

Anatomy In Action: Incorporating 3D Printing in Pre-Collegiate Anatomy Education

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Background and Objective:

The CU Pre-Health Scholars (CUPS) Program is an academic enrichment program for underserved high school students who are interested in healthcare and STEM-related professions. Part of the program's curriculum includes an anatomy course that aims to prepare students for the rigor of undergraduate anatomy education while inspiring interest in healthcare-related fields of study.

To increase student engagement, the anatomy curriculum was redesigned to incorporate the use of 3D printed anatomic models. In the redesigned Anatomy in Action Curriculum, students have a hands-on experience of discovering the relationship between structure and function by learning to 3D print anatomic structures in addition to more traditional lecture-based teaching.

Methods:

- 3D printing activities were chosen to engage students' visuospatial abilities by manipulating anatomic structures during the modeling process and after the model was printed.
- Funding was acquired to build a 3D printing lab which included five Prusa 3D printers (Figure 1).
- PrusaSlic3r software was used in the modeling process and open source online libraries of printable anatomic structures like Embodi3D were used.
- Models were also made using real imaging studies.
- Throughout the academic year, students attended monthly anatomy lectures, learned the basics of 3D modeling, and practiced printing models. Students then participated in an intensive six-week course during the summer (Table 1).
- Students worked in groups to choose a topic of interest and 3D printed a model that required mastery of anatomic principles to create (Figure 2).

Figure 1. Prusa i3 MK3 3D Printers in the CUPS 3D Printing Lab.



Table 1. Outline of the CUPS Summer Curriculum.

Week	Description
1	Body Structure and Organization Refresher Lectures Introduction to Summer Projects and Groupwork
2	Building and Manipulating Models Activities Literature Search Thorax and Cardiovascular System Lectures Introduction to Medical Imaging Lectures Slic3r Workshops and Troubleshooting Modeling Resources and Mentor Check-In
3	Abdomen and Digestive System Lectures Cadaver Lab Visit 3D Printing Workshop Group Activities Literature Search Digital Modeling Group Activities
4	Nervous System Lectures Cadaver Lab Visit Modeling Resources and Mentor Check-In 3D Printing Activities
5	Pelvis and Urogenital System Lectures Modeling Resources and Mentor Check-In 3D Printing Activities
6	Modeling Resources and Mentor Check-In 3D Printing Activities Final Presentations

Results:

Students printed their project-specific model and created a research poster which they presented at the CUPS Symposium during the final week.

Figure 2. Example of a student research poster modeling myelomeningocele in an embryo.

3D Model of Myelomeningocele in an Embryo

Introduction

- Spina bifida is a spine defect in which exposes the spinal cord and the meninges which is caused by the backbone having a gap.
- The reason of this defect is due to the insufficient intake of folic acid.
- Out of the four variations of Spina Bifida myelomeningocele is the only one that's severe.
- Myelomeningocele affects the bones protecting the central nervous system, like the vertebral bones.
- This topic is poorly understood therefore it is interesting to learn how procedure pre-birth is taken place without disturbing the fetus. A low prevalence of this defect has also affected public awareness.
- The focus was on medical and organization websites to research into treatments, diagnosis, and disease effects.

Figure 1: The normal anatomy of a fetus
Figure 2: The birth defect, myelomeningocele. It's clearly seen the hydrocephalus (fluid buildup) puts pressure on the brain. The cerebellum is also pulled down onto the spinal canal. The bulge that is seen on the back is where the spinal cord and the meninges formed.
Figure 3: The fetus after the surgery.

Results

The purpose of the 3D model is a closer look to educate up close of what myelomeningocele looks like. The model that was produced shows the skeletal structure of spina bifida. In both models you can clearly see the outcome of the spinal cord due to a missing Vertebrae which leads to our groups satisfaction of learning in a physical and visual way.

Figure 4: Blender Model
Figure 5: 3D Printed Model

Materials and Methods

Embodi3D was used to find a data set. In our case we found one of a normal spinal cord.

Slicer was used to cut, re-form, and build. This would lead to a 3D model.

Lastly, blender was used to smooth out the final product and make a sagittal cut through the spinal cord.

Discussion

Despite the challenges encountered throughout the project the goal of the project was reached. Some specific areas encountered was finding a data set for the 3D model. Our group overcame the obstacle by pulling different sets of data and mixing them together to make one for myelomeningocele spina bifida. The project was also fulfilled by gathering new information on spina bifida and expanding on one of the versions of it: Myelomeningocele.

Figure 6: 3D models could be improved by showing where the spinal fluid flows. This is because it will give a more clear picture of why the skin bulges out in this situation and what is inside the bulge.

Summary/Conclusions:

- Both students and program leadership reported increased student engagement following adoption of the new curriculum.
- 3D printing has many applications within medical education and can be successfully integrated in a multimodal approach to pre-collegiate anatomy education.

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