Low-Cost Integrated Phototherapy and Monitoring Device for Resource-Limited Neonatal Care

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Design Project Goal

Our project aims to create a low-cost integrated phototherapy device for the treatment and monitoring of neonatal jaundice in resource-limited NICUs and acute care units in order to reduce ward crowding and streamline delivery of care.

Background and Motivation

- **Neonatal jaundice** occurs when latent liver development results in build-up of **bilirubin**, a byproduct of red blood cell turnover
- Excess bilirubin results in **yellowing of the skin**, and in severe cases can cause a type of brain damage called **kernicterus**
- **6 in 10 neonates** typically develop jaundice, and 1 in 20 need treatment, usually either phototherapy or blood exchange
- **Phototherapy**, the most common treatment of jaundice, involves the intensive **delivery of blue-green light** to convert bilirubin into water-soluble isomers that can be excreted
- In Uganda's **Kawempe National Referral Hospital**, the NICU typically treats **10-12 cases** of neonatal jaundice at any time
- Existing phototherapy devices often house **several patients** at once, **lack adjustable light delivery** and monitoring, and often **harm neonates' eyes** due to the intense blue light

Design Objectives

Design Objective	Target Value	Result
Delivers correct light wavelength	Light delivery between 425-475 nanometers	**PASS** - Uses standard recycled phototherapy lights
Delivers correct light intensity	Intensity between 30 - 65 μW/cm^2/nm tested with Luxometer	**Not Yet Tested** - No access to Luxometer, but correct distance to light followed
Monitors light delivery accurately	Intensity error ≤ 10% compared to Luxometer	**Not Yet Tested** - No access to Luxometer
Protects neonate's eyes	Adjustable eye covering; No UV passes through	**PASS** - Opaque adjustable with velcro straps
Poses no safety risks	All wires routed away from neonate; no irritants present	**PASS** - Wire grid secured; macintosh mattress and head support used
Is easy to use	Average score ≥ 4/5 on user-friendliness UDS	**PASS** - 4.3/5 average rating with 10 participants
Is entirely sanitizable	All surfaces can be disinfected	**FAIL** - Wood outer casing used for first prototype

Project Constraints

This project was carried out in the BME Design Cube at Makerere University in Kampala, Uganda. The total project budget was 300,000 UGX (~$80USD). Some manufacturing for our project, including wood cutting, laser cutting, welding, acrylic bending, and mattress construction, was outsourced to craftsmen located in the nearby Kampala area.

Design Solution

A. B.

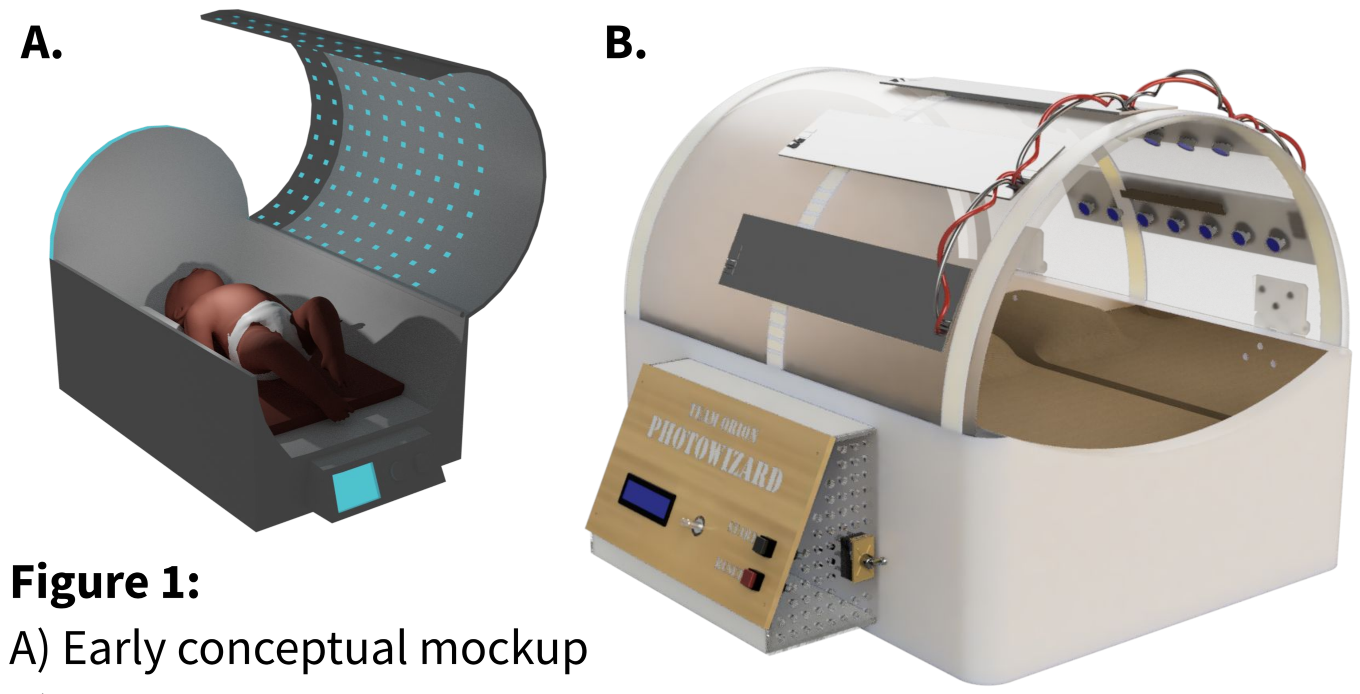


Figure 1:
A) Early conceptual mockup
B) Final CAD design

Figure 2: Final Integrated Prototype with LED panels turned on

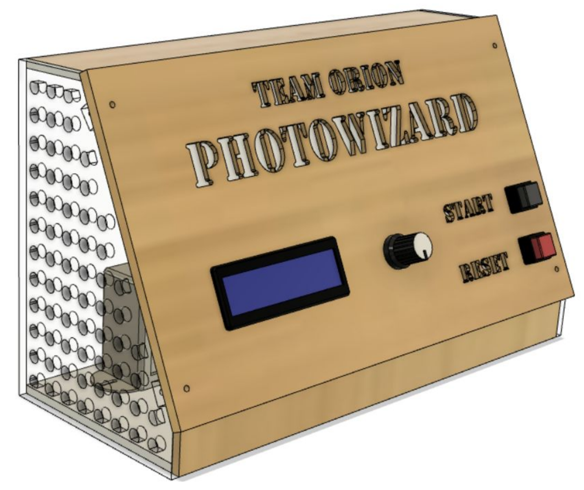


Figure 3:
CAD Model of user interface panel with LCD, start/stop and reset buttons, and potentiometer dial for lights

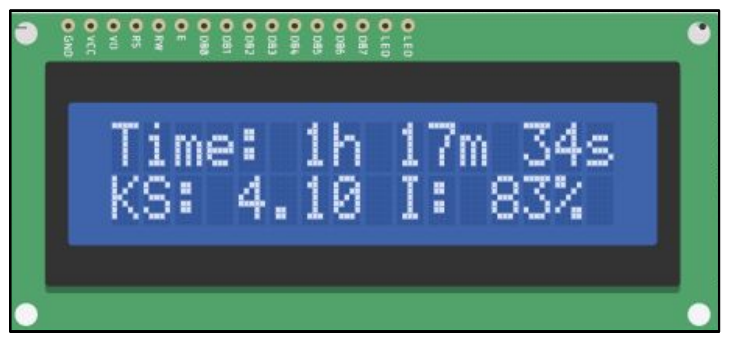


Figure 4:
LCD showing treatment duration, Kramer's Scale rating of bilirubin level, and light intensity reaching skin

Figure 5:
Sanitizable foam mattress and neck support cushion with sanitizable macintosh cover

Figure 6:
3-layered cloth eye mask with adjustable Velcro strap and removable light sensor

Electronics Systems

A.

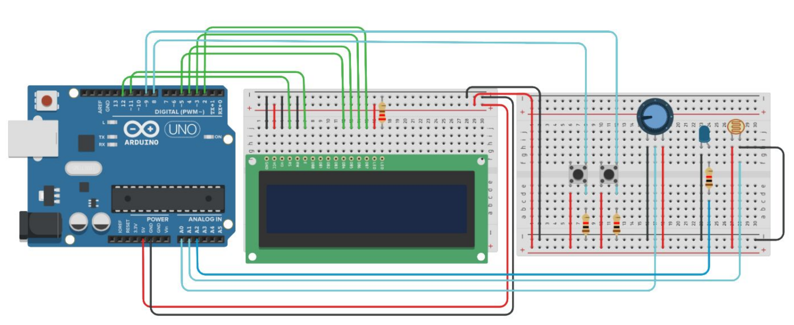
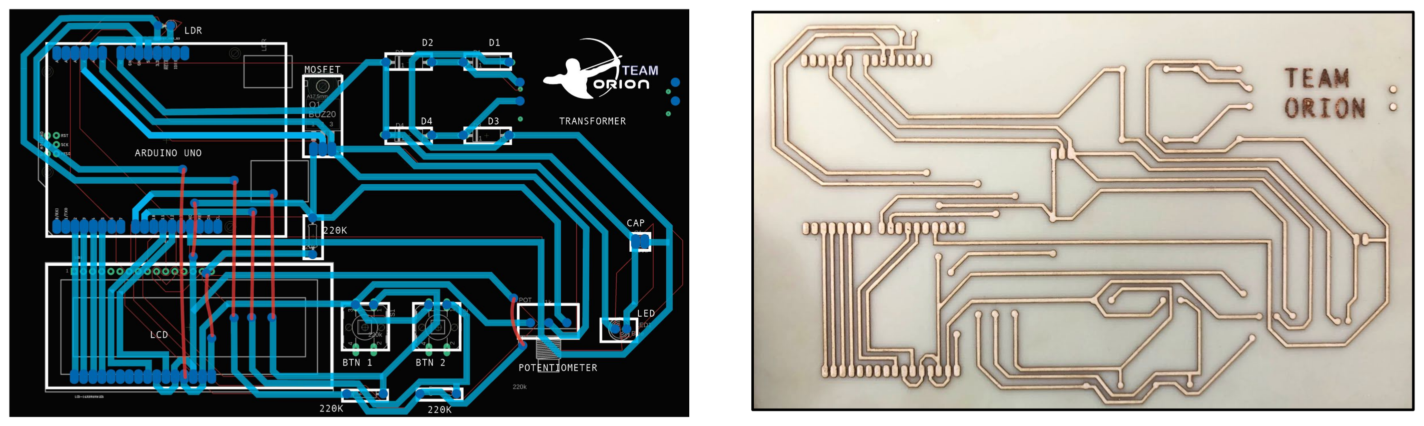


Figure 7:
A) TinkerCAD Circuit
B) Illustrator PCB layout and reference sheet
C) Final laser-cut and etched PCB

B. C.



Electrical Subsystems and Components:

- Laser-cut and chemically etched printed circuit board (PCB)
- Arduino UNO microcontroller, 16x2 LCD display
- Power System - wall power, 220v to 12v transformer, bridge rectifier, capacitor, MOSFET, 5 recycled phototherapy panels
- Timer reset and start button, potentiometer, power switch
- Light-dependent resistor for light sensing, cooling fan

Conclusions and Future Work

Our prototype successfully indicates proof-of-concept for a low-cost integrated phototherapy delivery and monitoring device. Future work may include:

- Testing and calibrating light delivery to ensure proper intensity reaches the neonate's skin
- Incorporating replaceable LED bulbs instead of recycled phototherapy panels
- Integrating temperature monitoring and display
- Shifting away from wood structure to ensure sanitizability

Possible limitations of use include inconsistent power access in hospitals, coexisting conditions in patients, overcrowding, and improper care techniques such as failure to cover the neonates' eyes or excessive covering of the skin limiting light exposure.

Acknowledgments

We would like to extend our thanks to the following:

- Dr. Ann Saterbak, Ph.D.
- Dr. Robert Ssekitoleko, Ph.D.
- Julius Mugaga
- DukeEngage 2022
- Makerere University Biomedical Engineering Department
- Duke Pratt School of Engineering
- Alfred Enywaku - Head Engineering Kawempe RH
- Sister Florence and Nurse Diana - Kawempe RH