Using Digital 3D Models to Learn Physical Objects

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Abstract

The study of human anatomy and physiology typically involves a laboratory component where students explore various anatomical structures through physical models and dissection. Previously, students were only able to access these models in the anatomy laboratory or would have to purchase costly models to access at home. Advances in technology have enabled the development of three-dimensional (3D) models which can be observed and manipulated through a web browser. There are now a wide variety of models available both within applications and web-based programs. With web-based platforms, the ability to create and share open-source 3D models is improving access to low-cost materials for students which are available on-demand anywhere there is internet. Web-based technologies have already been shown to assist students in learning anatomy and physiology (Pringle and Rea, 2018). Oregon State University Ecampus created virtual tools for our online Anatomy and Physiology course to help students learn the bones and features of the human skeleton. Our questions are: can students translate their knowledge of bones and features from the 3D rendering to a physical model? And, how does physical bone and bone feature identification proficiency compare in students who learned online using 3D models compare to students who learned in-person with physical models in the laboratory. As such, the goal of this project is to assess the ability of students who study with 3D models to identify the same object in its physical form.

Statement of the Problem

Advances in technology have enabled the creation of digital 3D models of the human body and its structures. Many students enrolled in college level human anatomy and physiology courses intend to pursue degrees in allied health professions. These professional programs expect students to enter with the prerequisite understanding of anatomical structures. Students completing the required courses for admission may elect to take these courses in traditional face-to-face or online modalities. Regardless of the modality in which courses are taken, the same level of proficiency is expected in structure identification in their professional programs. What has yet to be determined is if using digital 3D models as learning tools for anatomy translates to the ability to identify those same anatomical structures on a physical model.

Background

The study of human anatomy and physiology typically involves a laboratory component where students explore various anatomical structures through physical models and dissection, and physiology through experiments. Previously, students were only able to access models or donors by physically attending classes in the anatomy laboratory or they would have to purchase costly models or order dissection kits for learning at home. The requirement of physical presence limits access to anatomy education.

Advances in technology have enabled the development of digital, three-dimensional (3D) models which can be observed and manipulated through a web browser. There are now a wide variety of models available both within applications and web-based programs that can be downloaded onto a smartphone, tablet or computer. With web-based platforms such as SketchFab, the ability to create and share open-source 3D models is improving access to low-cost materials for students which are available on-demand anywhere there is internet (Reid et al., 2020). Multimedia tools have been suggested to have great pedagogical value and enhance accessibility (Attardi and Rogers, 2014). Subscription based anatomy applications and programs such as Complete Anatomy and Biodigital are excellent learning tools, but do have costs associated with them (34D Medical, 2023; Biodigital, 2023).

Web-based technologies have been shown to assist students in learning anatomy and physiology (Pringle and Rea, 2018). Several studies have examined 3D technology in education. In a meta-analysis of 3D visual technology educational methods, Drs. Yammine and Violato examined the effectiveness of 3D visual technology in teaching and learning anatomy compared to all teaching methods. They concluded that 3D visual technology is superior to 2D methods in the acquisition of anatomy knowledge among medical students (Yammine and Violato, 2014). In addition, interactive 3D digital materials have been shown to have positive effects on medical education, more than textbooks alone (Battulga et al., 2012). Outside of medical education, researchers found that 3D learning is better than 2D for performance and understanding appearance in orthographic views in a graphical course in engineering (Wu and Chaing, 2012).

With respect to transferable skills between digital 3D models and physical models, researchers found a positive correlation between the virtual tooth identification assessment and the real tooth identification assessment (Suh et al., 2022). In this study, students learned on and were tested on both the virtual and physical models.

While there is support for the use of digital 3D models, there have also been some inconclusive and discouraging studies regarding the value of the 3D models, especially when testing on a 2D static image (Vandenbossche et al., 2022; Preece et al., 2013, Saltarelli et al., 2014). Spatial ability may influence the effectiveness of 3D models, especially when using 2D assessments. The authors did note a potential limitation in the use of a less detailed 3D model when compared to the highly detailed 2D static image. It is possible that when investigating more complex structures such as the pelvic bone, the digital model needs to be sufficiently detailed to allow for better understanding. It is also important to consider spatial ability when comparing 3D and 2D assessments (Vandenbossche et al., 2022). When considering learning a complex computer image such as magnetic resonance imaging (MRI), learning on a physical model was shown to be better than a digital 3D model (Preece et al., 2013). In a study comparing human cadaver use to a multimedia learning system, researchers found that the laboratory experience had a significant advantage when assessing knowledge on a physical cadaver. The authors noted the importance of including pedagogical strategies to support the transfer of knowledge to real-world situations (Saltarelli et al., 2014).

In the BI241 in-person laboratory space at Oregon State University (OSU), students are given a box or trunk of plastic models of human bones to explore. These bones are unlabeled and disarticulated (i.e., disassembled skeletons). Students are provided a list of bone names and features and are asked to use their resources to locate and identify them on the models. The students use the models, photographic atlases, and multimedia applications to discover the features and names of the bones over the course of 2-3 weeks. Students are assessed on their ability to identify the bones and features during a lab practical exam where the bone models are labeled with numbers or letters and the students identify the bones and structures by filling in the blanks on an exam sheet. When developing the online version of this laboratory experience, we worked to create a very similar process and experience. The OSU Ecampus media team created virtual tools for the online Anatomy and Physiology course (BI254) to help students learn the bones and features of the human skeleton. The virtual tools include two web-based applications where students can view and manipulate 3D renderings of human bones and quiz themselves using digital flashcards. The process of student-led inquiry to learn the bones and features is the same in both courses. Historical course data indicates that students in both modalities are similarly able to display knowledge of anatomical structures when assessed in the format in which they learned.

Our questions are: can students translate their knowledge of bones and features from the 3D rendering to a physical model? How does bone and bone feature identification proficiency compare in students who learned online using 3D models to students who learned in-person with physical models in the laboratory. As such, the goal of this project is to assess the ability of students who study with digital 3D models to identify the same object in its physical form.

The Proposed Study

The proposed study will examine the ability of students to apply identification knowledge gained in the online, digital, 3D learning environment to the same models in their physical form. The proposed study will also compare the application of the knowledge gained in the traditional laboratory format to that of the online course.

Research Questions

The primary research question of the proposed project is: is the knowledge gained from learning the features and bones of the human skeleton through digital 3D models transferable to physical bone models? A secondary research question of the proposed project is how does the learning modality (digital vs. in-person) compare when assessing the content on physical models?

Methods and Design

Our study will examine the impact of the learning environment on proficiency in the identification of anatomical features. This project seeks to compare learning gains of college students in Ecampus and in-person courses. Specifically, we will utilize pre- and post-tests coupled with learning interventions to evaluate proficiency in identification of bones and bone features. The Department of Integrative Biology at OSU offers equivalent Ecampus and in-person course series in Human Anatomy and Physiology. Although students in these courses engage in different learning modalities, the courses share learning outcomes. The results of this study will help determine whether learning outcomes are differentially achieved in online and face-to-face courses. During the 2022-2023 academic year, the project team engaged in an OSU College of Science Community of Instructional Excellence Scholarly Fellowship to define the scope of this work and begin the literature review and IRB application process.

Participants

Participants will be recruited from students enrolled in BI241 (Introduction to Human Anatomy and Physiology, on-campus) and BI254 (Principles of Human Anatomy and Physiology). Recruitment will take place during Week 0 of Fall term 2024. We aim to recruit 20 students from each course.

Proposed Intervention

Participants will complete a 2D pre-test on bone and bone feature identification early in the term. This is prior to the bone unit in both courses and should provide us with a baseline measure of proficiency prior to the utilization of learning tools. During Fall 2023, we asked students in BI254 to complete a similar pre-test asking them to identify bones and features of the human skeleton before beginning their bone units. Students were asked not to use the internet, course notes, or anything other than what is already in their brain. The average score was 20%. Based on this, we expect students entering BI254 to have very little familiarity with bones and bone features, allowing us to measure gains following the intervention. Because students of similar class standing and with similar course experience take BI241, we anticipate those students will also enter the course with little familiarity of the bones and bone features.

Following the pre-test, the learning intervention will occur as students proceed to complete their respective course units on bone. For BI241 students, this includes an introduction to the content by their lab instructor, labeling printed lab manual diagrams, answering questions about bones and bone features, and practicing identification using plastic models and real human bones. BI241 students will have low stakes assessments in the form of quizzes and a high stakes assessment in the form of a midterm exam involving bone and bone-feature identification. For BI254 students will watch a video introduction to the content, complete Canvas based questions and labeling activities answering questions about bones and bone features, and practicing identification using 3D renderings of human bones. BI254 students will also have low stakes assessments in the form of quizzes and a high stakes assessment in the form of a midterm exam involving bone and bone-feature identification. The primary difference between the experience of the students is whether they are utilizing paper images and physical bones, or digital images and 3D renderings of bones.

Upon completion of the bone units in BI241 and BI254 (approx. Week 6-10), participants will complete the 2D pre-test again as well as a 3D post-test in which they will be asked to identify physical bones and bone features. BI241 participants will take the physical model post test in person at OSU. BI254 participants will be mailed the physical model post test which will be proctored over zoom. Given that the interventions will be the use of the learning tools that are part of BI241 and BI254, the pre- and post-test are the only additional tasks required of participants in the study.

Procedure

After receiving IRB approval, participants will be recruited from the courses BI254 and BI241 at Oregon State University during Fall term 2024. Informed consent will be obtained. Before beginning the skeletal identification laboratories, students will take a pre-test of 2D bone images and will answer 16 fill in the blank questions which takes on average 10 minutes to complete. Students will then be given the list of bone structures to identify and all laboratory materials. In both courses students are given text book resources, 2D images, multimedia applications, and questions to guide their learning. To show the 3D nature of the bones, in BI254, unlabeled digital 3D models and flashcards are provided. In BI341, students are given physical bone models while in the laboratory. Both classes have access to the digital 3D models for studying. The primary difference between the two courses is the access to the physical bone models while in the laboratory.

Students will have 2-3 weeks to study all the bones and their features. After this time period, each class takes a midterm assessment. Following their exam, the students will complete two more assessments for the study with an approximate time commitment of less than one hour. This includes retaking the 2D pre-test, and an additional proctored practical exam on the physical bone models. An 18-question practical exam will be administered to all study participants. For the in-person BI241 course, students will sign up for 20-minute time slots to take the exam on OSU's campus. For the online BI254 course, students will be mailed a box including the practical exam. Students will sign up for 30-minute time slots to take the exam online. The additional 10-minutes will be used to view the opening of the box and arranging of the bones before starting the 20-minute time window to complete the 18-questions. Post-tests will be proctored remotely using a web camera over Zoom. Post-test proctoring will not be recorded. The mailed exam boxes will include a prepaid shipping label for students to return the bones after completion of the assessment.

Measures

Pre- and post-tests will be graded by both Co-PIs and scores will be compared to ensure accuracy of grading. We will assess individual student gains in anatomical identification proficiency and compare group average by learning modality. The students' individual 2D pretest scores will be compared to their own 2D post-test scores. The scores of the 3D post-test will be compared to the 2D post-tests within participants. Finally, we will compare 3D post-test scores between groups. Below is the proposed list of bones and features to be identified on the pre-test and post-test.

Pre-Test

1. Anterior Skull
    a. Nasal bone
    b. Ethmoid bone
2. Lateral Skull
    a. Zygomatic bone
    b. Styloid process
3. Cervical Vertebra
    a. ID bone
    b. Transverse foramen
4. Tibia
    a. ID bone
    b. Tibial tuberosity
    c. Medial malleolus
5. Fibula
    a. ID bone
6. Hand
    a. Distal Phalange
    b. Scaphoid
7. Hip
    a. ID bone
    b. Acetabulum
8. Scapula
    a. Spine
    b. Glenoid fossa

Post-Test:

1. Skull
    a. Frontal bone
    b. Maxilla
    c. Nasal
    d. Parietal bone
    e. Mastoid process
    f. Occipital bone
2. Thoracic Vertebra
    a. ID bone
    b. Spinous process
    c. Transverse process
    d. Body
3. Femur
    a. ID bone
    b. Head
    c. Greater trochanter
4. Radius
    a. ID bone
    b. Ulnar notch
5. Foot
    a. Metatarsal
6. Scapula
    a. ID bone
    b. Acromion process

The 2D tests and 3D post-test include some shared bones, but have unique questions to account for test effect. Including a variety of bone types in the assessment, like the bones of the axial skeleton (head, neck, and back) and appendicular skeleton (limbs and limb girdles) will allow us to also determine whether there are differences in proficiency for each modality based on specific bone types. For example, are Ecampus students better able to transfer their knowledge to long bones like the femur, than complex bones with intricate shapes like the vertebrae or os coxae.

Expected Outcomes and Value of Potential Findings

We anticipate that our project will allow us to answer the proposed research questions:

- Is the knowledge gained from learning the features and bones of the human skeleton through digital 3D models transferable to physical bone models?
- How does the learning modality (digital vs. in-person) compare when assessing the content on physical models?

We expect that all participants will increase their knowledge of bones and features as will be evidenced by the pre- and post- test comparison. We will evaluate the data for differences in learning gains overall, difference by bone and bone type, and differences in feature identification between course modality.

In answering these questions, we will be able to further inform the pedagogical choices we make and tools we provide to our students in online laboratories. Our goal is to build our courses with evidence based best practices from empirical data that support our students' learning. Furthermore, if our data indicates comparable or better proficiency in Ecampus students, this would provide strong evidence for the validity of online learning in fields that require understanding to be transferred to physical objects. Alternatively, if we find differences in proficiency, this data can guide our refinement of our online tools and pedagogical practices to continue to strive for equivalent learning experiences for our online and in-person students.

Plan for Dissemination

To disseminate the outcomes of our proposed research project, we would like to present at the 2025 Ecampus Faculty forum and the CoSCIES showcase extravaganza. In addition, we plan to attend at least one conference to present the findings of our study. The idea for this study was presented in Fall 2023 at the NWeLearn Conference in Newberg. The authors have already been invited back to present our findings after completing the study. Additional conferences we plan to submit to are North West Managers of Educational Technology (NWMET) and the Human Anatomy and Physiology Society (HAPS).

In addition to presenting at conferences, we would like to submit a paper for publication to the Journal of Anatomical Sciences Education.

Proposed Timeline

	2024				2025			
	W	S	Su	F	W	S	Su	F
IRB Submission	X							
Data Collection				X				
Data Analysis					X			
Write Paper					X			
Dissemination						X		X

Team Members

Principles of Human Anatomy and Physiology Instructor: Staci Bronson

Staci Bronson earned a Ph.D. in Exercise and Sport Science. Dr. Bronson will serve as Co-Principal Investigator and has been at OSU as an instructor for 3 years. She developed and teaches the Ecampus Human Anatomy and Physiology Series in collaboration with Ecampus. She has worked closely with the Ecampus Media Team to develop the 3D tools and simulations used in the laboratory portion of her series. Dr. Bronson received the Ecampus Innovation Award in 2022 for her work on this series. Dr. Bronson has performed research with human participants in her previous work as a graduate student at OSU.

Introduction to Human Anatomy and Physiology Instructor: Lindsay Biga

Lindsay Biga earned a Ph.D. in Environmental Science. Dr. Biga is a Senior Instructor II who has been teaching Introduction to Human Anatomy and Physiology at OSU for 9 years. She was also on the team that proposed the creation of the complimentary Ecampus Human A&P series. Dr. Biga has collaborated extensively with Dr. Bronson throughout the development and deployment of the BI25X series. Dr. Biga's scholarly work at OSU is focused on pedagogical interventions and their impacts on student learning, particularly in large lecture and laboratory courses.

Project Budget

Please see attached document.

Letter of Support

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10/27/2023

Re: Letter of support for Ors. Staci Bronson and Lindsay Biga

To Whom It May Concern,

I write in support of the Ecampus Research Fellowship application of Ors. Staci Bronson and Lindsay Biga. I strongly support their endeavor to evaluate anatomical identification proficiency of students enrolled in Ecampus and in-person courses in Human Anatomy & Physiology. Staci and Lindsay have each developed and are assigned to teach complimentary course: the BI24X and BI25X Introduction to Human Anatomy & Physiology courses. These courses serve students in different learning venues, but with shared interests and goals. This proposal is the culmination of thoughtful engagement and planning through the College of Science Community of Instructional Excellence Scholarly (CoSCIES) Fellows program that Staci and Lindsay participated in during the 2022-2023 academic year. The data gathered in this project will allow Staci and Lindsay to evaluate the achievement of course learning outcomes and the utility of the 3D virtual learning tools used in BI25X.

In Integrative Biology, we prioritize providing equivalent academic experiences in online and face-to-face classes and strive to see all our students meet course level learning outcomes. The Department of Integrative Biology fully supports instructional faculty engagement in pedagogical research including this Ecampus research fellowship.

Sincerely,

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Dee Denver
Professor and Department Head

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