs. 3D Models of Prosections of the External Heart

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Abstract When incorporating new technology into medical curricula, it is essential to evaluate student success and resource preference. Our team created a database of virtual 3D scanned prosections for students to use while studying Gross Anatomy. Incoming first year medical students were recruited to take part in a study examining the effectiveness and preference for this resource. The study was conducted in four parts: first, a pre-test using physical prosections and images of virtual 3D scans of prosections; second, a teaching session using physical prosections or virtual 3D scans of prosections; third, a post-test identical to the pre-test; forth, a post-test survey. Twenty-nine students participated in this study (physical prosection teaching group [physical]= 15; virtual 3D scans teaching group [virtual] = 14). Exam scores significantly increased in both groups regardless of past anatomy experience with no significance found between groups (physical = 42.6% ± 17.9%; virtual = 44.3% ± 24.0%; $P < 0.01$). Students taught using the virtual 3D scans were more likely to agree that they "would be able to sufficiently learn anatomy using 3D scans" (physical = 3.0 ± 0.8; virtual = 4.1 ± 1.1; $P < 0.01$). Regardless of teaching group, students disagreed that they "would have a similar lab experience if they learned 3D scans instead of dissection" (physical = 2.1 ± 0.6; virtual = 2.5 ± 0.8), but agreed that they would use the virtual 3D scans to prepare for the dissection lab and practical/written exam (physical = 4.5 ± 0.8; virtual = 4.9 ± 0.3). This study demonstrates that virtual 3D scans are comparable to physical prosections in anatomy learning, but students do not support this resource replacing the dissection process.

Keywords anatomical sciences/medical education, 3D imaging techniques, effectiveness of anatomy education, Gross Anatomy, teaching anatomy

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1 Introduction

Recently, many educators have been challenged to revise the delivery of the Gross Anatomy laboratory sessions due to various pressures such as reduced student contact hours, increased class size, decreased access to donor bodies, cost of anatomy lab upkeep, and shortage of qualified instructors. To accommodate this, many medical programs have attempted to supplement in-person dissections with virtual resources (Estai & Bunt, 2016; Shin et al., 2022). This was magnified during the COVID-19 pandemic when many schools shifted their Gross Anatomy lab to an online format and donor body use decreased overall (Attardi et al., 2022; Harmon et al., 2021). Additionally, remote anatomical courses and institutions that do not participate in dissection-based learning due to financial or religious reasons can benefit from quality virtual resources (Habbal, 2009). The issues or situations described all support the need for alternate well-developed and accessible virtual Gross Anatomy resources as adjuncts to donor body use.

In response to the pressures previously mentioned, some institutions have reduced the student contact hours in the lab because of the time consuming and resource intense format of donor body dissection, and they have replaced it with methods such as virtual resources, 3D printed models of dissections, and prosection demonstrations (McMenamin et al., 2014; McMenamin et al., 2018; Miltykh et al., 2023; Yang, 2023). In fact, some schools have completely abandoned dissection and offer only virtual Gross Anatomy labs (McLachlan, 2004; Sugand et al., 2010). An anatomy course without dissection may be possible with the creation of in-house materials and the use of other virtual anatomy resources. Some resources available include open access dissection images, such as University of Michigan's BlueLink (Alsup & Fox, 2025) and American Association for Anatomy's Virtual Dissection Database (Vilburn & Simet, 2025), and virtual 3D models, such as University of British Columbia's Clinical Anatomy (Krebs et al., 2025), as well as commercially available interactive 3D, augmented and virtual anatomy models (Attardi et al., 2022; Kurul et al., 2020). Since the use of these resources has exponentially increased, more knowledge exists about student preference and how these resources impact student learning.

Research addressing the use of technology-based Gross Anatomy resources demonstrates that while virtual materials are useful, they result in significantly lower rates of self-perceived learning and satisfaction compared to dissection (Mathiowetz et al., 2016; Peterson & Mlynarczyk, 2016). In addition, medical students that experienced virtual labs during the pandemic reported that the online anatomy learning during this time was not sufficient for their medical education (Franchi, 2020). Previous studies (Biasutto et al., 2006; Estai & Bunt, 2016; Ghosh, 2017; Venail et al., 2010; Yammine & Violato, 2015) have shown that pairing both in-person and online resources was preferred by students and resulted in increased student performance. Numerous benefits of technology in education have been revealed, such as enhanced collaboration among students, encouragement of self-directed learning, and flexibility and accessibility of material in any location (Allen et al., 2016). Virtual anatomy resources have been shown to improve student learning in various ways including allowing students to visualize structures in different positions, as well as structures that are too deep or small to see on a physical donor body (Moro et al., 2017).

In the last decade, virtual 3D models have become more accessible. Virtual 3D models have been shown to be an effective educational tool as they allow manipulation of the scans, improve identification of anatomical structures, are accessible outside of the classroom, and have had positive reviews among students for ease and pleasantness of the programs (Duraes et al., 2022; Yammine & Violato, 2015). Most of the virtual 3D models available are computer-generated or used CT/MRI imaging to construct the virtual 3D scan (Beermann et al., 2010; Triepels et al., 2020). Photogrammetry has been used to incorporate anatomical dissections into virtual reality (VR) or augmented reality (AR) environments, but these require the use of a headset and are not as accessible (Krause et al., 2023). In general, the use of anatomical dissections as a virtual 3D resource is not as common and may be due to the ethical guidelines around body donation and the inclusion of terms in the consent form to involve virtual materials (Hennessy et al., 2020). Previous studies that focus on the effectiveness of virtual resources mostly used computer-generated CT or MRI reconstructions to produce the 3D models and compare them to a 2D image, video, or no model. In addition, some studies use different software that produce layered dissection sequences that do not rotate or use monoscopic virtual 3D scans that are not as interactive as stereoscopic scans (Allen et al., 2016; Beermann et al., 2010; Codd & Choudhury, 2011; Ng et al., 2015; Nicholson et al., 2006; Peterson & Mlynarczyk, 2016; Saltarelli et al., 2014; Venail, et al., 2010). All of these variables, such as the method used to create the scan, the compared learning resource, amount of interactivity, and sharing software, can produce varying results across studies. To our understanding, virtual 3D models of scanned donor body prosections have not been compared to the exact physical prosection that was scanned.

Our team at Drexel University College of Medicine (DUCOM) used surface scanning technology to create a preliminary database of computer-based 3D models of donor body prosections ranging from isolated organs to entire regional prosections. To better understand the effectiveness of our database as a learning resource, we asked first-year medical students at DUCOM who had not yet taken the medical Gross Anatomy course to participate in an instructor-led learning session using either the virtual 3D model or the exact physical prosection. The aim of this study was to investigate whether virtual 3D models of donor body prosections are a comparable learning resource to physical donor body prosections. In addition, our team aims to report student satisfaction and preference of learning resources.

2 Materials and Methods

2.1 | Participants

This study was offered during orientation week prior to the start of first-year medical courses. First-year medical students at DUCOM (Class of 2026) were recruited to participate in this study via email. Participants signed up for a 1-hour time slot to partake in this study using SignUpGenius (SignUpGenius, 2025). Participants were given a random number sequence so the pre-test, post-test and survey could be linked to a single participant. Groups of 3–5 students were in each time slot and would go through the sequence together. Groups were randomly assigned into the physical prosection (15 total participants) or the virtual 3D models of prosection (14 total participants). At the completion of the survey, participants had the option to enter into a raffle for gift cards.

2.2 | Sequence of Study Events

Participants first reported to the lab and took the pre-test. This was followed by a 5-minute introduction to both physical prosections of hearts and the virtual 3D scan of the heart prosection accessed by a QR code on their personal device. The introduction included time for independent exploration of both resources. All participants were allowed to touch the prosections using gloved hands and manipulate the virtual 3D model during this time. Participants then listened to a 15-minute instructor-led information session on the external heart using either the physical prosection or the virtual 3D scan. During the learning session, the participants only had access to their assigned resource and were encouraged to follow along and identify the structures the instructor was referring to using their assigned resource. The instructor used an outline to replicate the talk between multiple time slots of physical and virtual 3D scan groups. Participants took the post-test and completed a survey. This sequence of the events is depicted in Figure 1.

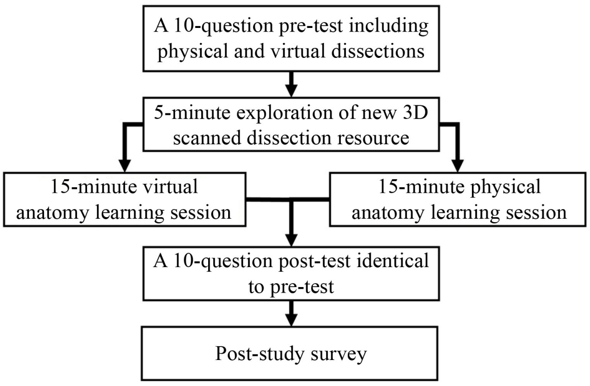

Figure 1 Flow chart of study procedures.

2.3 | Performance Exam

The performance exam (i.e., pre-test and post-test) was designed to mimic the in-person Gross Anatomy practical examinations conducted at DUCOM. The pre-test and post-test were identical and consisted of 10 fill-in-the-blank questions on Qualtrics (Qualtrics, 2025). All questions pertained to external heart anatomy, with half of the questions utilizing physical heart prosection and the other half displaying images of virtual 3D models of the external heart from our database (see Figure 2). Each question asked the students to identify the heart structure indicated by either a pin (physical heart prosection) or an arrow (3D models). The physical heart prosections and the virtual 3D models each had a question on a coronary artery, cardiac vein, chamber, and great vessel. Each station had 1 question and students had 60 seconds at each station. The exam questions asked are available in the Electronic Supplementary Material. Participants were not allowed to touch the specimens or manipulate the virtual 3D scans during the exam. The exam was monitored by research staff and there was no collaboration allowed.

2.4 | Survey

After completing all other study activities, students were asked to fill out an anonymous survey to provide feedback on the online database and their perception of learning success. The survey used was modified from a survey study completed by Jeyakumar et al. (2020) that demonstrated adequate validity and reliability. The survey was created in Qualtrics (Qualtrics, 2025), and was completed by participants prior to leaving the study area. The first part of the survey consisted of questions related to background information including previous degrees obtained, career pathway interests, and previous Gross Anatomy course and dissection experience, if any. Students were also provided links to view a series of other example virtual 3D scans (e.g., regional scans of thorax) to further explore the database. They were then asked Likert-scale (1 = strongly disagree to 5 = strongly agree), multiple choice and slider-type (0 = virtual resources and 100 = physical resources; 0 = 3D models and 100 = dissection videos) questions assessing the overall view of virtual resources

Figure 2 Images of the virtual 3D scans of a heart prosection.

and the virtual 3D scans that they viewed. A space was provided for comments regarding the virtual 3D scans and their perceived utility as a resource for the Gross Anatomy course. The survey used is available in the Electronic Supplementary Materials.

2.5 | Data Analysis

Exam performance was assessed and the pre- and post-tests scores of physical and virtual groups were compared utilizing a two-way ANOVA between groups and test with test taken as a repeated measure. Post hoc analysis was performed to compare the pre-test and post-test scores of participants within each group using a paired two-tailed-test and between the groups using an unpaired two-tailed *t*-test. Percent improvement and previous anatomy experience were compared using a two-way ANOVA.

Background information from the survey was reported as the percentage of respondents in each group. Mean values and standard deviations were calculated and reported for questionnaire items that were assessed using the Likert-scale questions. Percentage of multiple-choice responses were reported. Average responses on slider questions were divided into 4 groups (0–24, 25–49, 50–74, 75–100) for visualization and percentage of respondents in each group were reported.

Students were compared by previous undergraduate major, career pathway interest, and previous dissection experience. Differences in responses to the Likert-scale questions based on previous degree, career pathway, and experience were compared using the Mann-Whitney U test. Appreciation of the human body using in-lab dissections versus virtual 3D scans was compared using Chi-squared (χ^2) tests. Slider-type responses ranging on a scale of 0 to 100 were compared between various groups using unpaired, two-factor *t*-test analysis.

Significance was set to $P < 0.05$ for all statistical analyses. All data was analyzed using Microsoft Excel and SPSS Statistics Version 26.

3 Results

3.1 | Background Information

A total of 29 students participated in the performance exam and survey sequence. Prior to medical school, 93% of participants had a previous science degree, while 7% had non-science degree. The career pathway interests of participants were 45% general medicine, 31% surgical, 3% radiology, and 21% undecided.

3.2 | Performance Exam Results

ANOVA revealed a significant main effect of test [F(1, 27) = 129.3, $P < 0.01$] with no group interaction. There was a significant increase from the pre-test to post-test scores for both physical (pre-test = 24.0% ± 25.3%; post-test = 66.6% ± 19.9%; $P < 0.001$) and virtual (pre-test = 35.0% ± 17.9%; post-test = 79.3% ± 18.6%; $P < 0.001$) groups (see Figure 3). The physical and virtual groups did not show a difference in the pre-test or post-test scores. In conclusion, percent improvement between the pre-test and post-test significantly increased in both groups with no significance found between groups (physical = 42.6% ± 17.9%; 3D scan = 44.3% ± 24.0%).

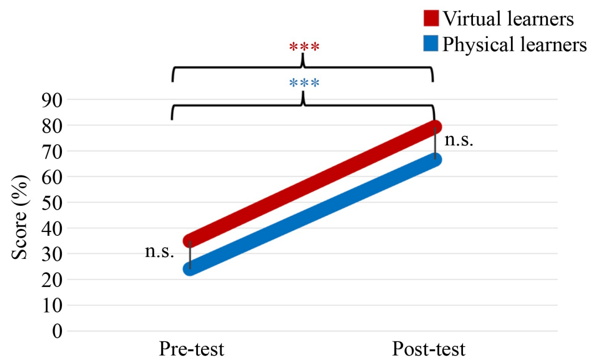

Figure 3 Results from the pre- and post-test for the physical and virtual learners. n.s: No significance.

Twenty-eight percent of participants had previous Gross Anatomy experience. There was no difference in percent improvement between participants with and without previous anatomy experience (physical with experience = 30.0% ± 22.3%; physical without experience = 49.0% ± 11.9%; 3D scan with experience = 43.3% ± 11.5%; 3D scan without experience = 44.5% ± 25.9%). There was no significance between students based on previous degrees or career pathway interests.

3.3 | Survey Results

Participants were asked a series of Likert-scale questions about using virtual scans in an educational setting. Participants taught using the virtual 3D scans were more likely to agree that they “would be able to sufficiently learn anatomy using 3D scans” when compared to those taught using physical prosections (physical = 3.0 ± 0.8; virtual = 4.1 ± 1.1; $P < 0.01$; see Figure 4). Participants taught using the virtual 3D scans were more likely to agree that they “enjoy using 3D scans to explore anatomical regions” when compared to those taught using physical prosections (physical = 4.1 ± 0.9; virtual = 5.0 ± 0.0; $P < 0.01$; see Figure 5). Regardless of teaching group, participants disagreed that they "would have a similar lab experience if I learned anatomy from 3D scans instead of dissection" (physical = 2.1 ± 0.6; virtual = 2.5 ± 0.8; see Figure 6). Participants commented that "*It looks very advanced, but nothing beats the real thing*" and "*I think that the virtual models are great for looking at the minute details of certain organs and regions, but I don't think it replaces dissection lab.*" Similarly, regardless of teaching group, participants disagreed that "using the 3D scans gives them appreciation for the human body" (physical = 2.7 ± 1.3; virtual = 2.7 ± 1.5). Finally, regardless of teaching group, participants agreed that they "would use 3D scans to prepare for the dissection lab" (physical = 4.5 ± 0.8; virtual = 4.9 ± 0.3) and "to study anatomy before lab practicals/written exam" (physical = 4.5 ± 0.8; virtual = 4.9 ± 0.3; see Figure 7). Participants commented that "*They were quite useful, easy to navigate, and are a good supplement to physical dissections*" and "*Integrating 3D models in Gross Anatomy class can augment our learning of dissection and help us prepare for exams!*"

Participants were asked about anatomy education and preference of resources using Likert-scale and slider-type questions. Both groups disagreed with the statement, "In the modern era, donor body-based anatomy teaching should be replaced by virtual/augmented reality applications or other computer-assisted methods," and there was no difference in responses (physical = 1.9 ± 0.9; virtual = 2.2 ± 0.8). Participants used a slider to demonstrate their preferred proportion of virtual (0) to physical (100) resources (physical = 60.0 ± 19.9; virtual = 50.1 ±

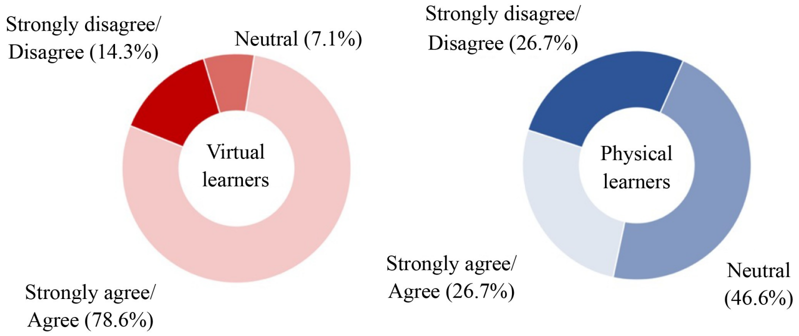

Figure 4 Student responses to the use of scans to sufficiently learn anatomy.

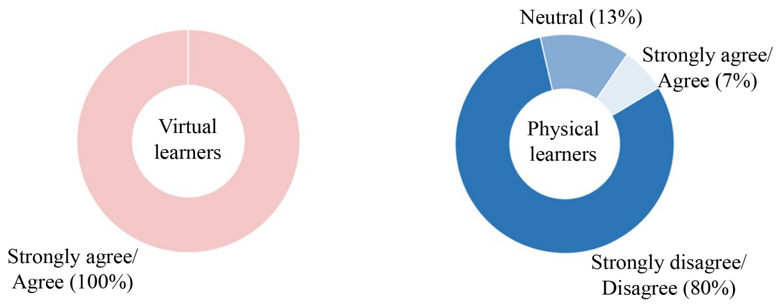

Figure 5 Student responses to enjoyment of virtual 3D scans for both physical and virtual learners.

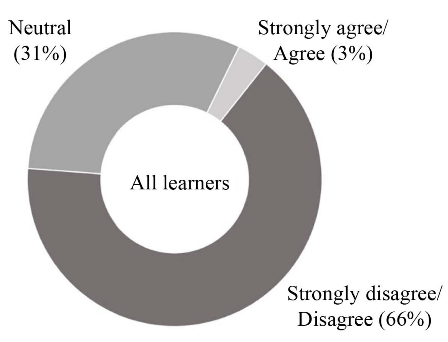

Figure 6 Student response to if they would have a similar lab experience using the virtual 3D scans.

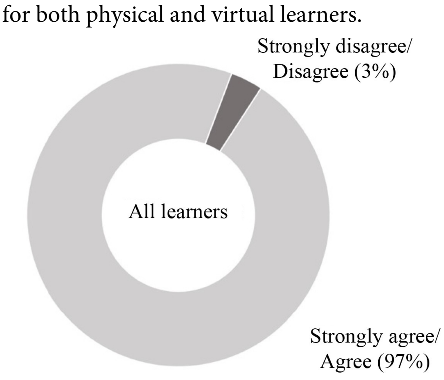

Figure 7 Student responses to the use of scans to prepare for lab practicals/written exam.

17.8) and virtual 3D scans (0) to dissection videos (100) as virtual resources (45.3 ± 16.7; 44.2 ± 19.7) while learning anatomy. There was no difference in the preferred learning resources between the groups.

Participants were then asked a series of Likert-scale questions about the appearance, usability, and features of virtual 3D scans. There were no differences between groups, and average scores are reported below. When asked if the visual appearance (color, texture, etc.) of 3D scans are comparable to physical prosections, the respondents agreed (3.7 ± 1.0). When asked about the ease of navigation of the virtual 3D models, the respondents strongly agreed that it was easy to manipulate the scans (4.6 ± 0.5). The most commonly requested type of virtual 3D scans in the online database were isolated organs, followed by examples of completed dissection chapters (e.g., anterior forearm) and completed regional dissections (e.g., upper limb). Participants most commonly requested features such as practical-type question quizzes (identification, action, innervation) and click-to-identify structures.

4 Discussion

Many studies have suggested that the best way to teach modern anatomy is by using a multimodal approach such as donor body dissections supported by innovative learning methods using technology (Biasutto et al., 2006; Estai & Bunt, 2016; Ghosh, 2017; Yammine & Violato, 2015). While donor body dissection has been practiced and studied for many years, new learning resources must be evaluated to ensure students' success and preferences. At DUCOM, we developed a new series of computer-based 3D models of scanned donor body prosections, and wanted to assess whether these were effective learning tools and gather feedback prior to implementation.

Our results demonstrated that pre-test and post-test scores, as well as percent increase in scores, were similar for both the virtual and physical prosection learners. This suggests that the virtual 3D scans of prosections are a comparable resource to physical prosections and are an effective tool to use when learning how to identify structures on a donor body. These results are similar to other studies comparing interactive learning softwares, such as computer-generated 3D models or those constructed by CT/MRI, to more traditional methods like dissection, prosections, and textbooks (Beermann et al., 2010; Codd & Choudhury, 2011; Ng et al., 2015). In addition, most participants in this study were first time learners of Gross Anatomy with no prior experience. No differences were seen between the participants with and without prior Gross Anatomy experience, suggesting that scans may be used for initial learning of the material as well as a review resource for students that may have learned the material previously.

The survey results at the end of the study suggested that the virtual learners were more positive about their enjoyment level and their ability to sufficiently learn anatomy using the virtual 3D scans. While both the virtual and physical learner groups were briefly exposed to the other resource that was not their assigned learning modality, this was most likely due to the virtual learners increased time with the scans, their experience during the learning session, and self-perceived performance on the post-test.

Both groups disagreed that they would have a similar lab experience if they learned anatomy primarily from virtual scans of donor body prosections. It seems that despite the advances in technology focused on education, students still prefer learning Gross Anatomy in the laboratory, ideally through donor body dissection. The act of dissecting has been traditionally regarded as a rite of passage but also as the most effective and preferred method, which the participants in this study also expressed (Franchi, 2020; Ghosh, 2017). While we only compared virtual 3D models of prosections to examination of physical donor body prosections, other studies have shown that performance is higher when 3D models are used compared to 2D models or no models (Nicholson et al., 2006; Petersson et al., 2009; Triepels et al., 2020; Venail et al., 2010). This suggests that efforts should be made to incorporate virtual 3D models into courses if access to a Gross Anatomy lab is not possible, such as in the cases of online courses, reduction in curricular time, or laboratory restrictions like during the COVID-19 pandemic.

A shift toward utilizing virtual educational resources is already evident, as another study found that approximately one quarter of medical schools in the U.S. planed to incorporate either virtual 3D anatomy software or virtual reality software into their anatomy curriculum (Shin et al., 2022). Current medical students, regardless of age, have already shown a higher level of technological readiness compared to previous years, indicating that many are prepared for updated resources (MacNevin et al., 2021). The COVID-19 pandemic certainly propelled the creation and implementation of innovative learning resources for students, but some institutions are still grappling with the best way to incorporate these resources into their medical curriculum.

Studies that reviewed student opinions found that while some courses offered virtual resources, even prior to the COVID-19 pandemic, they were not integrated into the course in a way that worked ideally for students (Rizzolo et al., 2010). Virtual resources have the ability to maximize the benefits from different teaching methods, accommodate different learning styles, and offer flexibility in studying location if incorporated properly using student feedback (Johnson et al., 2012; Sugand et al., 2010; Triepels et al., 2020). When asked about the proportion of virtual vs. physical materials used to learn anatomy, the participants preferred about half virtual and half physical resources. Participants in this study agreed that the scans would be best used as a preparation tool for dissection lab and as a study resource for exams. We plan to offer the virtual 3D scans of donor body prosections to students as a supplemental resource while reducing some of the outdated resources. We hope that this will accommodate different learning styles and provide more interactive learning and offer flexibility in studying location for students. Also, we anticipate that the availability of virtual 3D scans of prosections will decrease the heavy use of our limited physical prosections available at our large medical school (> 300 students/year) so that we can reuse them for future classes.

As mentioned previously, many of the virtual 3D models studied are computer-generated or reconstructions of CT/MRI imaging. These computer-generated 3D models are useful for studying internal structures and are frequently used for medical purposes (Haleem & Javaid, 2019) but are relatively expensive, require special resources, and do not have the same appearance of dissected human tissue. We believe that offering virtual 3D models of scanned donor body prosections is more valuable to students, as this should be similar to what they uncover in the dissection lab and be more representative in what they would encounter during a surgery. Manipulating virtual 3D scans of donor body prosections not only allows for better visualization of true anatomical relationships in detail but also strengthens the learners' understanding of the 3D anatomy when students are not present in the lab (Krause et al., 2023). Additionally, students are able to see a clear example of a completed dissection and have a comparable resource when identifying structures during a practical exam.

Interestingly, both groups did not feel an appreciation for the human body while using the virtual 3D scans of donor body prosections. This is most likely because there is not tactile experience associated with the virtual 3D scans and users may feel that it is more "game-like." Other studies have shown that an appreciation for the human body, including intricacies of structures, variations between donors, or that the donor was once a living person, are all important values sharpened in the Gross Anatomy dissection lab (Flack & Nicholson, 2018). For many students, this is their first interaction with the emotions associated with death and dying. While challenging, this teaches students professional management of their emotions, builds their self-confidence, and fosters their respect for the donor, which are all skills that will prepare them for clinical practice (Bertman & Marks, 1985; Dyer & Thorndike, 2000; Flack & Nicholson, 2018; Netterstrøm & Kayser, 2008; Weeks at al., 1995). This finding supports the idea that the virtual 3D scans should be a supplement to the dissection lab and not the main learning resource.

There are a few limitations of this study. First, the sample size of 29 participants, with only 14 and 15 participants in each group, is relatively small. This was most likely due to the scheduling of this study on the weekend before orientation week when many students were moving into local housing. Also, the participants were aware that they were signing up for a study comparing virtual 3D models to donor body prosections, therefore, this may have attracted participants that were more interested in technology and the subject of Gross Anatomy. This may have potentially skewed the results in favor of the virtual 3D models. We did not gather data on learner preferences, spatial ability or previous use of 3D softwares, or games prior to the start of the study, which may have impacted the learning curve associated with interacting with the virtual 3D scans. Additionally, the only region studied was the external heart and the comparison to other regions of the body is needed. Lastly, only short-term knowledge was tested and long-term retention of materials remained unknown.

Future studies include increasing the number of participants and testing the long-term retention effects of using virtual 3D models for anatomy education, which would strengthen the conclusions of this study. Additionally, we aim to incorporate the virtual 3D scans into our Gross Anatomy laboratory resources for students to use. We will continue to increase the number of scans focusing on regional dissections and isolated organs, in addition to improving the quality of the scans by using photogrammetry to improve surface texture. Also, we plan to continue studying student use of the virtual 3D scans and features associated with student success.

5 Conclusions & Future Directions

This study demonstrates that virtual 3D scans of Gross Anatomy prosections are a comparable resource to physical prosections and are an effective tool to use when learning how to identify structures on a donor body, with both learning groups showing similar significant improvement after learning from either resource. Overall, the visual appearance, interactive features, navigation of the software, and enjoyment while using the virtual 3D models were all positive. Students did not support replacing the physical dissection process with virtual 3D scans but agreed they would be useful for studying and preparing for labs as well as practical and written exams. Future goals include offering this resource to students and other institutions, as well as continuing to study the efficacy of our database.

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Conflicts of Interest The authors declare that they have no conflicts of interest related to the content of this paper.

Ethics Statements The authors declare that their Institutional Ethics Committee confirmed that no ethical review was required for this study. Written informed consent for participation was not required because all participants' data was anonymized before the statistical analyses were done.

Data Availability Statements The authors confirm that all data generated or analysed during this study are included in this published article.

Electronic Supplementary Material Supplementary material is available in the online version of this article at https://doi.org/10.1007/s44366-025-0064-9 and is accessible for authorized users.

References

Allen, L. K., Eagleson, R., & de Ribaupierre, S. (2016). Evaluation of an online three-dimensional interactive resource for undergraduate neuroanatomy education. *Anatomical Sciences Education*, *9*(5), 431–439.

Alsup, B. K., & Fox, G. (2025, February 18). *BlueLink Images*. Available from the BlueLink website.

Attardi, S. M., Harmon, D. J., Barremkala, M., Bentley, D. C., Brown, K. M., Dennis, J. F., Goldman, H. M., Harrell, K. M., Klein, B. A., Ramnanan, C. J., & Farkas, G. J. (2022). An analysis of anatomy education before and during COVID-19: August–December 2020. *Anatomical Sciences Education*, *15*(1), 5–26.

Beermann, J., Tetzlaff, R., Bruckner, T., Schöebinger, M., Müller-Stich, B. P., Gutt, C. N., Meinzer, H. P., Kadmon, M., & Fischer, L. (2010). Three-dimensional visualisation improves understanding of surgical liver anatomy. *Medical Education*, *44*(9), 936–940.

Bertman, S. L., & Marks, S. C. Jr. (1985). Humanities in medical education: Rationale and resources for the dissection laboratory. *Medical Education*, *19*(5), 374–381.

Biasutto, S. N., Caussa, L. I., & Criado del Río, L. E. (2006). Teaching anatomy: Cadavers vs. computers? *Annals of Anatomy–Anatomischer Anzeiger*, *188*(2), 187–190.

Codd, A. M., & Choudhury, B. (2011). Virtual reality anatomy: Is it comparable with traditional methods in the teaching of human forearm musculoskeletal anatomy. *Anatomical Sciences Education*, *4*(3), 119–125.

Duraes, M., Akkari, M., Jeandel, C., Moreno, B., Subsol, G., Duflos, C., & Captier, G. (2022). Dynamic three-dimensional virtual environment to improve learning of anatomical structures. *Anatomical Sciences Education*, *15*(4), 754–764.

Dyer, G. S., & Thorndike, M. E. (2000). Quidne mortui vivos docent? The evolving purpose of human dissection in medical education. *Academic Medicine*, *75*(10), 969–979.

Estai, M., & Bunt, S. (2016). Best teaching practices in anatomy education: A critical review. *Annals of Anatomy–Anatomischer Anzeiger*, *208*, 151–157.

Flack, N. A. M. S., & Nicholson, H. D. (2018). What do medical students learn from dissection. *Anatomical Sciences Education*, *11*(4), 325–335.

Franchi, T. (2020). The impact of the COVID-19 pandemic on current anatomy education and future careers: A student's perspective. *Anatomical Sciences Education*, *13*(3), 312–315.

Ghosh, S. K. (2017). Cadaveric dissection as an educational tool for anatomical sciences in the 21st century. *Anatomical Sciences Education*, *10*(3), 286–299.

Habbal, O. (2009). The state of human anatomy teaching in the medical schools of gulf cooperation council countries: Present and future perspectives. *Sultan Qaboos University Medical Journal*, *9*(1), 24–31.

Haleem, A., & Javaid, M. (2019). 3D scanning applications in medical field: A literature-based review. *Clinical Epidemiology and Global Health*, *7*(2), 199–210.

Harmon, D. J., Attardi, S. M., Barremkala, M., Bentley, D. C., Brown, K. M., Dennis, J. F., Goldman, H. M., Harrell, K. M., Klein, B. A., Ramnanan, C. J., & et al. (2021). An analysis of anatomy education before and during COVID-19: May–August 2020. *Anatomical Sciences Education*, *14*(2), 132–147.

Hennessy, C. M., Royer, D. F., Meyer, A. J., & Smith, C. F. (2020). Social media guidelines for anatomists. *Anatomical Sciences Education*, *13*(4), 527–539.

Jeyakumar, A., Dissanayake, B., & Dissabandara, L. (2020). Dissection in the modern medical curriculum: An exploration into student perception and adaptions for the future. *Anatomical Sciences Education*, *13*(3), 366–380.

Johnson, E. O., Charchanti, A. V., & Troupis, T. G. (2012). Modernization of an anatomy class: From conceptualization to implementation. A case for integrated multimodal-multidisciplinary teaching. *Anatomical Sciences Education*, *5*(6), 354–366.

Krause, K. J., Mullins, D. D., Kist, M. N., & Goldman, E. M. (2023). Developing 3D models using photogrammetry for virtual reality training in anatomy. *Anatomical Sciences Education*, *16*(6), 1033–1040.

Krebs, C., Fejtek, M., & Mordhorst A. (2025, February 18). *Clinical Anatomy*. Available from Clinical Anatomy website.

Kurul, R., Ögün, M. N., Neriman Narin, A., Avci, Ş., & Yazgan, B. (2020). An alternative method for anatomy training: Immersive virtual reality. *Anatomical Sciences Education*, *13*(5), 648–656.

MacNevin, W., Poon, E., & Skinner, T. A. (2021). Technology readiness of medical students and the association of technology readiness with specialty interest. *Canadian Medical Education Journal*, *12*(2), e31–e41.

Mathiowetz, V., Yu, C. H., & Quake-Rapp, C. (2016). Comparison of a gross anatomy laboratory to online anatomy software for teaching anatomy. *Anatomical Sciences Education*, *9*(1), 52–59.

McLachlan, J. C. (2004). New path for teaching anatomy: Living anatomy and medical imaging vs. dissection. *The Anatomical Record*, *281B*(1), 4–5.

McMenamin, P. G., McLachlan, J., Wilson, A., McBride, J. M., Pickering, J., Evans, D. J. R., & Winkelmann, A. (2018). Do we really need cadavers anymore to learn anatomy in undergraduate medicine. *Medical Teacher*, *40*(10), 1020–1029.

McMenamin, P. G., Quayle, M. R., McHenry, C. R., & Adams, J. W. (2014). The production of anatomical teaching resources using three-dimensional (3D) printing technology. *Anatomical Sciences Education*, *7*(6), 479–486.

Miltykh, I., Kafarov, E. S., Covantsev, S., Dadashev, A. S., Skarlis, A. A., & Zenin, O. K. (2023). A new dimension in medical education: Virtual reality in anatomy during COVID-19 pandemic. *Clinical Anatomy*, *36*(7), 1007–1015.

Moro, C., Štromberga, Z., Raikos, A., & Stirling, A. (2017). The effectiveness of virtual and augmented reality in health sciences and medical anatomy. *Anatomical Sciences Education*, *10*(6), 549–559.

Netterstrøm, I., & Kayser, L. (2008). Learning to be a doctor while learning anatomy! *Anatomical Sciences Education*, *1*(4), 154–158.

Ng, C. L., Liu, X. D., Chee, S. C. J., & Ngo, R. Y. S. (2015). An innovative 3-dimensional model of the epitympanum for teaching of middle ear anatomy. *Otolaryngology–Head and Neck Surgery*, *153*(5), 832–837.

Nicholson, D. T., Chalk, C., Funnell, W. R. J., & Daniel, S. J. (2006). Can virtual reality improve anatomy education? A randomised controlled study of a computer-generated three-dimensional anatomical ear model. *Medical Education*, *40*(11), 1081–1087.

Peterson, D. C., & Mlynarczyk, G. S. A. (2016). Analysis of traditional versus three-dimensional augmented curriculum on anatomical learning outcome measures. *Anatomical Sciences Education*, *9*(6), 529–536.

Petersson, H., Sinkvist, D., Wang, C. L., & Smedby, Ö. (2009). Web-based interactive 3D visualization as a tool for improved anatomy learning. *Anatomical Sciences Education*, *2*(2), 61–68.

Qualtrics. (2025). *Qualtrics*. Available from Qualtrics website.

Rizzolo, L. J., Rando, W. C., O'Brien, M. K., Haims, A. H., Abrahams, J. J., & Stewart, W. B. (2010). Design, implementation, and evaluation of an innovative anatomy course. *Anatomical Sciences Education*, *3*(3), 109–120.

Saltarelli, A. J., Roseth, C. J., & Saltarelli, W. A. (2014). Human cadavers vs. multimedia simulation: A study of student learning in anatomy. *Anatomical Sciences Education*, *7*(5), 331–339.

Shin, M., Prasad, A., Sabo, G., Macnow, A. S. R., Sheth, N. P., Cross, M. B., & Premkumar, A. (2022). Anatomy education in US medical schools: Before, during, and beyond COVID-19. *BMC Medical Education*, *22*(1), 103.

SignUpGenius. (2025). *SignUpGenius*. Available from SignUpGenius website.

Sugand, K., Abrahams, P., & Khurana, A. (2010). The anatomy of anatomy: A review for its modernization. *Anatomical Sciences Education*, *3*(2), 83–93.

Triepels, C. P. R., Smeets, C. F. A., Notten, K. J. B., Kruitwagen, R. F. P. M., Futterer, J. J., Vergeldt, T. F. M., & Van Kuijk, S. M. J. (2020). Does three-dimensional anatomy improve student understanding. *Clinical Anatomy*, *33*(1), 25–33.

Venail, F., Deveze, A., Lallemant, B., Guevara, N., & Mondain, M. (2010). Enhancement of temporal bone anatomy learning with computer 3D rendered imaging software. *Medical Teacher*, *32*(7), e282–e288.

Vilburn, M., & Simet, S. (2025, February 18). *Virtual Dissection Database.* Available from Virtual Dissection Database website.

Weeks, S. E., Harris, E. E., & Kinzey, W. G. (1995). Human gross anatomy: A crucial time to encourage respect and compassion in students. *Clinical Anatomy*, *8*(1), 69–79.

Yammine, K., & Violato, C. (2015). A meta-analysis of the educational effectiveness of three-dimensional visualization technologies in teaching anatomy. *Anatomical Sciences Education*, *8*(6), 525–538.

Yang, J. (2023). Technology-enhanced preclinical medical education (anatomy, histology and occasionally, biochemistry): A practical guide. *Advances in Experimental Medicine and Biology*, *1431*, 65–93.