Thesis Project Portfolio

Designing an Affordable Distal Radius Fracture Reduction Simulator for Medical Training

(Technical Report)

Fit Analysis of Personal Protective Equipment Across Healthcare Worker Demographics During COVID-19

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

Natalie Bretton

Spring, 2025

Department of Mechanical and Aerospace Engineering

Table of Contents

Sociotechnical Synthesis

My technical report and research project both focus on the design of inclusive medical technology. The products that engineers develop play a role in shaping the world, and if the needs of different users are not considered in the design process, the outcome risks perpetuating existing inequities or creating new ones. My STS research project takes a deep dive into how Personal Protective Equipment (PPE) production and distribution during the COVID-19 pandemic contributed to discrepancies in fit and functionality across various healthcare worker demographics. This research provides insights for my technical project on designing an accessible, 3D-printed distal radius fracture reduction device that allows medical professionals to practice setting a broken wrist.

Distal radius fracture (DRF) is a common type of wrist fracture that affects people of different ages, sexes, races, and backgrounds. Despite being one of the most frequently occurring fractures, the medical training devices for treatment are limited. Many DRF fractures result in a small fragment of bone near the thumb side of the wrist displacing due to the forces from tendons and muscles pulling on it. This fragment must be put back into its location or 'set' before treatment can proceed. Oftentimes, medical students get their first experience setting this type of fracture by performing the procedure on a real patient with guidance from a professional. While there are a few simulators, these can cost thousands of dollars and are often built to represent a large, White male, demonstrating the historical biases often found in medical technology design, as explored in my STS research. My report details the design of an almost fully 3D-printed device that will cost medical facilities less than $150 to recreate. In addition to being affordable, the general sizing of the device was built to approximate a 50th percentile female. While bone size in the forearm does not vary much with sex, the hand shape was scanned from an average female. Moreover, elastic bands control the tension of the model and allow the user to adjust the force needed to set the bone, one of the main characteristics that varies between different people. The model was also designed using a clear-colored silicone as the outer shell of skin, contrasting with the often pale tan skin tone used on the market. Lastly, since the device is 3D printed, it remains scalable to different sizes and can be adjusted to represent different fracture patterns, all while accounting for affordability, inclusivity, and ease of manufacturing.

Historically, there have been many medical technologies that do not equally represent different groups of people. My STS paper dives into a specific example of a medical technology not serving all of its users equally. During the COVID-19 pandemic, healthcare workers relied on PPE to keep themselves safe and help stop the spread of the virus. However, it was discovered that the PPE that was widely used fit White men the best and left groups like women and people of East Asian descent vulnerable. This issue stemmed from the fact that the ‘universal fit’ masks that were mass-produced and distributed during COVID-19 mainly accounted for facial dimensions that had historically been based on White males. By analyzing the social and organizational structures surrounding PPE production and distribution through the lens of the Social Construction of Technology (SCOT) framework, this paper argues that the failure to provide properly fitting PPE was an unintentional consequence of an overwhelmed supply chain, broken feedback loops, and systems that prioritized a male-centric standard and did not account for the diverse anthropometry of a significant portion of the healthcare workforce. This ultimately compromised their safety and well-being and emphasized how critical inclusivity is to the design and distribution of all medical technologies. While there is not just one specific thing that caused PPE to lead to disparity, understanding the sociotechnical system this problem resides in allows us to better consider how to avoid accidentally creating medical disparities in the future.

Working on both of these projects simultaneously was a very insightful experience. While I initially set out on my capstone project intending to take into account the needs of diverse users and ensure that the product I design does not unintentionally ostracize any users, my STS research paper made the many aspects of equitable design more apparent. Witnessing the real-world impact of design choices that inadvertently marginalized significant user groups within the PPE context reinforced the importance of proactive inclusivity in my own engineering practice. Medicine is such an interesting area of design, and since the best care is generally personalized, sometimes it is difficult to design a universal fit product that works for all users. This solidified the importance of designing a flexible device that can easily be adapted to represent different sizes due to its 3D-printed nature. Additionally, a huge limitation the wrist fracture reduction simulator attempts to address is the massive costs of many medical devices. Learning about supply chain shortages and the lack of access hospitals had to life-saving medical equipment due to costs both inspired and motivated my capstone project. Overall, completing these projects at the same time opened my eyes to the many interwoven social, technical, and organizational factors that all play a role in the impact of a technology. I am grateful I got the opportunity to work on such related and important work.