Thesis Project Portfolio

Refinement of an Ultraviolet Light Sanitation Device for Central Lines

(Technical Report)

Latent Dysfunctions in Device Innovation: An STS Perspective on Equity and Access

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

This project offered a critical opportunity to explore how engineering solutions must operate within broader social systems. My technical work and STS research, while distinct in scope, both centered on healthcare innovation and access. The technical project focused on refining a UV sterilization device to prevent central line-associated bloodstream infections (CLABSIs), while the STS research examined the systemic barriers that contribute to inequitable access to medical technologies. Although initially approached as separate efforts, together, they revealed that technical excellence alone cannot guarantee effectiveness without careful consideration of human behavior, institutional structures, and cultural contexts. Applying a Science, Technology, and Society (STS) framework reinforced that engineering practice is inherently sociotechnical. Technical systems are embedded in social worlds, and the ethical dimensions of design are not optional additions; they are integral to whether a technology ultimately succeeds or fails in practice.

In my STS research, I investigated how affordability, usability, and hospital integration collectively influence access to medical devices for marginalized populations. Relying on secondary data analysis, I uncovered that innovations in manufacturing, such as 3D printing and modular design, can reduce costs but often fall short when contextual barriers are overlooked. Devices that are affordable yet unusable in low-resource environments, whether it be due to factors like unreliable electricity or lack of maintenance infrastructure, perpetuate, rather than resolve, health inequities. Through the lens of manifest and latent function theory, my research demonstrated how well-intentioned medical innovations frequently generate unintended dysfunctions when stakeholder engagement, real-world testing, and cultural considerations are neglected. Cases such as the racial bias in pulse oximeter readings illustrated how exclusion during development can embed inequity directly into clinical technologies. Responsible Research and Innovation (RRI) principles emerged as vital, emphasizing anticipation, inclusivity, and reflexivity. This analysis highlighted that affordability must be paired with social awareness and ethical design if healthcare technologies are to meaningfully serve all communities.

The technical portion of my project produced a refined UV sterilization device that aims to reduce CLABSI rates by providing real-time fluid sterilization through central lines. Working under the mentorship of Dr. Thiele, my Capstone team redesigned the original prototype to be smaller, more ergonomic, and better suited to clinical workflows. The updated device integrates a Luer lock system for seamless attachment and features a power supply designed to minimize interference with patient care equipment. Additionally, the prototype includes a reusable housing component and a disposable component to balance sustainability with practicality. Bacterial reduction testing will validate the device's efficacy against multiple CLABSI-causing pathogens, while medication degradation analysis will ensure compatibility with a range of treatments. A key focus throughout the design process was manufacturability, ensuring that the device could eventually be produced at scale to make widespread adoption feasible. By centering not only technical performance but also clinical usability and cost-effectiveness, the project sought to create a device that could make a meaningful impact in real-world hospital environments.

Completing both the technical project and the STS research paper deepened my understanding of the intertwined nature of engineering and society. Initially, I viewed challenges faced in my technical project, such as miniaturization or flow optimization, as separate from questions of ethics or equity. However, as my work progressed, it became clear that every design choice carries ethical weight, influencing who is served and who may be excluded. I came to see that engineering practice must incorporate stakeholder perspectives, anticipate diverse real-world conditions, and recognize the historical inequities embedded in healthcare systems. Ethical considerations are not barriers to innovation; rather, they are prerequisites for technologies that achieve broad, lasting impact. Moving forward, I will approach engineering not just as a technical discipline, but as a form of social participation, one where responsibility for equitable outcomes begins at the very first stages of design. I am deeply grateful to Dr. Thiele, my Capstone team, and the professors and mentors who supported this work, and whose guidance helped me to see innovation as not only a technical goal but a human one.