

ECE 445
Senior Design Laboratory
Design Document

Desk Learning Aid Device

Team 27:
Conan Pan (cpan23)
Aidan Johnston (aidanyj2)
Ethan Ge (ethange2)

TA: Kaiwen Cao
Professor: Michael Oelze

March 6th, 2025

Table Of Contents

1. Introduction.....	3
1.1 Problem.....	3
1.2 Solution.....	3
1.3 Visual Aid.....	4
1.4 High-Level requirement list.....	4
2. Design.....	5
2.1 Block Diagram.....	5
2.2 Subsystem Overview.....	6
2.2.1 Input Subsystem.....	6
2.2.2 Microcontroller Subsystem.....	8
2.2.3 Web Application.....	10
2.2.4 Power subsystem.....	12
2.2.5 RFID/NFC (Keycard) subsystem.....	14
2.2.6 Interface Subsystem.....	17
2.3 Tolerance Analysis.....	19
2.3.1 Link-Budget Calculation.....	19
3. Cost and Schedule.....	20
3.1. Cost Analysis.....	20
Labor Costs.....	20
Parts & Equipment Costs.....	20
Machine Shop & Equipment Costs.....	23
Grand Total Cost.....	23
3.2 Schedule:.....	23
4. Discussion of Ethics and Safety.....	25
4.1 Ethics.....	25
4.1.1 Privacy.....	25
4.1.2 Transparency.....	26
4.1.3 Bias.....	26
4.1.4 Inclusivity.....	26
4.1.5 Safety.....	26
4.1.6 Lab Policies.....	26
4.2 Safety Considerations.....	26
4.2.1 Battery Safety.....	27
4.2.2 Physical Durability and Classroom Safety.....	27
4.2.3 Compliance with Laboratory Safety Guidelines.....	27
5. Citations.....	28

1. Introduction

1.1 Problem

In recent years, there has been a growing trend of integrating technology into schools. This trend has been accelerated by the lasting impacts of the Covid-19 pandemic and the continuous advancements in digital devices and tools. Schools across the nation have adopted computers, tablets, and virtual learning platforms to enhance education and increase accessibility in the pursuit of modernizing the classroom. While these technologies offer incredible benefits, they also introduce challenges, particularly in elementary school classrooms.

One of the most critical problems is the effect screen time is having on students. By incorporating technological devices in classrooms, students are spending prolonged periods interacting with screens. Studies have begun to highlight how this excessive screen time can lead to a severe lack of social skills, shorter attention spans, and higher frequencies of disruptions. These trends contribute to a less effective and unhealthy learning environment. Furthermore, studies are exploring connections between prolonged exposure to screens and decreases in mental and physical well-being. Therefore, in the pursuit of generating a more social, engaging, and nurturing environment for young students we propose the desk learning aid device.

1.2 Solution

The desk learning aid device will function through various buttons and a scroller connected to a customized PCB device. These buttons and the scroller will correspond to responding to polls/questions, comprehension checks, asking questions, and more. The device will communicate to an application that can be monitored by the teacher where they will receive real-time feedback. The teacher can have a better understanding of the student's comprehension levels and be able to properly cater towards providing the students the most effective lesson. The purpose of this device would be to provide a cost-effective solution that can be set up at each student's desk to promote a stronger and healthier learning environment for students. This differs from other options on the market due to easier set up because other options require you to create a question in order to receive a response, however, our device allows for many passive inputs including comprehension and other urgent needs. In addition, other portable solutions require students to buy each device individually costing them hundreds of dollars, but our solution only requires the purchase of a reusable RFID keycard that is cheap and easy to use.

1.3 Visual Aid

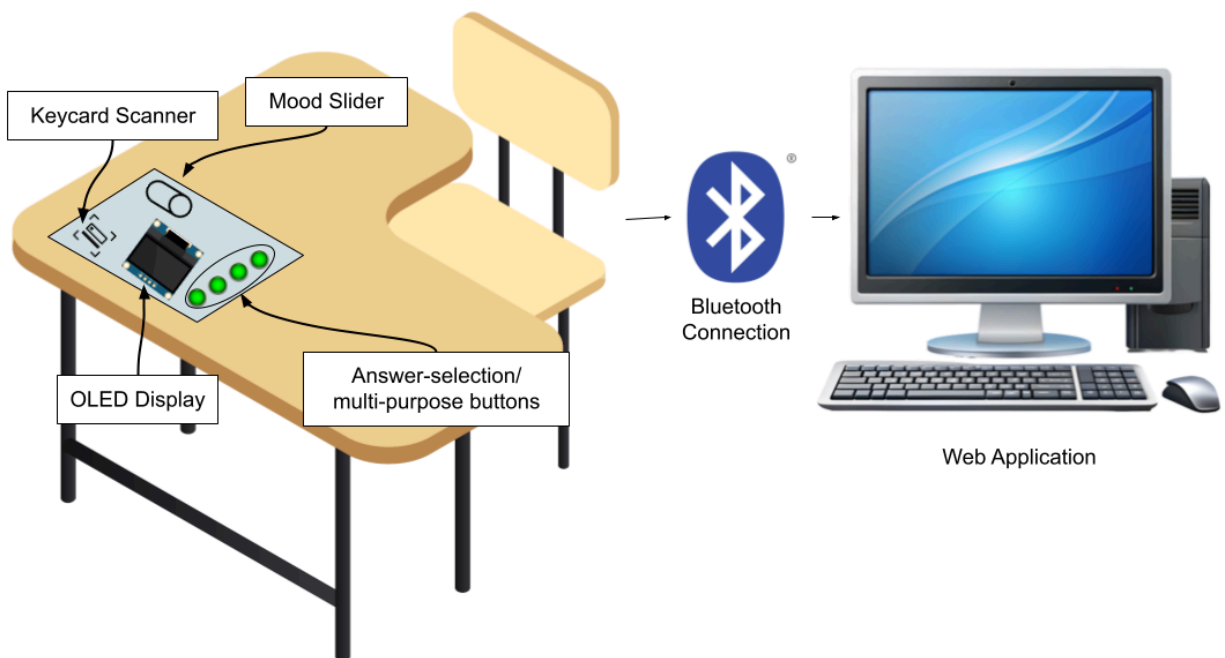


Figure 1: Visual representation of the device setup

1.4 High-Level requirement list

Successful design and construction of the device should result in the device's functionality satisfying the following high-level requirements:

1. The microcontroller and subsequently the PCB device must establish a low-latency and secure bluetooth connection with the web application to ensure that RFID scanning is authenticated and sent to the application and that data collected from button/scroller interaction is secure.
2. The web application must receive user data and provide personalized feedback and engagement tracking that includes; machine learning engagement analysis/feedback, notifications for participation, and a variety of dashboards.
3. The screen must be able to display the user's RFID card name when the user scans in, confirm answer selections, notify users of any errors, and relay notifications from the web application.

2. Design

2.1 Block Diagram

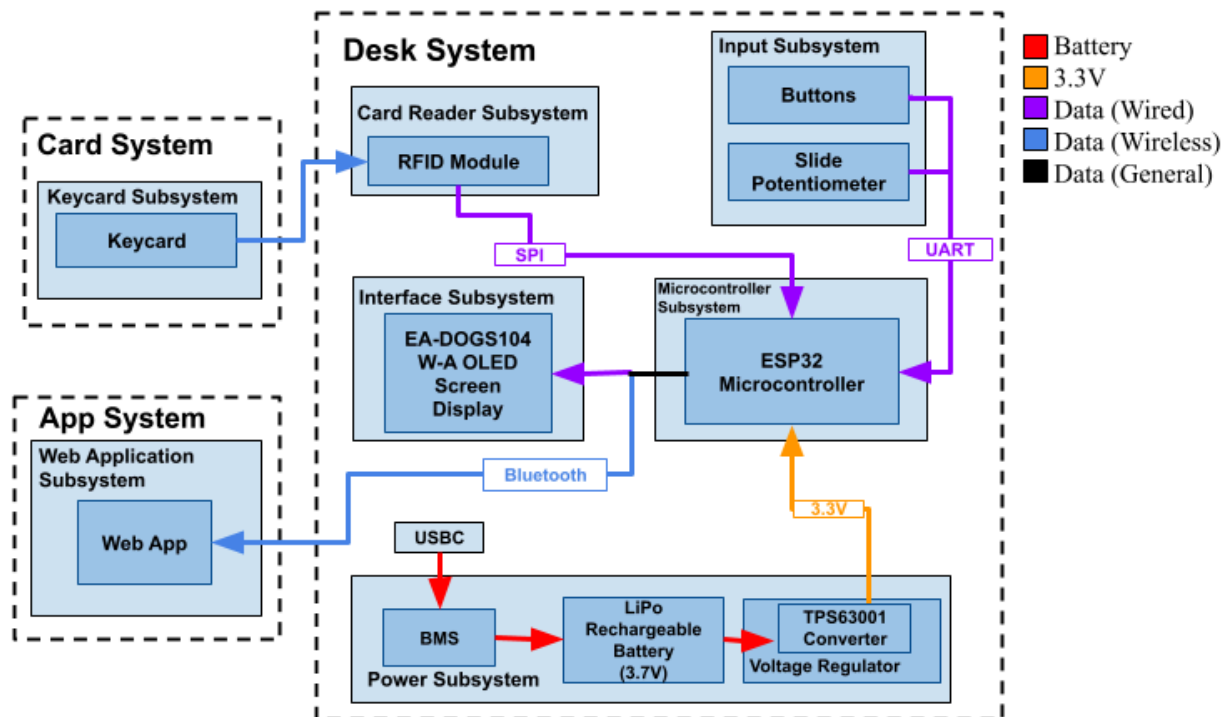


Figure 2: The device block diagram

The block diagram above accurately depicts the three main systems of the Desk Learning Aid Device. The Card System is composed of the keycard which will interact with the card reader in order to transmit user data to the microcontroller. The Desk System is composed of several subsystems including the card reader, input, interface, microcontroller, and power subsystems. The card reader and input subsystems transmit data via wired connection to the microcontroller while the power subsystem is used to power the microcontroller and the card reader. In turn, the microcontroller transmits data to the interface and web application. The App System is composed of the web application that will receive user data from the microcontroller and perform data cleansing, analysis, and display data visualizations.

2.2 Subsystem Overview

2.2.1 Input Subsystem

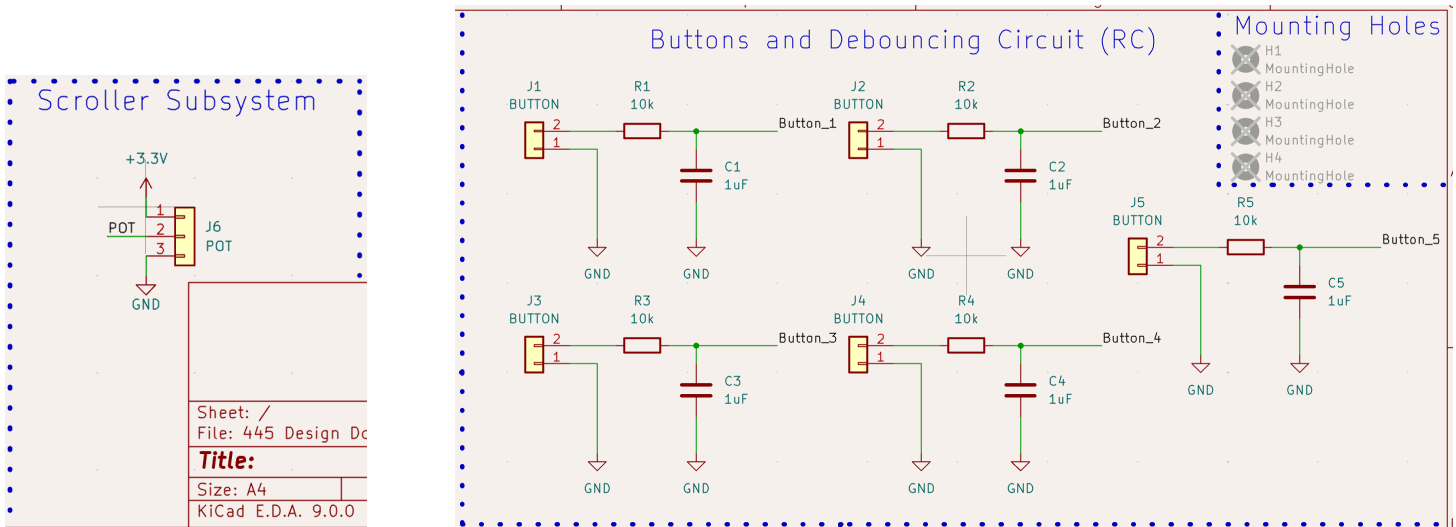


Figure 3: The input subsystem schematic including the scroller and the five buttons

This subsystem will include response (Adafruit 492) buttons for comprehension checks, request for assistance buttons, feedback buttons, and mental/emotional health check-in buttons. These buttons will be labeled accordingly so that student interaction with the device is simplified. The advantage with having a variety of buttons is to enable teachers to have as little interaction with the app as possible. In addition, this subsystem will include a turnable knob (Bourns PDB181-E415K-102B) that will enable students to indicate in real-time how they are feeling throughout the day, on a scale from 0 to 10.

The Input Subsystem is responsible for capturing student interactions through a set of designated buttons and a rotary scroller. The buttons include comprehension check responses, request for assistance, feedback submission, and mental/emotional well-being tracking. These buttons will be labeled clearly to allow young students to use them intuitively without extensive training. The emotion scroller will provide an additional method for students to continuously indicate their comfort or comprehension level throughout the lesson.

This subsystem ensures that students can provide feedback efficiently while minimizing distractions in the classroom. By incorporating multiple input methods, teachers will have access to a richer dataset regarding student engagement and comprehension levels. The collected data will then be transmitted to the microcontroller for further processing.

Requirements	Verification
<p>The input subsystem must transmit button and scroller data to the microcontroller with less than 100 ms latency.</p>	<ol style="list-style-type: none"> 1. Connect an oscilloscope to the button/scroller input lines and the corresponding microcontroller GPIO pins. 2. Measure the time difference between input signal detection and GPIO response through button presses / scroller adjustments. 3. Ensure that the time difference is less than 100 ms for 100 consecutive trials of button presses / scroller adjustments.
<p>The input subsystem must effectively debounce and filter out noise.</p>	<ol style="list-style-type: none"> 1. Connect an oscilloscope to the button/scroller input lines. 2. Perform rapid button presses and scroller adjustments. 3. Verify that no spikes or bouncing occurs and that the inputs remain stable.
<p>The input subsystem must be robust enough to handle repeated presses over an extended period.</p>	<ol style="list-style-type: none"> 1. Connect an oscilloscope to the button/scroller input lines and the corresponding microcontroller GPIO pins. 2. Setup an automated actuator that will press buttons and make scroller adjustments at repeated intervals of time. 3. Record input data logs over an 8-hour session. 4. Review the input data logs to ensure that the inputs remained stable with low latency and no bouncing over the course of the session.

Table 1 - Input Subsystem Requirements and Verification

2.2.2 Microcontroller Subsystem

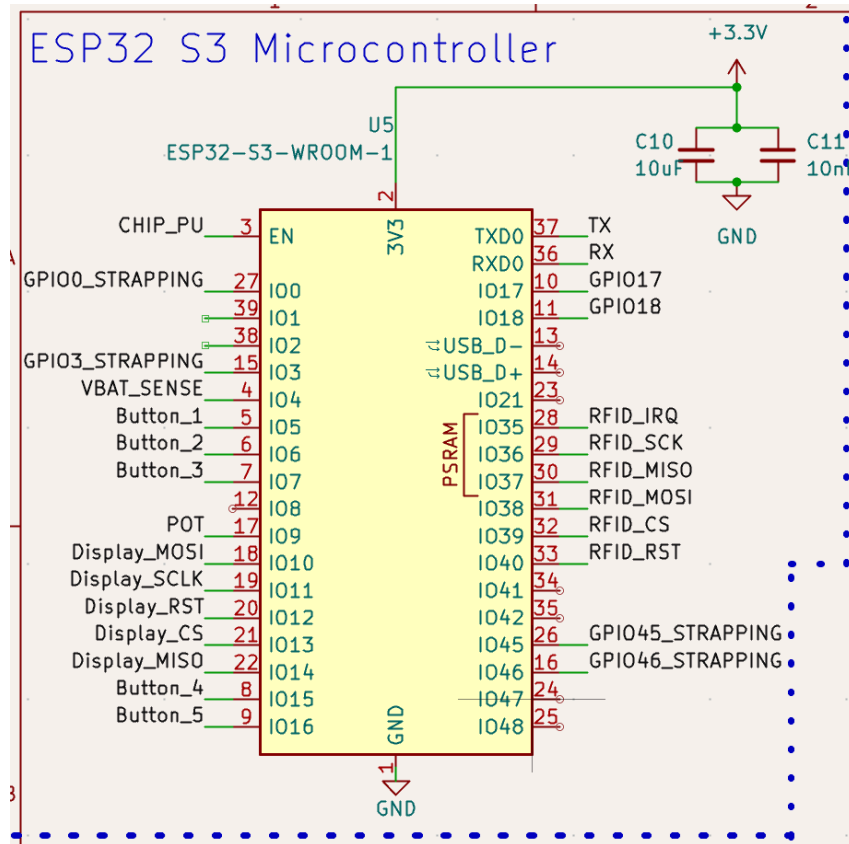


Figure 4: The ESP32 S3 Microcontroller Schematic

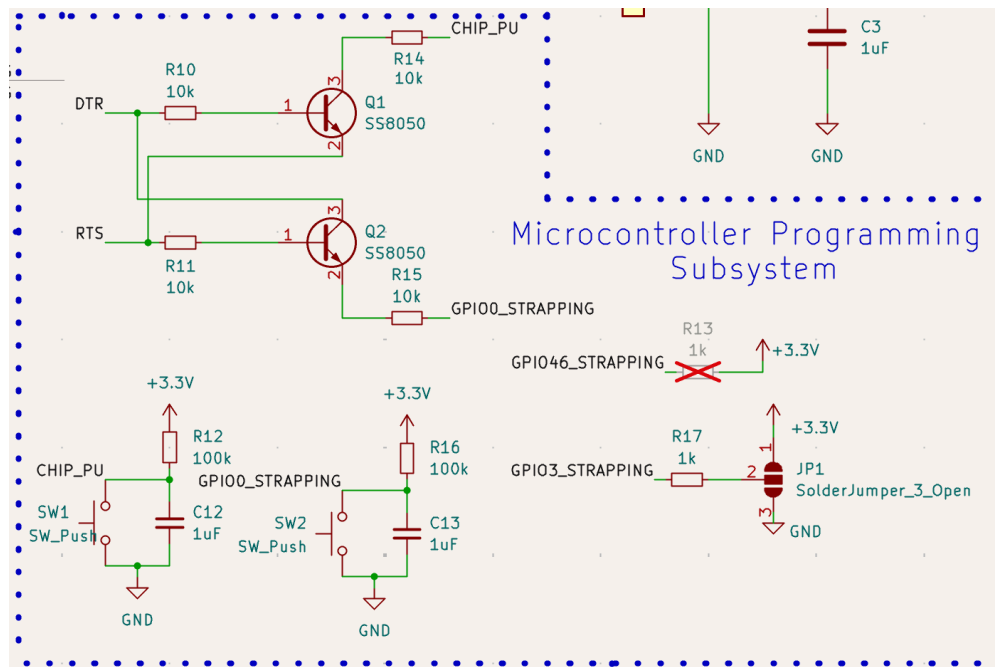


Figure 5: The ESP32 S3 Microcontroller Programming Subsystem Schematic

The Microcontroller Subsystem is the core processing unit of the Desk Learning Aid Device. It is responsible for receiving inputs from the Input Subsystem, processing RFID/NFC authentication, and transmitting data to the Web Application Subsystem via a low-latency wireless connection. The microcontroller also interfaces with the Power Subsystem to ensure efficient energy consumption and proper power regulation.

At the core of our system, the ESP32-S3 Microcontroller processes all incoming inputs from the buttons and scroller, logs interactions, and transmits the data to the Web application. It is responsible for receiving inputs from our input subsystem, processing RFID/NFC authentication, and transmitting data to the Web App Subsystem via Bluetooth. The microcontroller also interfaces with the Power Subsystem to ensure efficient energy consumption and proper power regulation.

We have chosen the ESP32-S3 as the microcontroller for this project due to its built-in Bluetooth Low Energy (BLE) capabilities, low power consumption, and sufficient processing power to handle real-time student interactions. The ESP32-S3 facilitates seamless communication with all connected components while maintaining reliable data integrity. The microcontroller plays a pivotal role in ensuring the seamless operation of the Desk Learning Aid Device. It performs the following functions:

- **Processing Input Signals:** Captures, processes, and classifies button presses and scroller adjustments from the Input Subsystem.
- **Wireless Data Transmission:** Transmits processed student data, including response selections and engagement metrics, to the Web Application Subsystem over Bluetooth Low Energy (BLE).
- **RFID/NFC Authentication:** Interfaces with the RFID/NFC Subsystem to authenticate students and ensure secure login via their assigned keycards.
- **Display Control:** Sends processed input data to the Interface Subsystem (OLED display) to provide real-time visual feedback.
- **Power Management:** Efficiently manages power consumption by utilizing deep sleep modes when idle to prolong battery life.

Requirements	Verification
The microcontroller must process all button and scroller inputs and transmit data to the Web Application within 500ms.	<ol style="list-style-type: none"> 1. Connect an oscilloscope to a button GPIO pin and monitor the time delay between button press and BLE transmission. 2. Measure the time difference between input signal

Requirements	Verification
	detection and data reception in the Web Application logs to ensure that total difference is less than 500ms.
The microcontroller must reliably interface with the RFID/NFC Subsystem to authenticate student keycards within 2 seconds of scanning.	<ol style="list-style-type: none"> 1. Tap an RFID keycard on the reader. 2. Measure the time taken for the student’s name to appear on the OLED display. 3. Ensure it is within the 2-second threshold.
The microcontroller must operate continuously for a full 8-hour school day on battery power.	<ol style="list-style-type: none"> 1. Fully charge the 2000mAh LiPo battery. 2. Continuously operate the microcontroller under normal classroom conditions. 3. Measure battery voltage at the end of 8 hours and ensure it remains above 3.3V.

Table 2 - Microcontroller Subsystem Requirements and Verification

2.2.3 Web Application

The Web Application Subsystem serves as the central interface for teachers to monitor student engagement, track participation, and adjust lesson pacing in real time. The application receives live data from student devices via Bluetooth, aggregates responses, and presents the information in a structured and visual manner. The teacher’s dashboard provides insights into student comprehension trends, assistance requests, and overall participation.

This subsystem is crucial to the overall Desk Learning Aid Device as it ensures that data collected from students is efficiently processed, stored, and displayed for meaningful classroom insights. Additionally, the RFID/NFC authentication system is integrated into the web app, allowing teachers to track attendance and student engagement over time.

1. **Frontend UI:**
 - Built with React for modular, scalable, and real-time updates.
 - State management ensures smooth updates when student data changes.
 - Intuitive dashboard with easy-to-read visual indicators.
2. **Backend & Communication:**

- Firebase Realtime Database provides instant synchronization between student devices and the teacher's dashboard.
- BLE integration with ESP32-S3 devices ensures low-latency data transfer.
- Efficient data handling allows the system to support at least 20 concurrent devices per classroom.

3. Data Processing & Visualization:

- D3.js or Chart.js generates engagement heatmaps, comprehension graphs, and response summaries.
- Aggregated student responses help teachers adapt lessons dynamically.

4. Authentication & Security:

- Google OAuth and school credentials provide secure access.
- Compliance with FERPA ensures student privacy and data protection.

Requirements	Verification
The web application must receive and process student data updates within 500ms.	<ol style="list-style-type: none"> 1. Set up a test environment with an ESP32-S3 sending timestamped BLE packets. 2. Log timestamps upon reception in Firebase. 3. Calculate the time difference and ensure it is $\leq 500\text{ms}$.
The web application must display real-time classroom engagement metrics with a refresh rate of at least once per second.	<ol style="list-style-type: none"> 1. Simulate 20 student devices using a single ESP32-S3 by cycling through 20 virtual device IDs and sending 20 BLE packets per second (one per virtual student). 2. Ensure that each packet contains a unique student ID and a sample button press or scroller value. 3. On the web application dashboard, log received student responses and timestamps. 4. Verify that the dashboard updates at least once per second, displaying the latest engagement metrics. 5. Introduce random packet delays or drops to simulate real-world BLE interference and check if the dashboard still maintains accurate updates.

Requirements	Verification
<p>The system must authenticate users correctly before allowing access to student data, ensuring only authorized teachers can view responses.</p>	<ol style="list-style-type: none"> 1. Implement Google OAuth and school credential authentication. 2. Attempt to access the system without authentication and verify that access is denied. 3. Ensure that only registered teachers with valid credentials can log in and view student data. 4. Conduct a session expiration test to confirm that users must re-authenticate after a timeout or logout.

Table 3 - Web Application Subsystem Requirements and Verification

2.2.4 Power subsystem

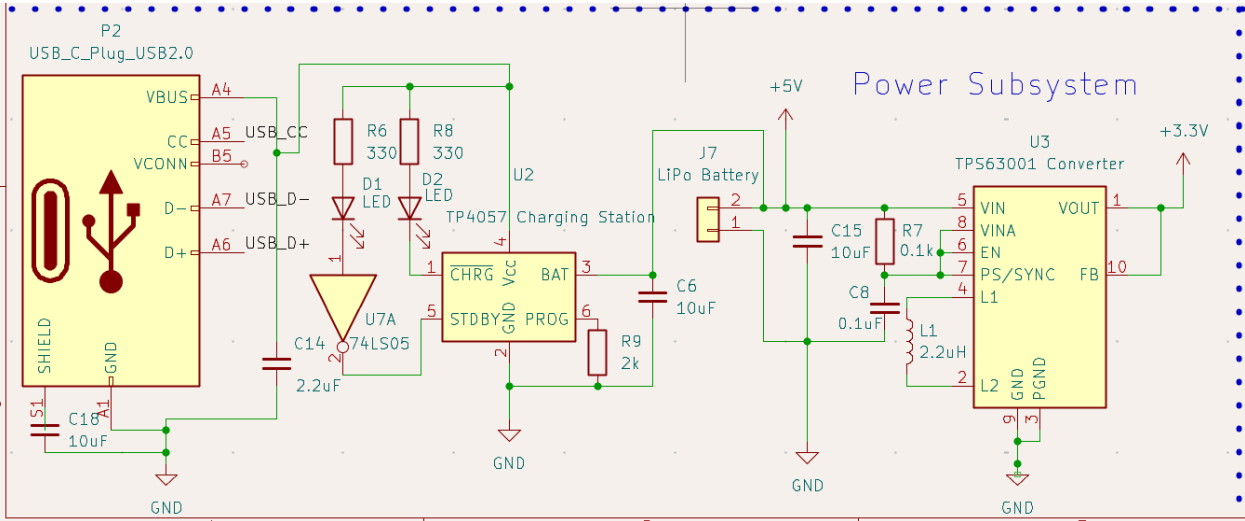


Figure 6: The Power Subsystem Schematic

The power subsystem should provide power to the rest of the device and allow it to operate, aside from the web application. This should include the microcontroller system, RFID system, and display system. It should include a rechargeable battery so that the device can be in operation throughout the school day and recharge afterwards. This is preferable in comparison to wired power for installation and cable management reasons.

For these purposes, we have chosen the following parts:

- 103454 LiPo rechargeable battery
- TPS63001DRCCR buck-boost converter

The LiPo battery has a capacity of 2000mAh and provides a 3.7V input. This is more than enough power for our purposes:

- ESP32 S3 microcontroller: 3.3V input, 50mA maximum current draw (BLE mode)
- RFID module: 3.3V input, 26mA maximum current draw
- OLED display module: 3.3V input, 20mA maximum current draw
- Total current draw: <100mA → capacity needed: <800mA

The buck-boost converter is used to convert the 3.7V battery input to the 3.3V operating voltage we need for our parts. This converter has roughly ~90% efficiency and thus the total power supplied will be equal to the following:

$$\frac{(3.3V \times 100mA)}{90\% \text{ efficiency}} = 0.36\bar{W}$$

Thus the total battery capacity required is equal to the total daily energy needed divided by the battery voltage:

$$\frac{0.36\bar{W} \times 8h}{3.7V} = 1086mAh$$

The battery should have more than enough capacity to support the full operation of the device.

Requirements	Verification
The battery continually provides at least a 3.0V output over the duration of the school day (8 hours)	<ol style="list-style-type: none"> 1. Fully charge the 2000mAh LiPo battery. 2. Continuously operate the microcontroller under normal classroom conditions. 3. Measure battery voltage at the end of 8 hours and ensure it remains above 3.0V.
The voltage regulator system maintains the input voltage between 3.0V and 3.6V as indicated by the microcontroller	<ol style="list-style-type: none"> 1. Set the input voltage (V_{in}) to the typical expected operating value (3.7V). 2. Measure and record the output voltage (V_{out}) at the

Requirements	Verification
datasheet.	regulator output.
	3. Verify that Vout is within 3.0V to 3.6V.

Table 4 - Power Subsystem Requirements and Verification

2.2.5 RFID/NFC (Keycard) subsystem

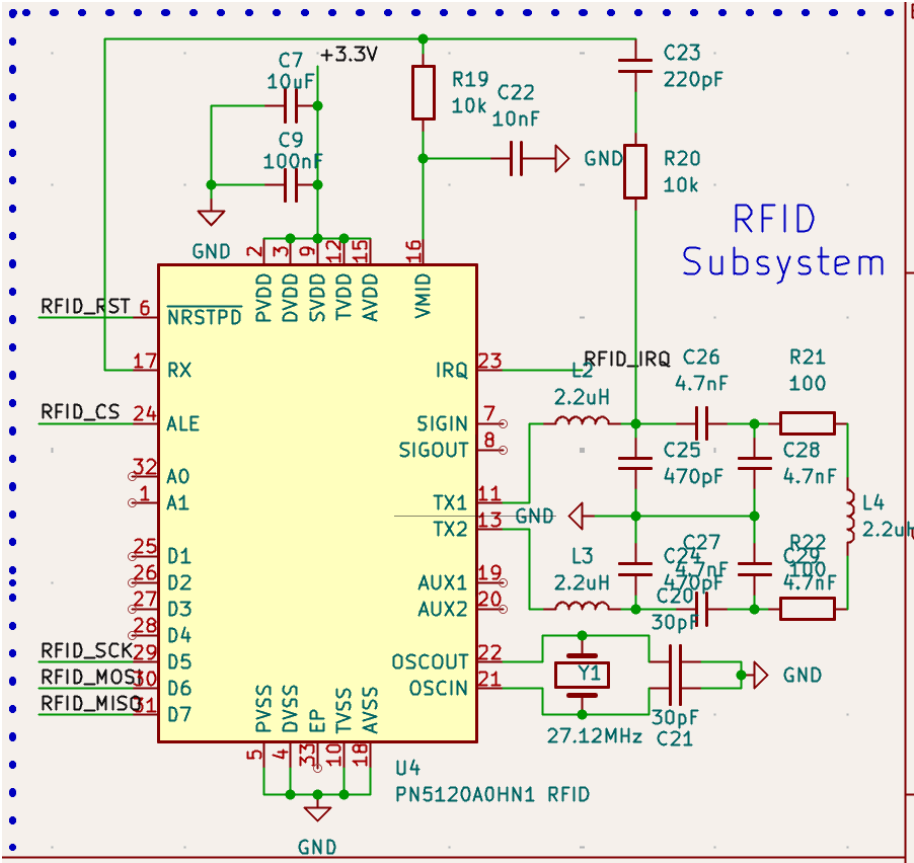


Figure 7: The RFID Subsystem Schematic

The RFID/NFC Subsystem provides a seamless and low-disruption authentication method for students using RFID keycards. This eliminates the need for manual name entry or personal devices, ensuring quick and anonymous login. By simply tapping their keycard, students authenticate their presence, enabling teachers to monitor participation and engagement trends efficiently.

This subsystem plays a critical role in ensuring that only authenticated students can interact with the system, linking each student to their corresponding desk device. It prevents

unauthorized participation, ensures accurate attendance tracking, and integrates directly with the Web Application Subsystem for real-time updates.

The RFID/NFC Subsystem is responsible for:

- Reading student keycards and extracting a unique identifier (UID).
- Verifying the UID and associating it with a student record.
- Transmitting authentication data to the Microcontroller Subsystem, which then relays it to the Web Application.
- Preventing fraudulent participation by ensuring that each student has a unique keycard.

RFID/NFC Reader Selection

- The system utilizes the PN512 RFID/NFC reader, which supports ISO/IEC 14443 Type A and B cards, including MIFARE 13.56 MHz cards, making it ideal for secure authentication.
- Communicates with the ESP32-S3 microcontroller via SPI, ensuring low-latency data transfer.
- Can detect keycards within a 3-5 cm range, allowing students to simply tap their card for login.

RFID Key Cards (MIFARE Classic 1K – 13.56 MHz)

- Each keycard contains a unique identifier (UID) stored in read-only memory, ensuring that students cannot duplicate or modify their IDs.
- Passive RFID design means no battery or external power is needed, making the keycards cost-effective and long-lasting.

Integration with Other Subsystems

- Microcontroller Subsystem: The ESP32-S3 receives the RFID UID via SPI and transmits it to the Web Application over BLE.
- Web Application Subsystem: Upon receiving an authenticated UID, the web app logs attendance and associates student interactions with their profile.

Requirements	Verification
The system must successfully authenticate RFID keycards when tapped on the reader.	1. Power on the system and tap a valid MIFARE 13.56 MHz keycard on the PN512 reader.

Requirements	Verification
	<ol style="list-style-type: none"> 2. Verify that the ESP32-S3 microcontroller correctly receives and displays the UID. 3. Ensure that the UID is transmitted to the Web Application and correctly linked to a student profile.
<p>The system must differentiate students' RFID keycards to prevent duplicate logins.</p>	<ol style="list-style-type: none"> 1. Assign two students RFID keycards with different UIDs. 2. Tap each card and verify that the system correctly distinguishes between the two students. 3. Attempt to use the same RFID card for two different students and ensure that the system rejects duplicate registrations.
<p>The authentication process must complete within 2 seconds of tapping a keycard.</p>	<ol style="list-style-type: none"> 1. Use a timestamp logger to record when the card is tapped and when the student name appears on the LCD display. 2. Ensure that the time difference is ≤ 2 seconds.

Table 5 - RFID/NFC (Keycard) Subsystem Requirements and Verification

2.2.6 Interface Subsystem

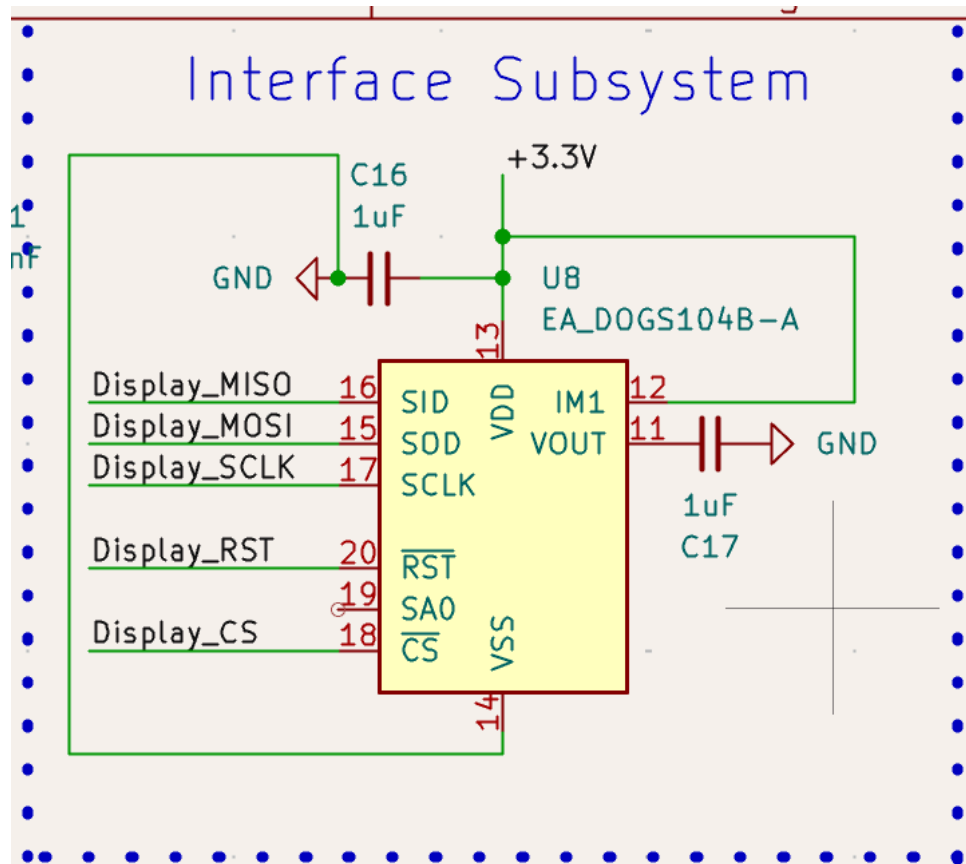


Figure 8: The Interface Subsystem Schematic

This subsystem will include a basic interface that serves several purposes:

- Will display the user's name once the user check's in thus verifying the check-in.
- Will display a range of emotions that students can select via their scroller.
- Will display the answer choice selected by the user for comprehension checks.

The Interface Subsystem provides real-time visual feedback through a small LCD display, showing the student's name upon successful login, allowing them to select from a range of emotions via the scroller, and confirming their chosen comprehension check answers. By rendering these updates promptly and clearly, this subsystem ensures that students receive immediate confirmation of their actions, enhancing usability and trust in the system. It directly supports the high-level requirement of creating an intuitive, interactive learning environment that minimizes disruptions.

A dedicated firmware program running on the ESP32-S3 microcontroller is responsible for updating the EA-DOGS104W-A display with real-time data. This program continuously

monitors input from the RFID reader, scroller, and other user interactions. Upon detecting a valid check-in, it retrieves the user’s name from a central database and updates the display accordingly. Similarly, when a student selects an emotion or answer choice, the program processes the input and refreshes the display to reflect the selection. Communication between the ESP32-S3 and the display occurs over an SPI interface, ensuring low-latency updates and efficient data transfer. This program is designed to run in a non-blocking manner, allowing seamless operation without interrupting other critical system functions.

Requirements	Verification
The interface subsystem must be able to display the user’s name within 2 seconds after authentication with the RFID keycard.	<ol style="list-style-type: none"> 1. Scan the RFID keycard with the scanner. 2. Use a logic analyzer to accurately measure the time it takes from when the keycard is scanned to when the name appears on the interface. 3. Repeat this procedure for 100 trials. 4. Ensure that for at least 95% of cases (95 trials) that the name appears within 2 seconds.
The interface subsystem must provide clear and legible text/icons for selected answers and emotions	<ol style="list-style-type: none"> 1. Load test images of selected answers and emotions onto the display. 2. Conduct readability tests with various students. 3. Ensure that at least 95% of students correctly identify text/icons.
The interface subsystem must refresh within 100ms after receiving new data.	<ol style="list-style-type: none"> 1. Perform independent button presses and scroller adjustments. 2. Use an oscilloscope to accurately measure the time it takes from when an independent event occurs to when the display is updated. 3. Repeat this procedure for 100 trials per each independent event. 4. Ensure that for at least 98% of cases (98 trials) that the update delay is less than 100ms.

Table 6 - Web Application Subsystem Requirements and Verification

2.3 Tolerance Analysis

A primary risk in our design involves the reliability and scalability of the Bluetooth Low Energy (BLE) link when 20 student devices simultaneously connect to the teacher's console or computer in a typical classroom. If wireless communication becomes congested, student responses may fail to appear on the teacher's dashboard, undermining the core functionality.

2.3.1 Link-Budget Calculation

We begin by assessing whether a single device can reliably transmit and receive BLE signals in a 10 m indoor environment, which is a realistic classroom scenario:

1. Path Loss

Using the log-distance path loss equation, $PL(d) = PL(d_0) + 10n \log_{10}(d / d_0)$
 $PL(d_0) \approx 40\text{dB}$ at $d_0=1\text{m}$ for 2.4 GHz indoors.
 $n \approx 2.7$ (path loss exponent in a cluttered classroom).
 $d=10\text{m}$.

Plugging in

$$PL(10\text{ m}) = 40\text{ dB} + 10 \times 2.7 \times \log_{10}(10) = 40 + 27 = 67\text{ dB}$$

2. Transmit Power & Receiver Sensitivity

- Typical BLE transmit power on the ESP32-S3 can be around +4 dBm.
- With an antenna gain near 0 dBi, the Effective Isotropic Radiated Power (EIRP) is still about +4 dBm.
- Many BLE modules maintain a receiver sensitivity of about -90 dBm at a 1 Mbps data rate.
-

3. Received Power & Link Margin

$$P_R = P_{TX} + G_{TX} - PL(d) = (+4\text{ dBm}) - 67\text{ dB} = -63\text{ dBm}$$

$$\text{Link Margin} = (\text{Receiver Sensitivity}) - P_R = (-90\text{ dBm}) - (-63\text{ dBm}) = 27\text{ dB}$$

This 27 dB margin shows the signal remains reliably above the sensitivity threshold, even considering typical interference. Our analysis suggests the BLE signal should experience <1% packet error under normal classroom conditions at ~10 m range.

3. Cost and Schedule

3.1. Cost Analysis

Labor Costs

To estimate labor costs, we assume an average salary for an ECE graduate at UIUC. According to recent salary surveys, the median starting salary for an Electrical and Computer Engineering graduate from UIUC is approximately \$45 per hour. The labor cost formula is:

Assuming each team member works 10 hours per week over 12 weeks:

- **Total Hours per Person** = $10 \times 16 = 160$
- **Total Labor Cost** = $45 \times 3 \times 160 = \$21,600$

Parts & Equipment Costs

The following table lists the key components and estimated costs required for the project:

Part	Manufacturer	Part #	Quantity	Cost per Unit (\$)	Total Cost (\$)
ESP32-S3 Microcontroller	Espressif Systems	ESP32-S3-WROOM-1-N16R2	2	5.53	11.06
Lithium Polymer Rechargeable battery	EEMB	LP103454	2	11.89	23.78
Buck-Boost Converter Voltage Regulator	TI	TPS63001DRCR	2	1.95	3.90
Near-Field Communication Front-End module	NXP	PN512	1	8.97	8.97

Character Display Screen	Mouser	EA-DOGS10 4W-A	2	16.27	32.54
Hex Inverter	TI	SN74LS05	6	0.75	4.50
Charging Station	EVVO	TP4057	4	0.41	1.64
USB-Serial Converter	JESSINIE	CH340G SOP-16	1	6.95	6.95
USB Plug	JAE Electronics	DX07S016JA 1R1500	2	1.51	3.02
Potentiometer	Bourns	PDB181-E41 5K-102B	1	1.30	1.30
LiPo Rechargeable Battery	EEMB	LP103454	1	11.99	11.99
Illuminated Push Buttons	Adafruit	492	5	3.95	19.75
1uF capacitor	KEMET	C0805C105K 5PACTU	9	0.28	1.81
10uF capacitor	KEMET	C0805C106K 8PACTU	10	0.07	0.67
0.1 uF capacitor	KEMET	C0805C104 M5RACTU	3	0.10	0.30
10nF capacitor	KEMET	C0805X103K 1RAC3316	2	0.16	0.32
2.2uF capacitor	KEMET	C0805C225K 8RACTU	1	0.20	0.20
30pF capacitor	KEMET	C0805C300 M5HACTU	2	0.10	0.20
220pF	Samsung	CL21C221JB	1	0.10	0.10

capacitor	Micro-electronics	ANNNC			
470pF capacitor	KEMET	C0805C471K5RACTU	2	0.10	0.20
4.7nF capacitor	KEMET	C0805C472K1GECTU	4	0.22	0.88
2.2uH inductor	TDK corporation	MLZ2012M2R2HT000	4	0.10	0.40
10kΩ resistor	Panasonic	ERJ-P06F1002V	11	0.086	0.95
330Ω resistor	Bourns	CR0805-JW-331ELF	2	0.10	0.20
100Ω resistor	Panasonic	ERJ-6ENF1000V	3	0.11	0.33
2kΩ resistor	Stackpole	RMCF0805FT2K00	1	0.10	0.10
100kΩ resistor	YAGEO	RC0805FR-07100KL	2	0.10	0.20
1kΩ resistor	YAGEO	RC0805FR-071KL	2	0.012	0.12
5.1kΩ resistor	YAGEO	RC0805JR-075K1L	1	0.08	0.08
Push button switch	Same Sky	TS02-66-60-BK-160-LCR-D	2	0.10	0.2
27.12 MHz crystal oscillator	NDK	LNCD1-25M	1	0.54	0.54
Red LED	Cree LED	C5SMF-RJF-CT0W0BB2	2	0.17	0.17

NPN Epitaxial Silicon Transistor	Comchip	SS8050	2	0.24	0.48
--	---------	--------	---	------	------

Total Cost of Parts: \$137.85

Machine Shop & Equipment Costs

Some components require custom machining or soldering:

Service	Estimated Hours	Hourly Rate (\$)	Total Cost (\$)
PCB Assembly	5	42.55	212.75

Total Machine Shop Cost: \$212.75

Grand Total Cost

Category	Total Cost (\$)
Labor	21,600
Parts	137.85
Machine Shop	212.75
Final Cost	21,950.60

3.2 Schedule:

Week	Date	Task	Team Members
1	2/26 - 3/3	<ul style="list-style-type: none"> - Finalize architecture & system design (Block Diagram, High-Level Requirements) - Select and order key components for the first prototype - Prepare for Design Document submission 	All
2	3/4 - 3/10	- Design Document Due (3/3)	All

		<ul style="list-style-type: none"> - First Round PCBWay Order (Must Pass Audit by Today, 3/3) - Start initial breadboard prototyping and circuit validation - Develop firmware skeleton for microcontroller functionality 	
3	3/11 - 3/17	<ul style="list-style-type: none"> - Breadboard Demonstration with Instructor & TA (3/10) - Test basic component functionality (buttons, RFID reader, OLED display) - Validate Bluetooth Low Energy (BLE) communication with web app - Second Round PCBWay Order (Must Pass Audit by Today, 3/10) 	All
4	3/18 - 3/24	No work scheduled	None
5	3/25 - 3/31	<ul style="list-style-type: none"> - Refine PCB design and address any issues from breadboard testing - Test battery power consumption and efficiency - Start developing microcontroller drivers for all subsystems 	Ethan, Aidan
6	4/1 - 4/7	<ul style="list-style-type: none"> - Third Round PCBWay Order (Must Pass Audit by Today, 3/31) - Individual Progress Reports Due (3/31) - Assemble first PCB and perform functional testing - Debug BLE communication and integrate with the web application 	Conan, Ethan
7	4/8 - 4/14	<ul style="list-style-type: none"> - Fourth Round PCBWay Order (Must Pass Audit by Today, 4/7) - Begin full system integration and initial software debugging - Conduct power management tests and optimize battery life 	Ethan, Aidan

8	4/15 - 4/21	<ul style="list-style-type: none"> - Team Contract Assessment Due (4/14) - Start testing real-time classroom interactions with the web application - Optimize PCB and firmware for responsiveness and low latency 	Conan
9	4/22 - 4/28	<ul style="list-style-type: none"> - Mock Demo During Weekly TA Meeting - Verify all high-level requirements are met - Debug remaining issues in hardware/software integration 	Conan, Aidan
10	4/29 - 5/5	<ul style="list-style-type: none"> - Final Demo with Instructor & TAs (4/28) - Conduct system-wide performance testing - Prepare presentation materials for final submission 	All
11	5/6 - 5/12	<ul style="list-style-type: none"> - Final Presentation with Instructor & TAs (5/5) - Final Papers Due (5/5) - Lab Notebook Due (5/5) - Award Ceremony (5/5) - Perform final documentation and lab checkout 	All

4. Discussion of Ethics and Safety

4.1 Ethics

4.1.1 Privacy

Ensuring the privacy and security of the user data being collected is crucial for the success of our project. As this device is designed to be integrated into elementary schools, it is vital that this device be secure such that parents and teachers can trust the

device to collect data in a strictly beneficial manner. This aligns with our pursuit in following ACM Principle 1.6, “Respect Privacy”.

4.1.2 Transparency

It is critical that the data collected and the analysis that comes from it be transparent to both the device users and the Web app users. The context in which this device will be used, in various learning environments, makes it such that transparency is a key factor in having our project be a success. That is why the Web application will be designed to organize, highlight, and show the data that is being collected.

4.1.3 Bias

It is crucial that no bias is introduced by the machine learning algorithm or through misinterpretations of the data being presented. The machine learning algorithm will be used to assess and analyze trends from various learning aid devices that are all connected to one classroom. It is essential that this algorithm is continuously tested throughout the school year to ensure fair recommendations and adjustments are made. In addition, the data being presented will be done so with clear data visualization tools in order to mitigate the potential for misinterpretation. This aligns with our pursuit in following ACM Principle 2.5, “Give comprehensive and thorough evaluations of computer systems and their impacts, including analysis of possible risks”.

4.1.4 Inclusivity

Ensuring the device is in compliance with ADA for those with disabilities is an essential aspect of our device. In this respect the device will be designed to be set up on student desks to accommodate each student in the classroom. The focus on simplicity by using buttons and a scroller further emphasizes our commitment to ensuring the device is accessible and inclusive. This aligns with our pursuit in following the IEEE Code of Ethics, specifically code two, as well as ACM Principle 1.4, “Be fair and take action not to discriminate”.

4.1.5 Safety

The electronic and hardware safety of our device. As this device will be around children ages 5-11, it is crucial that these devices meet FCC Part 15 regulations, UL 60950-1, and ISO 14971. These regulations ensure safety in electronic emissions, IT equipment, and risk management in electronic devices. In addition to these regulations, we will follow the IEEE Standard 1725 to ensure the safety of the batteries used within the device.

4.1.6 Lab Policies

We will ensure to adhere to the University of Illinois Urbana-Champaign laboratory safety guidelines throughout the construction of the learning aid device.

4.2 Safety Considerations

4.2.1 Battery Safety

- The LiPo battery used in the device is compliant with IEEE Standard 1725, ensuring it meets safety requirements for rechargeable battery packs.
- The device will be equipped with a low-power sleep mode, reducing unnecessary energy consumption and battery stress.

4.2.2 Physical Durability and Classroom Safety

- The casing is designed with rounded edges and durable materials to prevent injuries in case of accidental drops.
- The device's components are securely enclosed to prevent tampering or accidental exposure to electronic parts by young students.

4.2.3 Compliance with Laboratory Safety Guidelines

- During development, the team follows UIUC's laboratory safety policies, ensuring that prototyping and testing environments are free from hazards.
- Team members working with PCB assembly and power electronics adhere to standard lab safety protocols, including the use of anti-static protection and insulated tools.

The procedures listed above will sufficiently ensure that both users and developers are protected from unsafe conditions caused by our project. Developers must adhere to the Compliance with Laboratory Safety Guidelines procedure which will protect them from any potential hazard during the production stage of the project. Users will be protected by Battery Safety and Physical Durability and Classroom Safety procedures. These procedures include the use of a battery that meets safety regulations and standards and a physically secure device that has been specifically designed for young students. These procedures will be upheld in the pursuit of ensuring the safe production and usage of the device.

5. Citations

IEEE. (2023). *IEEE Code of Ethics*.

Want, R. (2006). *An Introduction to RFID Technology*. IEEE Pervasive Computing, 5(1), 25-33.

Espressif Systems. (2023). *ESP32-S3 Technical Reference Manual*.

Espressif Systems. (2023). *ESP-IDF programming guide*.

NXP Semiconductors. (2023). *MFRC522 standard communication protocol for RFID applications*.

EEMB Battery. (2023). *103454 3.7V LiPo rechargeable battery datasheet*.

Texas Instruments. (2023). *LM317 voltage regulator datasheet*.

Mayer, R. E. (2021). *Multimedia learning* (3rd ed.). Cambridge University Press.

Espressif Systems. (2023). *ESP32-S3 datasheet*.

NXP Semiconductors. (2023). *MFRC522 standard communication protocol for RFID applications*.

Solomon Systech. (2023). *SSD1306 datasheet - 128 x 64 dot matrix OLED/PLED segment/common driver with controller*.

Texas Instruments. (2023). *TPS63001 buck-boost converter datasheet*.

Electronic Assembly. (2023). *EA DOGS104E LCD module datasheet*.

Texas Instruments. (2023). *SN74LS05 hex inverter datasheet*.

Shenzhen Injoinic Technology. (2023). *TP4057 linear Li-ion battery charger datasheet*.

JAE Electronics. (2023). *DX07S016JA1R1500 USB Type-C connector datasheet*.