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Developing Teaching: Reports and Reflections

Teaching Virtual Forensic Anthropology Labs: Methods and Reflections

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Abstract
Development of virtual labs for Forensic Anthropology was complicated by the notion that the skeleton cannot be learned without physical manipulation. This was addressed by using free programs to teach using 3D models of bone. Successes and shortcomings are discussed based on student and educator feedback. Integration of 3D models in teaching is plausible as it reduces deterioration of specimens and increases accessibility of the lab, however, the ethics of digital archaeology, including curation of human skeletal models, is an unsolved challenge. Overall, although 3D modelling cannot replace hands-on learning, teaching virtually can indeed ensure high-quality instruction is delivered.

Keywords
Forensic anthropology, 3D modelling, digital bioarchaeology, osteology, biological anthropology.

Introduction

Professional bioarchaeologists often hold the opinion that the human skeleton can only be successfully learned through first-hand manipulation. While this stance is commonplace, it was challenged during the 2020-21 academic year wherein the opportunity for in-person learning was no longer possible due to the COVID-19 pandemic. Educators across the globe were obliged, eager or not, to transition all courses and laboratory sessions to virtual formats. From biology to chemical engineering, post-secondary institutions all strived to develop inventive methods for running virtual labs (Ayega & Khan, 2020; Glassey & Magalhães, 2020). The third-year Forensic Anthropology class at Lakehead University in Thunder Bay, Ontario was no different, which ran for the winter semester of 2021 with twenty-eight students enrolled. In this course, forensic science is discussed as well as its relationship to biological anthropology. A case study approach allows students to engage with the procedures and responsibilities of forensic anthropologists. Each stage of responsibility of a forensic anthropologist is covered from recovery of evidence, methods of skeletal and biochemical analysis, and the role of the scientific expert in court. A significant aspect of this course is learning human osteology since this course functions as most students' first introduction to the human skeleton. When in-person learning was possible, students were acquainted with osteology through hands-on laboratory sessions.

Dr. Tamara Varney led the transition to online for the lecture portion of the class, whereas organizing and leading the laboratory sessions for this class was a multi-faceted, rapidly evolving project, involving the work of four individuals. Lab technicians, Clarence Surette, Chris McEvoy, and I, Jade Ross, the teaching assistant, all collaborated with Dr. Tamara Varney to develop these virtual lab sessions. Traditionally, labs for this class run in person with multiple stations that students work through in groups. Each station consists of the specimens needed to answer the corresponding question. Specimens included items such as animal and human bones (or casts) and other materials (coral, shells, rocks) that may be confused with bone. There was a concern regarding whether the lab format could be effectively converted to an online environment. This reflection aims to outline the process of how we utilized 3D modelling technology, including which software and websites were used, to lead Forensic Anthropology labs. Feedback from educators and students regarding their experience was also collected and will be shared. To conclude, the ethical considerations that are emerging with the increase in reliance on digital platforms to teach anthropology and archaeology will be briefly examined (Ulguim, 2018).

Though we may not have the answers yet, this reflection serves as a how-to (or sometimes how not to) manual on leading virtual labs as well as a point of discussion for the ethics of digital archaeology.

Hardware Requirements

To create digital models for virtual labs in a short amount of time, we used three scanners: two NextEngine laser scanners and one Afinia/EinScan-S structured light scanner. While the NextEngine scanner was preferable due to its superior visual texture, the mesh accuracy of both types of scanners were comparable at a precision of 100 microns. Each NextEngine scanner was paired with a laptop with a minimum Intel Core i3 processor, 4GB of random-access memory (RAM), integrated graphics card, and 500 GB hard drive, given that the scans can be processed later with a computer with higher performance. The Afinia/EinScan-S scanner was paired with a Dell Inspiron gaming laptop with an Intel Core i7 processor with a 2 GB GeForce GTX graphics card, 16 GB of RAM, and a 500 GB hard drive as the individual scans cannot be processed later. Within Afina/EinScan-S, we edited and aligned each scan and when enough scans were collected to capture all the surface features of the model, they were fused. To process the scans from the NextEngine scanner in ScanStudio and post-process the finished 3D models (from both types of scanners), a desktop gaming computer was required with an AMD Ryzen 7 3800X 8 core processor with an 8 GB EVGA Geforce RXT 2060 graphics card, 32 GB of RAM, 1 TB solid-state drive (SSD), and a 1 TB hard drive.

Setup and Operation

To scan the bones, each model was placed on the scanning platform and held in place using various part holders, vices, or beaker clamps (Figure 1). Since the platform rotates, we selected a collection of 12 to 14 individual scans to complete a 360º arc designed to capture all morphological features in a broad horizontal zone from the base to the tip of the object. The objects were re-oriented as required on the platform to capture all sides of the model. Heightened object complexity results in the necessity for more orientations to create a digital topological model, increasing the amount of time required to gather the data. Captured scans were aligned, edited, and fused in the respective software for each type of scanner. Fused models were exported as Polygon File Format or PLY files to be post-processed later in other software. For the NextEngine Scanner the visual colour texture was kept, while for the Afinia/EinScan-S, it was not. Even without the visual textures, all features and landmarks were visible on the bones.

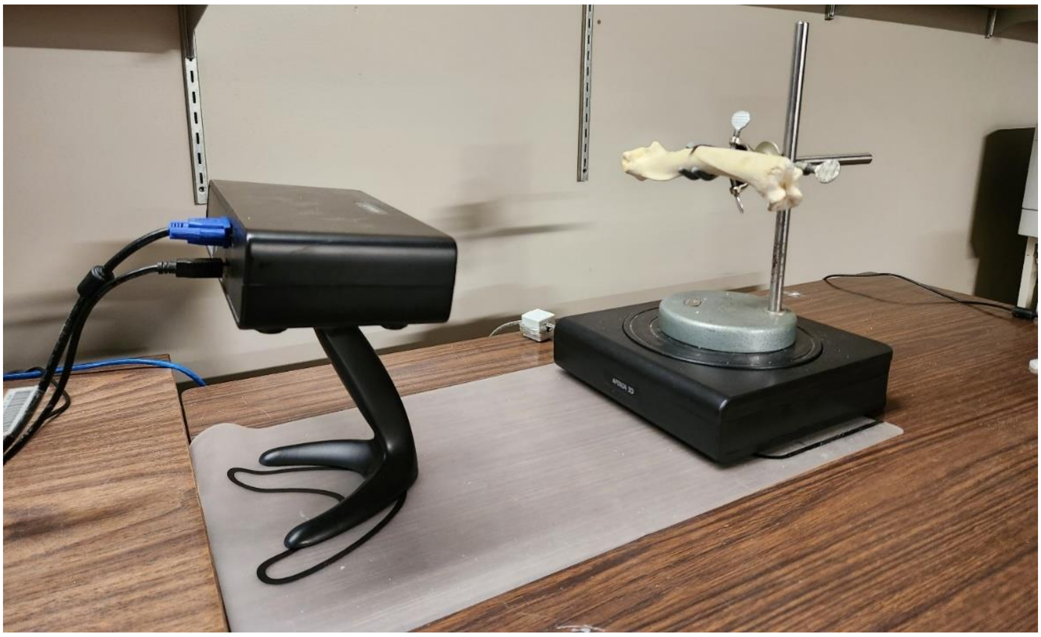

Figure 1: Afinia/EinScan-S scanner in process of scanning canine humerus.

Post-Processing of 3D Models

To allow for manipulation or modification the models, we simplified the file size for each model in MeshLab (since exported PLY files can be quite large). For simple models, this was all that was required but for other models, errors in the mesh needed to be corrected. This required the use of several software such as Windows 3D Builder, MeshLab, and MeshMixer. These are free open-source programs that can be downloaded by an unlimited number of users. Once errors in the mesh were corrected, bones with various angles or cavities such as the skull, sacrum, and pelvis needed to be restored. Sculpting tools in MeshMixer were used to restore features not captured in the scans. To sculpt missing features as accurately as possible, the original models were used as a guide. Once completed, models were exported as PLY files to be visualized in MeshLab for student use.

Preparation of Models for Student Labs

Depending on lab requirements, modification and/or manipulation of the models was necessary. For some labs, only a portion of the bone was required, while for others, multiple models needed to be oriented and organized in the same file. Models could be cut, organized, and oriented in MeshMixer, then exported as PLY files to be visualized in MeshLab. MeshLab was also used to make interactive project files where multiple models or parts of a models could be selected or de-selected for specific lab questions (Figure 2). Furthermore, models were uploaded in Sketchfab so they could be annotated and used for quizzes. Sketchfab is an online platform where models can be viewed for free. A paid subscription is required to upload models to the platform each month. An example of some of the models scanned and produced by Lakehead University Anthropology Department can be viewed in Figure 3 below. To supplement the scanned models used for classes, it was recommended that students make use of BioDigital to visualize the entire human skeleton. On this website, it was possible to isolate and annotate features on bones for lab use and study guides. BioDigital has a free and paid version, with the free version utilized for this class, though the restrictions of the version limited user interaction and the ability to produce results.

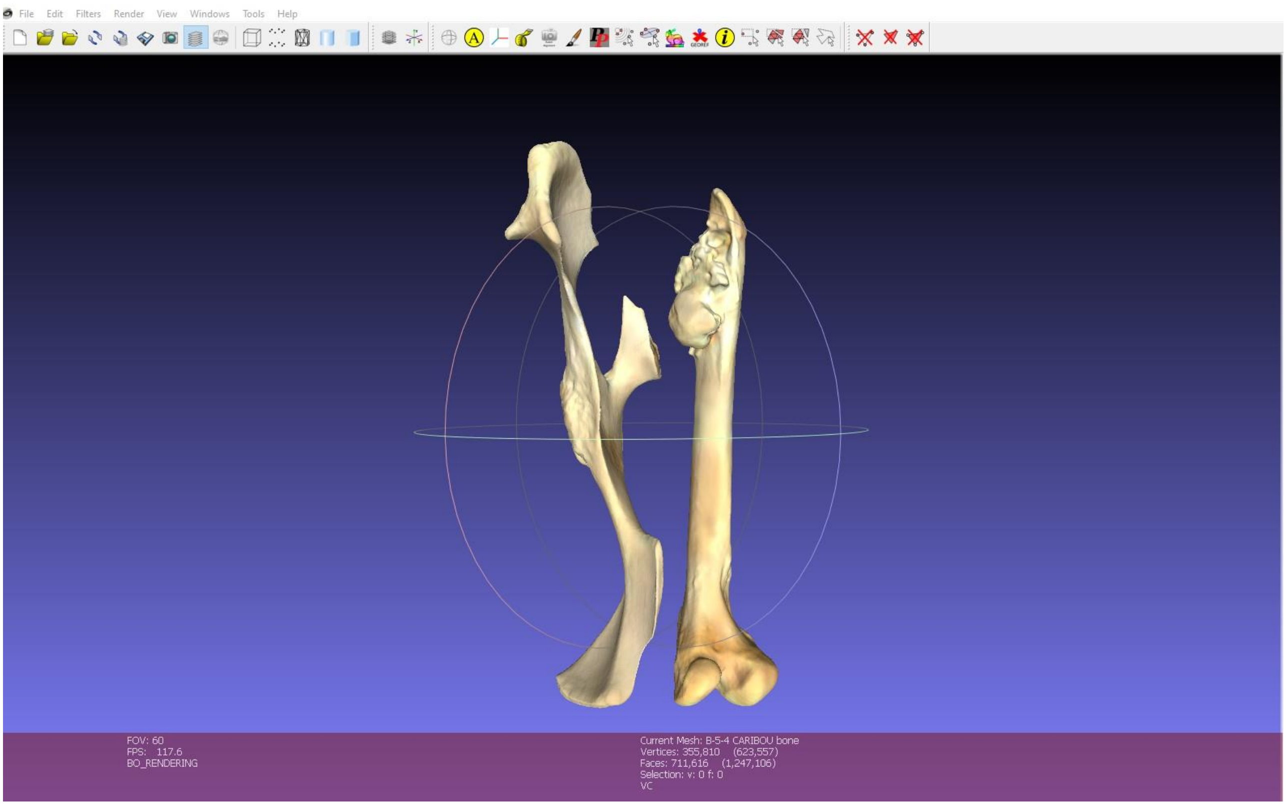

Figure 2. Caribou os coxa and femur showing hip dysplasia viewed in MeshLab

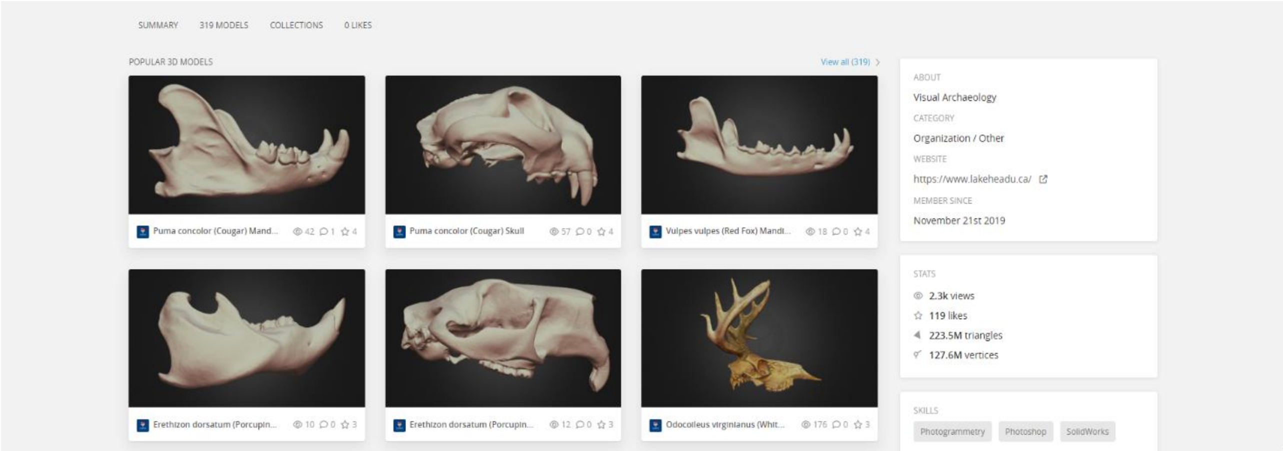

Figure 3: Lakehead University Anthropology Sketchfab page.

Design of Laboratory Sessions

With the necessary technology in place to view and manipulate the models, the next planning stage was designing the lab sessions and enabling resource sharing with the students. The first step was hosting a Zoom tutorial lab session wherein students were led through basic exercises involving opening MeshLab files and manipulating the models. We shared the main functions of MeshLab, such as zooming in and out or importing multiple models at once. Students were encouraged to follow along on their devices to ensure they understood the program's functionality. During this session, there was no graded assignment, but it gave students the opportunity to become comfortable with the software in advance of the actual lab.

For the labs, specimen files were organized according to necessary station and divided into various Google Drive folders encompassing all required material needed (Figure 4). Some specimens had 3D models, others had JPEG images, while most had both available. The lab periods were three hours during which we would host a Zoom call and split the class into breakout groups. Students were encouraged to work together through the questions while Dr. Tamara Varney, Clarence Surette and I cycled through the rooms answering inquires. The students had the weekend to complete and submit the lab, which was an extended deadline compared to in-person labs that were due at the end of the period. Three labs were hosted during the semester, each with a key learning goal. The first focused on recognition of bone and whether bones were human or animal, the second dealt with attribution of sex, and the final lab examined age at death as well as trauma.

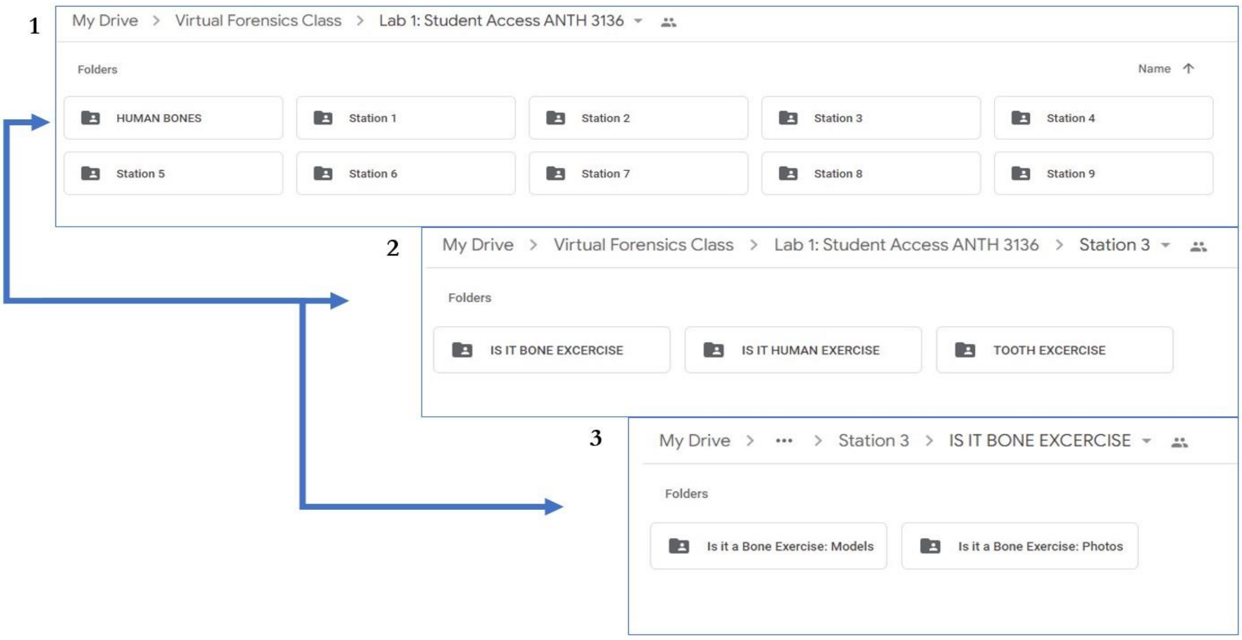

Figure 3: Example of the Google Drive file layout for a lab section.

The final assignment for Forensic Anthropology labs is usually a bell ringer test but this was modified to an independent lab, following a format similar to the previous three labs. Though Forensic Anthropology did not include a virtual bell ringer test, Dr. Kathleen Whitaker designed a bell ringer test for Human Skeletal and Dental Biology. For this, everyone was at the same "station" together and Dr. Kathleen Whitaker either held up bones or shared her screen and showed individual bones or fragments in MeshLab. There was a time limit for each station and a Lego person was added in each station so they could very quickly grasp scale of the models as students progressed through the stations. Though not ideal, this seemed an effective solution for implementing a bell ringer style test.

After a semester filled with challenges as well as excitement learning new skills and techniques, there was success in using 3D models to teach osteology in a Forensic Anthropology class in general. It is important, however, to examine the intricacies involved in this method of teaching from both educators' and students' perspectives.

Educator Perspective

In terms of feedback from educators, the sample is small as I will only be able to discuss the experience of Dr. Tamara Varney, Clarence Surette, and Dr. Kathleen Whitaker, who taught multiple sessions of Human Skeletal and Dental Biology using the virtual 3D models. As this mode of teaching becomes more common, it will be interesting to garner insights from other professionals regarding their experiences.

Challenges

One of the main challenges utilizing this technology is unfamiliarity with this mode of teaching and the programs. This sentiment is echoed across disciplines, with adapting to modern technology discussed by Lynch and Ghergulescu (2017) as a significant challenge of virtual labs in general. It was especially difficult at times to learn how to use MeshLab alongside the students, which meant a significant amount of time spent practicing with these programs prior to labs beginning. The user interface of MeshLab specifically is not intuitive, and the program is an open-source system thus it can be difficult to utilize the program to its full potential. This method of teaching is also challenging for educators since most have extensive experience as osteologists, handling and viewing bones in person, as opposed to virtually. In this way, many key teaching tips are no longer viable when anatomy is taught from 3D models. It is also key to note that programs such as BioDigital have been created with a medical-oriented perspective, which is not always applicable when teaching from an anthropological standpoint. Adapting to this innovative technology and method of teaching is a significant challenge.

This method of teaching also requires the development of upwards of hundreds of 3D models. In this specific example, Lakehead University 's anthropology lab technicians scanned and prepared 3D models in advance of the classes beginning. This was a significant initial time investment, but it is only required to be completed once and then the models are available for repeated use in subsequent years. Scanning would not be possible in every scenario, meaning some may have to rely on open-access models from platforms such as Sketchfab. Teaching from an institution with resources to have its own collection of 3D models or ability to readily create 3D models was a privilege and advantageous as without this technology or access, designing effective virtual labs would be momentously more challenging. This issue speaks to the importance of open access and 3D models, a topic that will be covered further in a later section.

Finally, as educators, it was challenging to troubleshoot students' technological problems virtually. As will be discussed in the *Student Perspective: Challenges* section, many issues with technology arose and it was not always clear how to solve these issues without being able to access the individual's machine. Some examples included files not opening correctly or inability to manipulate models in a certain fashion. Despite the perceived issues, with experience as well as impressive student ingenuity and problem-solving, these technological challenges were resolved.

Benefits and Outlook

From educators' perspectives, there are numerous benefits to leading labs with 3D models. It significantly reduces the time spent in the physical lab space, allowing extra time for development of other curricula. Traditionally, labs are hosted in person but there are also study sessions hosted for students to independently practice with the specimens prior to the bell ringer test. With all materials readily available virtually, there was no need to host extra sessions and leading the lab sessions from home was a much more accommodating experience for all.

There is also the benefit that specimens, including real and cast human and animal bones, can be better preserved, and cared for if the main method of teaching involves utilizing 3D models of said specimens. Damage and typical wear have been incurred over the years to many of the teaching specimens and thus reducing physical contact with them can result in better preservation for the years to come. The department could use funds that would have to be allocated to replacing damaged specimens to integrate and acquire new specimens for the teaching lab. Virtual models also proved efficient for creating interactive test question involving identification of specific landmarks. These landmarks, such as the pubic symphyses, are often some of the primary areas where damage occurs on specimens. With the necessity of online testing, access to models which could be annotated in programs such as Sketchfab was a useful feature as they provide immersive exam or test questions, such as fill-in-the-blanks or feature identification questions. These models could also be shared via password-protected links, ensuring students can only access the models during the test period.

From a teaching point of view and in our experience, utilizing 3D models and virtual labs in forensic anthropology was successful given the constraints of virtual teaching but they are not a replacement to in-person learning. If students wish to pursue bioarchaeology or forensic anthropology further, it would be highly recommended they work with human bones in person instead of relying solely on 3D models. This sentiment is echoed by a recent study which showed that 3D models showed limited efficacy for novice students learning how to determine sex based on cranial traits (Kuzminsky, Snyder, & Tung, 2020). Similarly, educators who conducted a similar survey in the UK concluded that 3D models could not replicate the experience of handling human remains during the learning process for students (Craik and Collings, 2022). With the educators' perspectives discussed, it is crucial to now consider the student point of view, an arguably more critical aspect of this reflection.

Student Perspective

To gauge student experience, a survey was designed and shared with the Forensic Anthropology class after completion of all lab sessions. In an attempt to get as robust a number of responses as possible, a bonus mark on their last lab was offered for completion of the survey. This, coupled with the online nature of the entire course, made anonymity very difficult to implement in the survey process, but important perspectives from students were still able to be determined through their responses. Their answers were not overwhelmingly positive, suggesting they felt comfortable sharing their concerns and criticisms regarding the course format. Since the survey was determined to be evaluative by the Manager of Research Ethics at Lakehead University, no research ethics board approval was necessary. The information shared here includes direct feedback and responses from students regarding their opinion of the virtual labs. Twenty-five out of twenty-eight students responded, and their insight was invaluable in considering how this technology should/will be applied in the future.

Challenges

When asked to pinpoint challenges with the virtual labs, a common response was difficulty loading models within MeshLab due to computing power. Many of the files used contained multiple models and were data heavy. This caused some individuals' computers to slow, resulting in increased difficulty opening and manipulating models. A solution we found to this challenge was to reduce file size by decimating the models within MeshLab. This solution, however, reduces resolution of the models. When asked on a scale of 1-5, with 1 implying very little detail and 5 suggesting significant detail, how much detail they felt they were able to view in the models, 76% of students rated a 3 or 4, with no students rating this a 5 (Figure 5). In written responses, students did indicate that the inclusion of JPEG images alongside the models helped in these situations as at times, details not visible in the models could be better viewed in the pictures. Another solution to students facing reduced computing power would be for all models to be uploaded and accessed via Sketchfab, which would remove the requirement to download an

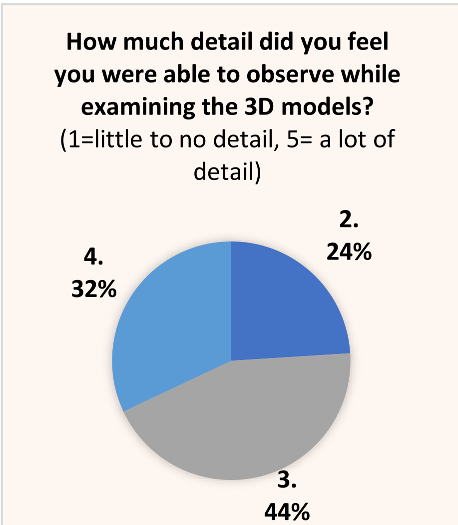

Figure 5: Pie graph of student responses to visible details on 3D models.

additional program (MeshLab), thus reducing the strain on computing power. Permissions and visibility would need to be granted by the authors via Sketchfab to ensure safe dissemination of the models. In a similar vein, students stated that the lack of scale within MeshLab created confusion during lab sessions. This was challenging especially when differentiating adult versus sub-adult bones as in person, size alone would often be sufficient. We recommended to students importing a reference model if size was an issue. They had access to 3D models of all bones in the adult human skeleton and therefore we encouraged them to import a femur or other bone of known relative size to aid with this issue. Another option in the future would be to integrate MeshMixer which has a more user-friendly measurement option.

Aside from technological challenges, students also indicated that the inability to feel the texture and weight of bones and physically manipulate them was a challenge. As individuals who did learn the skeleton through physical touch and practice, this is the biggest challenge that we do not think can be effectively solved. Virtual 3D models, and even physical casts for that matter, cannot replace the experience of handling bones and learning to identify fragmented or damaged bone. The usefulness of 3D models in hosting virtual labs when in-person learning was not possible cannot be understated, but it is not a functional replacement to learning osteology in the future. Though not a proxy, the importance of this technology has lasting implications and benefits as students also identified.

Benefits and Outlook

Survey answers from students revealed the successes of the virtual lab sessions. On a scale from 1-5, with 1 suggesting very difficult to navigate and 5 implying very easy to navigate, 85% of students gave a 3 or higher relating to the navigability of MeshLab. Despite technological challenges, this shows that MeshLab is a suitable program for sharing and viewing 3D models with students. Students also emphasized how the ability to view the models from various aspects through manipulation and rotation felt like the closest experience to handling the bones in person. Features including the ability to adjust lighting, zoom in and out, and measure features on the bones (Figure 6), were mentioned as capabilities that added to their experiences as well.

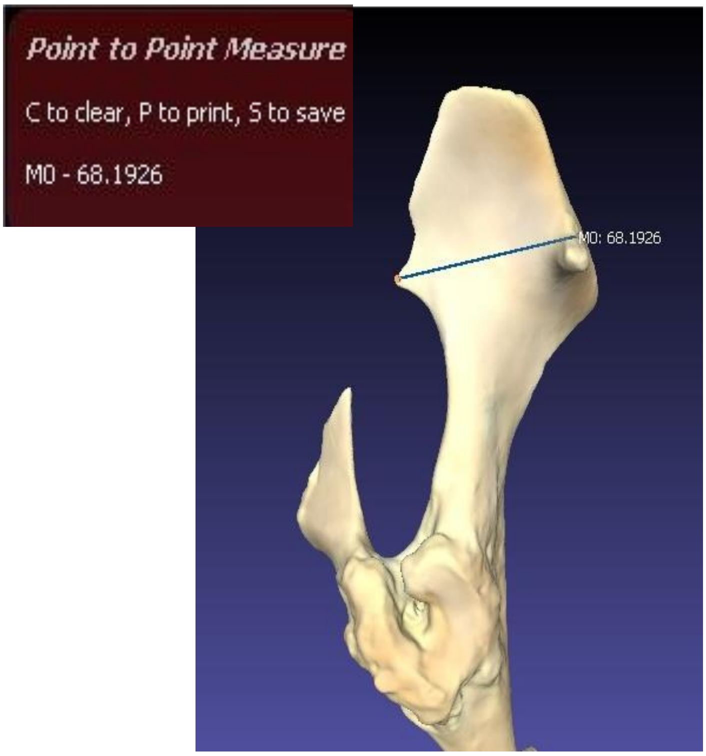

Figure 6: Example of the measurement tool in MeshLab measuring caribou os coxa.

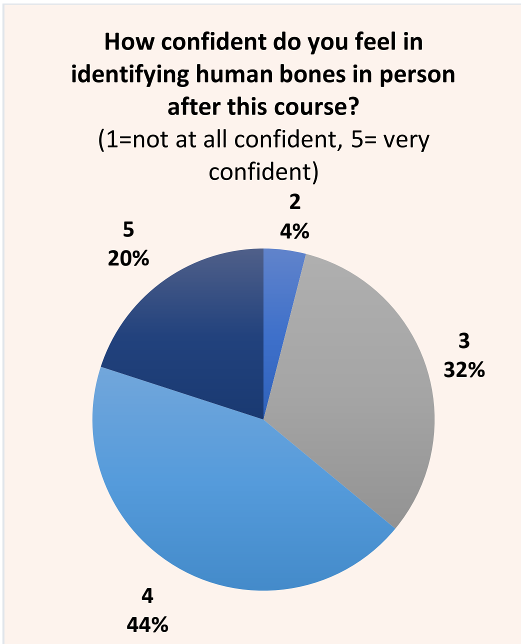

Figure 7: Pie graph of student responses to confidence in identifying human bone in person.

In response to the question, "Based on your learning of osteology during this course, how confident do you feel in identifying human bones in person?" 64% of students rated a 4 or 5, with 5 suggesting very high confidence in their ability to identify human bones in person (Figure 7). This question emphasizes the success of this mode of teaching and highlights the confidence of the students and their ability to identify bones. It is assuring to consider that despite the unavailability of in-person learning, students still had the opportunity to participate in a lab where they successfully learned osteology.

A major benefit of using 3D models consistently pointed out by the students was the accessibility of this method. One student commented that by utilising the 3D models, there was no need to ensure equal time for each student spent with the models, as would be an issue in class. Each student could access the model on their own device whenever they wished for however long was necessary. This benefit extends past students no longer having to share. Being able to study and view reference material whenever was convenient for the students and was an aspect they all seemed to appreciate. The incorporation of 3D models into future classes, even ones taught in class, could aid in removing barriers some students face when deciding to take a class with a lab section. Due to extenuating circumstances, such as work or family, some students may struggle to attend lab sessions or make time to attend the extra study sessions. The option to participate from home and continue to study at home on their own time was a relief for many students as evidenced by their comments. As indicated through a survey question, 88% of respondents felt that 3D models will remain a useful teaching tool into the future (Figure 8).

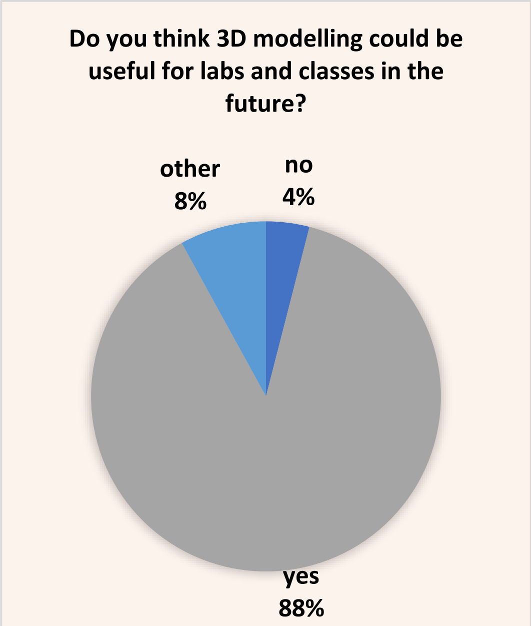

Figure 8: Pie graph of responses to whether or not 3D models could be useful in future classes.

Despite the challenges faced by students and educators alike in utilizing 3D models, the semester can be considered a success. Although we do not envision 3D models as a permanent replacement for in-person learning, the benefits of incorporating it in addition are immense. Considering this, it is important to evaluate how this rapidly emerging technology will be managed within teaching institutions in terms of ethics and administration.

Ethical Considerations and Conclusion

With the knowledge of how pedagogy can benefit from the inclusion of 3D models and the increasing popularity of this methodology within archaeology and anthropology, it is vital to examine the ethical considerations of this technology. The literature discussing the ethics of digital archaeology is just beginning to flourish, lagging quite behind technological advancements (Richardson, 2018; Smith and Hirst, 2020; Spiros et al., 2022; Ulguim, 2018). Similar to how lab technicians at Lakehead University have produced hundreds of scanned versions of items within the department collection, University of Toronto anthropologists have created databases of their collections to use for virtual labs, as well as to share with the public (Lonergan, 2020). Within the news article by Lonergan (2020), it is briefly mentioned that scans of real bone and fossils will only be available to students whereas other models can be shared more widely. A similar resource is made available by the Museum of London, called *Digitised Diseases*, which is an open-access web platform that displays upwards of 1,600 3D models of human remains with descriptions of the visible pathological conditions (Digitised Diseases, 2022). On their website, the creators emphasize the importance of respectful use of these models, and that 3D printing of the models is prohibited (Digitised Diseases, 2022). The 3D MMS Initiative is another open-access website aimed towards forensic anthropology and bioarcheology students and researchers, created from the Michigan State Forensic Anthropology Laboratory Donated Collection, that places an emphasis on ethical approaches to digital pedagogy (Spiros et al., 2022). The benefits of open-access resources are widespread, including equitable access globally, as Spiros et al. (2022) emphasizes. An example of open-access 3D models benefitting those globally is demonstrated in Thompson et al. (2020), wherein models available on Sketchfab made it possible for forensics courses to maintain their lab portion at institutions in India, amid the COVID-19 pandemic. Amongst these benefits, there remain challenges that come with creating an open-access resource such as how to sufficiently monitor the ways the models are being used. It may not always be possible to be aware of and regulate disrespectful or impermissible actions that the public could engage in, such as the unethical printing and sale of models for monetary profit. There is not yet a clear, singular answer for this obstacle and remains an area of important, future research.

This leads to the focus of ethical considerations when creating databases of 3D models: access and ownership. Though the increased accessibility of archaeological data through scanning is beneficial in many cases, the necessity of constant regulation and curation of the databases pose challenges that also do not yet have clear solutions (Caffell and Jakob, 2020; Cook & Compton, 2018; Smith and Hirst, 2020; Ulguim, 2018). Should models be made available to the public, and if so, which models and what platforms are most suitable for sharing? How do institutions modulate the use of scans shared with students and the public alike, avoiding misuse? In addition to increased accessibility, how can institutions work to educate students and the public in more engaging and community-based ways using 3D modelling technology? These questions are just a few of many which anthropologists and researchers have posed and have begun delving into. Smith and Hirst (2020) surveyed practitioners working with 3D imaged human remains, such as researchers and curators, to investigate some of the attitudes and best practices towards the ethical curation of 3D databases. The authors concluded that joint ownership agreements between all involved parties, such as curating institutions, researchers, and communities as well as detailed, formal research agreements should be established for any 3D modelling of human remains but that very few practitioners had yet implemented this practice (Smith and Hirst, 2020). Additionally, Caffell and Jakob (2020) call attention to the importance of ensuring any data sets gathered, including raw data from students' projects, should be collected, curated, and sufficiently documented to ensure electronic archives are not lost as technology advances.

In terms of our experience thus far, models of bones have only been made available to students in relevant classes. In a teaching context, discussing the ethics of 3D models and respectful interaction with the models is crucial, as emphasized by Spiros et al. (2022) and Caffell and Jakob (2020). Students and educators alike should understand the inherent value and meaning associated with models, handling the digital models with the same respect they would provide the physical bones (Caffell and Jakob, 2020). In the future, curating the database beyond the sharing of a selection of models on Sketchfab, so that some models are accessible to the public with educational features is a goal. Before we reach this step, however, the posed questions will require more solidified answers to ensure ethical and inclusive practice is carried out, which will include the development of sufficient joint ownership and research agreements. The key ethical tenants of the digital distribution of human remains, as presented by Errickson and Thompson (2020), and discussed by Spiros et al. (2022), include permission, respect, justification, and education, and if any 3D models of human bones are to be shared, these principles need to be heavily considered from all involved parties. We are not at this stage, however, and do not plan to share culturally sensitive material for the present time.

Based on our experience using 3D models to lead virtual Forensic Anthropology labs, we emphasize the utility of this method and its implications for accessibility in education on a local and global scale. Though not a substitute to learning in person, as emphasized by the experience of other educators, using 3D models is an amazing resource for students and educators, especially in changing times (Craik and Collings, 2022; Kuzminsky et al., 2020). Understanding that this technology proves useful in institutions through increasing accessibility to archaeological knowledge, it is of utmost importance that the ethics of these practices are discussed further. As we at Lakehead University continue to develop a database of 3D models, we aim to focus on addressing these ethical questions, building a sufficient ethical framework, and to work alongside other institutions on a similar journey. The future of digital archaeology within education is bright and we must not let this be dimmed by insufficient attention to the impact of this practice on communities and long-term ethical considerations. These questions should come first and foremost.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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