

GNG 5140
Engineering Design
Design Project User and Product Manual

Submitted by:

Open-Source Educational Toy, Team-A

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Table of Contents

Table of Contents	ii
List of Figures	v
List of Tables	vi
List of Acronyms	vii
1 Introduction.....	1
2 Overview.....	2
3 Getting started	5
3.1 Set-up Considerations	5
3.2 Accessing the System.....	5
3.3 System Organization & Navigation	6
3.3.1 Main Menu.....	6
3.3.2 Game Page	7
3.3.3 File Page.....	8
3.4 Exiting the System	9
4 Using the System	10
4.1 Alphabetic Game.....	10
4.2 Counting Game	10
4.3 Upload Files	10
4.4 View Files	10
4.4.1 Create Folder.....	11
4.4.2 Delete Files & Folders	11
4.4.3 Rename Files & Folders.....	11

5	Troubleshooting & Support	12
5.1	Special Considerations	12
5.2	Support	12
6	Product Documentation	13
6.1	Electrical System.....	13
6.1.1	BOM (Bill of Materials)	13
6.1.2	Equipment list	13
6.1.3	Instructions.....	13
6.2	Software System.....	14
6.2.1	Equipment list	14
6.2.2	Instructions.....	14
6.3	Mechanical System	15
6.3.1	Equipment list	15
6.3.2	Instructions.....	15
6.4	Testing & Validation.....	17
6.4.1	Prototype Test	17
6.4.2	Test Results	19
7	Conclusions and Recommendations for Future Work	22
7.1	Conclusion.....	22
7.2	Future Recommendations.....	22
8	Bibliography	23
8.1	Adafruit Learning Platform: “Adafruit ES32-S3 Setup”	23
8.2	Arduino Uno Libraries: “Libraries to Install”	23

9	APPENDICES	24
9.1	APPENDIX I: Design Files.....	24

List of Figures

Figure 1: Learning Pad (Left) and Amazon Fire Kids Tablet (Right)	3
Figure 2: Final Prototype designed by our team	3
Figure 3 ToysAP page and IP address	5
Figure 4: Main Menu of the Companion App	6
Figure 5: Game Page of the Companion App.....	7
Figure 6: File Page of the Companion App	8
Figure 7: Upload Page of the Companion App.....	8
Figure 8: Directory List Page of the Companion App.....	9
Figure 9 Circuit Diagram	14

List of Tables

Table 1 Acronyms.....	vii
Table 2 List of Test Cases.....	19
Table 3 Average Test Results	21
Table 4. Referenced Documents	Error! Bookmark not defined.

List of Acronyms

Acronym	Definition
BusyPad	Name of the existing product (Toy)
LED	Light-Emitting Diode
ESP32	A Microcontroller used in Toy
LCD	Liquid-Crystal Display
OTA	Over-the-air
CSA	Canadian Standards Association
ASTM	American Society for Testing Materials
dB	Decibel
ESP 32	A Microcontroller
GPIO	General Purpose Input/Output

Table 1 Acronyms

1 Introduction

This report elaborates on the user manual of our toy “BusyPad 2.0” on what kind of material is used, how to assemble all the parts of the toy and how to rebuild the product from the scratch, and additional files are provided to easily get the idea behind the working process of the toy.

Moreover, this report provides information on the overall overview of and basic information of the toy, convention and the warnings of the usage of the toy. In the next part, this report briefly elaborates on getting started to build up the “BusyPad 2.0” on set-up steps, user access, system access, and overall system organization and navigation from one feature to another feature as well as on how to shut down the system after using it.

In addition, it also describes on what kind of features this toy has and how to use each of the feature and its sub-features using the user manual and how to easily get to know about the toy. Also, troubleshooting methods and support system, error messaging and maintenance tips are provided.

At last, this report concludes with the step-by-step information on how to build the product from scratch with the list of the materials used and also equipment list which were used to build this toy, with clear instruction of each part. Moreover, team has included the overall testing and validation comments on the toys for future references and development for future teams. Also, all the design file has provided through the MakerRepo link in the appendix section for better understanding of the toy’s structure and code files.

2 Overview

Our project is an open-source educational toy designed as an affordable, fun, and customizable handheld device for users aged 4 to 24. It features a screen, speaker, LEDs, buttons, a microSD card, and sensors. The BusyPad is paired with a companion app, enabling users to download games and content from cloud storage while allowing parents to monitor and control their children's activities. Switching between games is simple, and the product offers learning insights to combine entertainment with education.

This project aligns with three Sustainable Development Goals (SDGs):

1. **Quality Education:** Priced at an affordable \$50, the toy provides accessible quality education. Its engaging features make learning enjoyable, encouraging children to view studying as a fun activity.
2. **Decent Work and Economic Growth:** By fostering a love for learning, the toy increases the likelihood of users pursuing education and, in turn, securing decent jobs. Additionally, it offers built-in educational programs for adults to develop job-related skills.
3. **Sustainable Cities and Communities:** Designed for a lifespan exceeding 10 years, the toy outlasts typical children's toys, which are often discarded within a year. While it uses a PLA plastic outer shell, its recyclability and durability minimize environmental impact.

This project bridges entertainment, education, and sustainability, offering long-term value for its users and the community.

The previous proof-of-concept (POC) prototype developed by our client included only two games. While these games are engaging for kids, the limited selection means they may quickly lose interest. To ensure the toy remains exciting and usable for over a decade, it needs to be updateable. Fixed games won't achieve this longevity, but enabling cloud-based storage for a wide variety of games and firmware updates will.

Additionally, the client envisions the toy supporting video, music, images, and text playback via its speaker and screen to enhance its entertainment value. The first step toward this goal is implementing SD card storage and file management capabilities. To further extend the toy's usability, an improved ergonomic design is essential.

These considerations define our three main objectives:

1. **Enable wireless updates** to add new features and games.
2. **Incorporate SD card storage** with user-friendly file management and upload functionality.
3. **Enhance the outer shell design** for better ergonomics and durability.

Achieving these goals will make the toy more versatile, enjoyable, and sustainable for users.

The market has two main competitors, represented by the following products:

1. **Learning Pad:** This device includes only six games, leading to kids quickly losing interest. In contrast, our product is updateable, offering a continuous stream of new games to keep users engaged. Additionally, our toy includes educational programs for teenagers and adults, broadening its appeal beyond just young children.
2. **Amazon Fire Kids Tablet:** While this tablet offers extensive functionality and a strong parental control system, it is prohibitively expensive, priced at \$150, with additional costs for many games. Furthermore, it targets only children, whereas our product is designed to be suitable for kids, teenagers, and adults alike.



Figure 1: Learning Pad (Left) and Amazon Fire Kids Tablet (Right)

Our product bridges these gaps by being affordable, updateable, and versatile across a wide age range.



Figure 2: Final Prototype designed by our team

The toy connects to Wi-Fi, allowing users to control it through a web app. To access the app, connect your device to the same Wi-Fi network and enter the IP address displayed on the toy's screen into a browser. The web app provides two main functionalities: Games and File Management.

For games, the toy offers two simple options: an alphabet game and a counting game, both playable with two buttons. In the alphabet game, one button moves forward and the other moves backward through the alphabet. In the counting game, the buttons add or subtract one. The toy stores only one game at a time. To play the current game, simply click it. To switch games, click the new game to upload it to the toy, and once the upload is complete, click again to play.

The file management page lets users view and manage files on the SD card. Features include creating folders, deleting, renaming files or folders, and uploading files. When uploading, if the specified folder doesn't exist, it will be created automatically, and the file will be stored inside it.

➤ **YouTube Link**

Here below is the YouTube link given of the demonstration of the video of the toy.

[YouTube Video BusyPad 2.0](#)

3 Getting started

3.1 Set-up Considerations

To set up the toy, start by connecting it to a power source using a Type-C cable. If the toy is functioning properly, the screen should initially appear black. Once the screen is black, wait a few seconds. A Wi-Fi network named "ToyAP" should appear in your phone's Wi-Fi manager. Connect to this network, and a configuration window should open automatically. Select "Configure Wi-Fi," choose your Wi-Fi network, and enter the password. The toy will remember these credentials for future connections. After setup, the screen will display: "Connected to 'WIFI', IP address: '...'." Connect your device to the same Wi-Fi network and enter the IP address in your browser to access the companion app.

3.2 Accessing the System

- Connect the phone or the laptop and "ToysAP" Wi-fi module to the same local Wi-fi. Figure 3 below shows the page of "ToysAP" Wi-fi manager page.
- As soon as "ToysAP" connects to the Wi-fi, toy's screen will pop-up the Ip address of the web app.
- Browse that Ip address in any of the web browser and you will get to the web app.

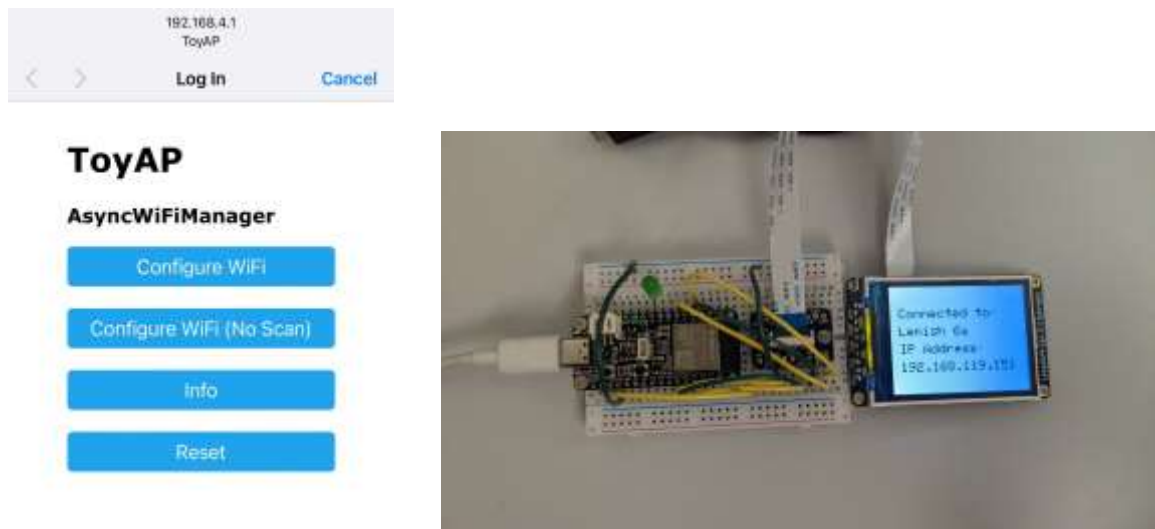


Figure 3 ToysAP page and IP address

3.3 System Organization & Navigation

3.3.1 Main Menu

You will be taken to the main menu of the companion app with the IP address, where you will see two buttons: 'Games' and 'File Management'. These buttons will direct you to the game page and file management page, respectively.

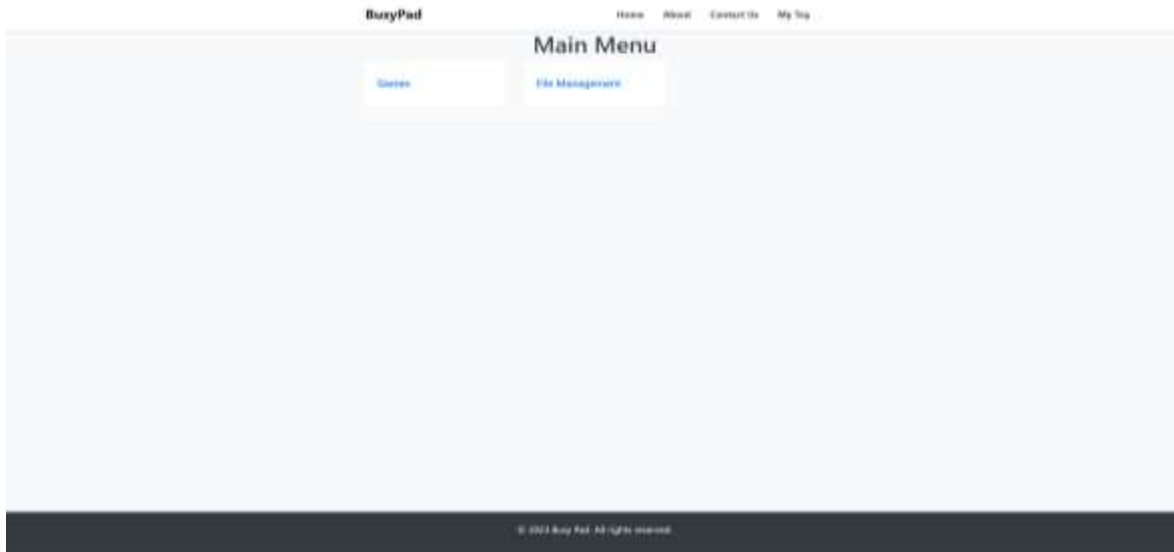


Figure 4: Main Menu of the Companion App

3.3.2 Game Page

On the game page, you can choose between two available games: the alphabet game and the counting game. Clicking the 'Back to Homepage' button will return you to the main menu.

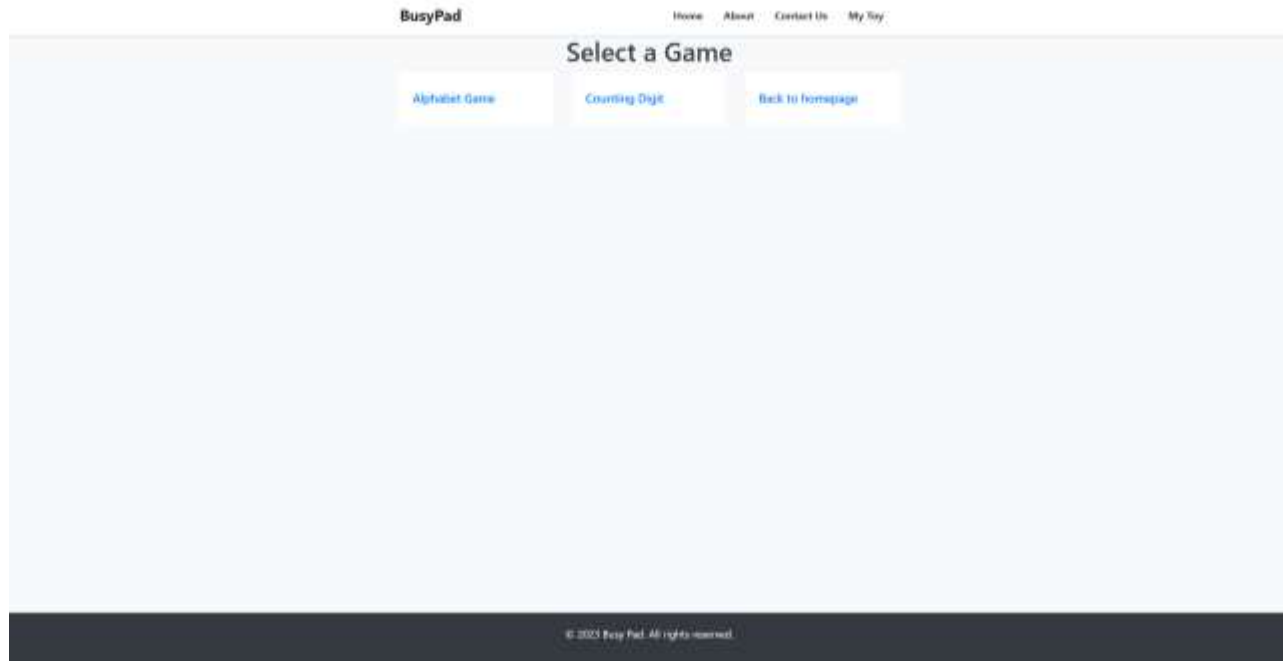


Figure 5: Game Page of the Companion App

3.3.3 File Page

On the File page, there are two functions: 'Upload Files' and 'View Files'. These buttons navigate to the upload page and the directory list page, as shown in Figures 6 and 7, respectively. Clicking the 'Back to Homepage' button will return you to the main menu.

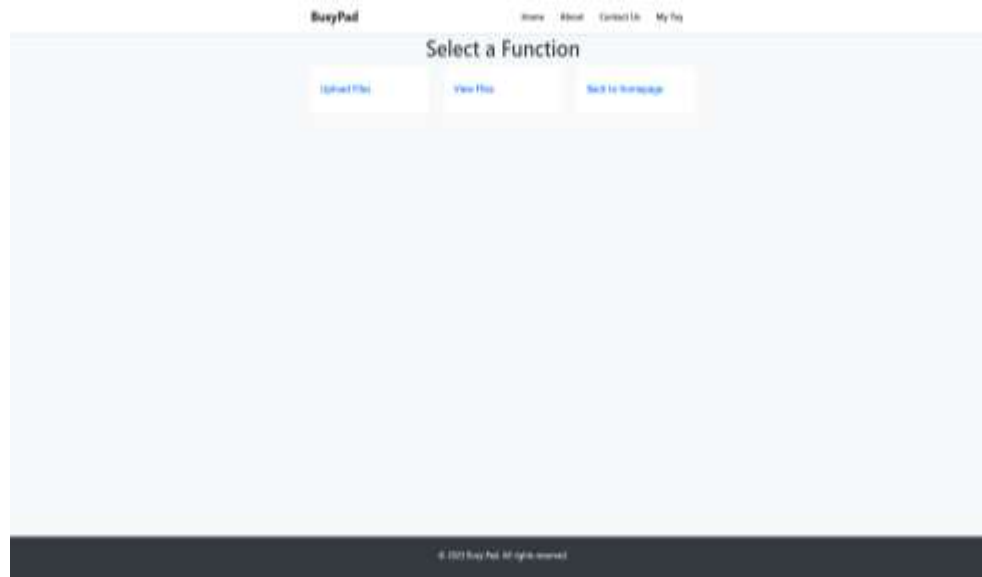


Figure 6: File Page of the Companion App

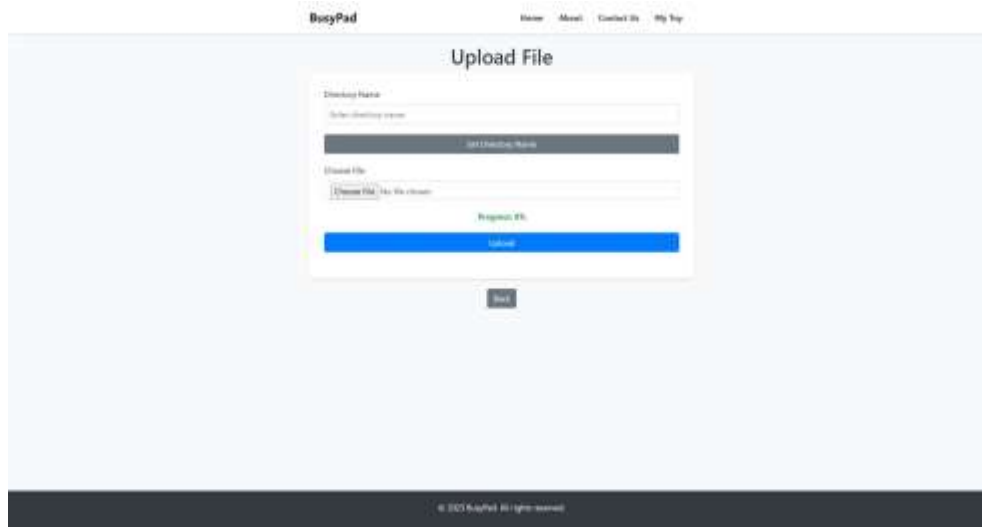
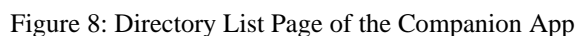


Figure 7: Upload Page of the Companion App



To exit the companion app, simply close the browser. To turn off the toy, unplug its power source.

4 Using the System

4.1 Alphabetic Game

Go to the game page of the companion app by clicking the 'Games' button on the main menu. If the alphabet game is already loaded on the toy, click 'Alphabet Game' to start playing. The screen will display 'Welcome to Alphabet Game,' followed by the letter 'A' in the center. Use the buttons below the screen to navigate forward (right) or backward (left) through the alphabet. If the game is not loaded, click 'Alphabet Game' once, wait until the screen shows 'Finish Loading' and returns to the IP address display, then click 'Alphabet Game' again to start playing.

4.2 Counting Game

Go to the game page of the companion app by clicking the 'Games' button on the main menu. If the counting game is already loaded on the toy, click 'Counting Digit' to start playing. The screen will display 'Welcome to Counting Game,' followed by the digit '0' in the center. Use the buttons below the screen to add 1 (right) or subtract 1 (left), with the count limited to a maximum of 20. Clicking the left button at 0 will loop the count to 20, and clicking the right button at 20 will loop it back to 0. If the game is not loaded, click 'Counting Digit' once, wait until the screen shows 'Finish Loading' and returns to the IP address display, then click 'Counting Digit' again to start playing.

4.3 Upload Files

Go to the file page of the companion app by clicking the 'File Management' button on the main menu, then click 'Upload Files' on the file page. This will take you to the page shown in Figure 6. To upload a file to the main folder, enter '/' in the 'Enter Directory Name' box. To upload the file to a specific folder, enter the folder name in the box. To upload to a subfolder, enter 'Main folder/subfolder'. After entering the directory name, click the 'Set Directory Name' button. Then, click 'Choose File' to select the file from your device, and click 'Upload'. Once the progress bar shows 'Progress: Uploaded', the file will be successfully uploaded to the SD card. The 'Back' button allows you to return to the previous page.

4.4 View Files

Go to the file page of the companion app by clicking the 'File Management' button on the main menu, then click 'View Files' on the file page. This will take you to the page shown in Figure 7, where you can view all files and folders on the SD card. Files within a folder will be indented to distinguish them from files in the main folder.

4.4.1 Create Folder

You can create a folder within a directory by clicking the 'Create Dir' button located to the right of each folder. For example, the 'Create Dir' button in the top-right corner allows you to create a folder in the main directory.

4.4.2 Delete Files & Folders

You can delete a file or folder by clicking the 'Delete' or 'Delete Dir' button to the right of each file or folder. Please note that clicking 'Delete Dir' will remove the folder along with all its contents.

4.4.3 Rename Files & Folders

You can rename a file or folder by clicking the 'Rename' button next to each file or folder.

5 Troubleshooting & Support

5.1 Special Considerations

There is an issue with the right button below the screen, as shown in the figure below. It may be accidentally triggered if the wires connected to it are moved. The likely cause is a loose connection between the wire and the 3.3V input.



5.2 Support

If you need assistance on anything regarding this toy please contact Mr.Zhang by the following email: hghan086@uottawa.ca or Lenish Vaghasiya: lvagh035@uottawa.ca. Please include what is the problem and a picture of the screen and the microcontroller.

6 Product Documentation

6.1 Electrical System

6.1.1 BOM (Bill of Materials)

1. 1 x [USB Micro-B Breakout Board PID: 1833](#) – 1.95 USD
2. 1 x [2.2" 18-bit color TFT LCD display with microSD card breakout - EYESPI Connector PID: 1480](#) – 24.95 USD
3. 1 x [EYESPI Cable - 18 Pin 200mm long Flex PCB \(FPC\) A-B type PID: 5240](#) – 0.95 USD
4. 1 x [Adafruit EYESPI Breakout Board - 18 Pin FPC Connector PID: 5613](#) – 1.95 USD
5. 1 x [Adafruit ESP32-S3 Feather with STEMMA QT / Qwiic - 8MB Flash No PSRAM PID: 5323](#) – 17.50 USD
6. 2 x [Breadboard Half Board](#) – 5 CAD
7. 2 x [white 12mm Momentary On Off Reset Push Button](#) – 1.5 CAD
8. 2 x [Micro Tactile Button \(6mm\)](#) – 0.5 CAD
9. DHL Express Worldwide – 13.20 USD (Split by Team B)
10. Duty Free Fees – 18.64 CAD (Split by Team B)
11. 1 x [MicroSD SPI or SDIO Card Breakout Board](#) – 5.14 CAD
12. 1 x [32GB 3D MICROSD CARD](#) – 19.70 CAD
13. SHIPPING – 8 CAD
14. HST - 4.27 CAD
15. 1 x [Jumper Cables \(pack of 10\)](#) – 1 CAD
16. 1 x [5FT HOOK-UP WIRE 22AWG \(Black\)](#) – 1.6 CAD
17. 1 x [5FT HOOK-UP WIRE 22AWG \(Red\)](#) – 1.6 CAD

Sub-total: 55.77 USD + 73.95 CAD

Discount Coupon: Welcome: -4.73 USD

Total: 150.82 CAD

6.1.2 Equipment list

1. A Soldering Machine
2. A wire cutter

6.1.3 Instructions

Solder all the pins of the microSD card breakout board following this [instruction](#). The instruction is for the screen however they work all the same and please do not solder the pin for the screen since we will use EYESPI cable instead.

Then connect all the pins to the microcontroller following the ECE schematics shown in below figure.

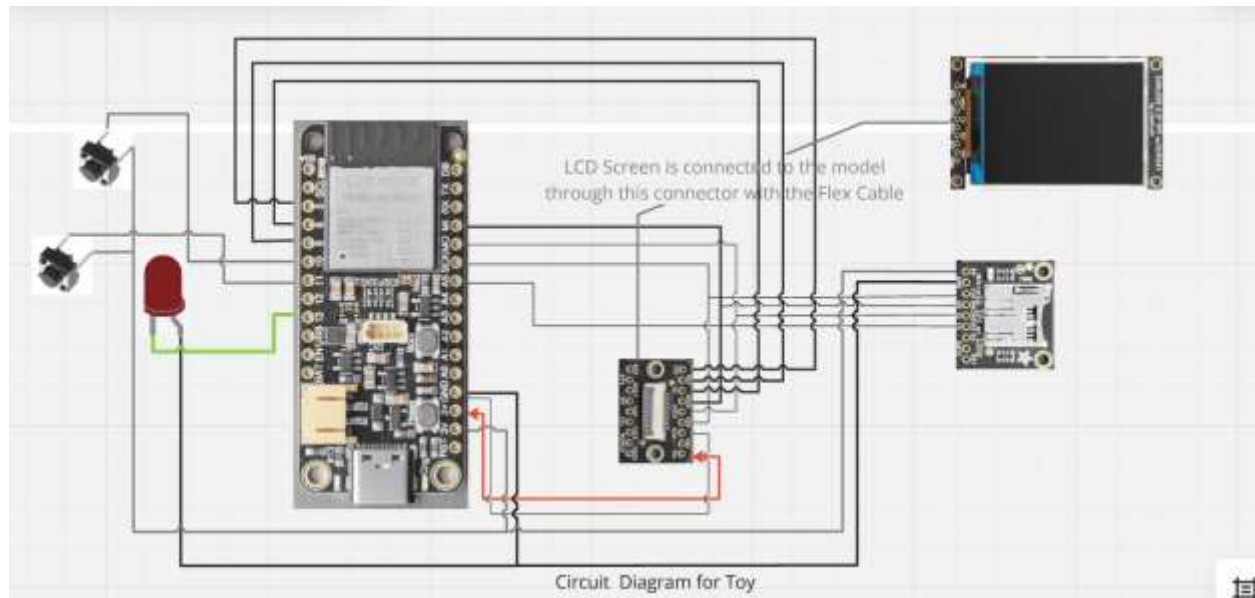


Figure 9 Circuit Diagram

6.2 Software System

6.2.1 Equipment list

1. A computer with Arduino IDE installed

6.2.2 Instructions

Follow this [instruction](#) to set up the environment into your computer. Add all necessary libraries that is suggested in the 'include' part of the code. If you are not familiar with how to add the library into Arduino IDE follow this [instruction](#). Then download our code and open it with Arduino IDE. Connect your microcontroller with the computer with a type-c cable good for data synchronization and then click upload in Arduino IDE. When the Arduino IDE told you the program is uploaded, click the 'Reset' button in the microcontroller.

6.3 Mechanical System

6.3.1 Equipment list

1. A computer with Solid works installed
2. Ultimaker Cura application
3. 3D printer

6.3.2 Instructions

First step is to install solid works software on the computer. This software will be used to design the parts and assembly for the toy.

The next step after designing in SolidWorks is to create a profile on the Ultimaker Cura website and download the application. This software will sync with the 3D printer in the Makers Lab to print your design. Once you have downloaded the application, open your SolidWorks design file within Ultimaker Cura app. From there, you can set your desired print quality and specifications. After configuring your desired specifications, slice the design using the app and save it to a removable storage device, such as a memory flash drive. The estimated printing time will be displayed in the Ultimaker Cura app once slicing is complete. Finally, insert the flash drive into the 3D printer, select your saved design, and begin the printing process.

Once the final design is crafted, it's time to bring it to life using the 3D printer! The machine requires about 10 minutes to heat up, building anticipation for the exciting moment ahead. After printing wraps up, it cools down for another 10 minutes, ensuring everything is just right. When the moment arrives, you can effortlessly lift your design from the machine, marveling at the transformation from digital design to a tangible masterpiece!

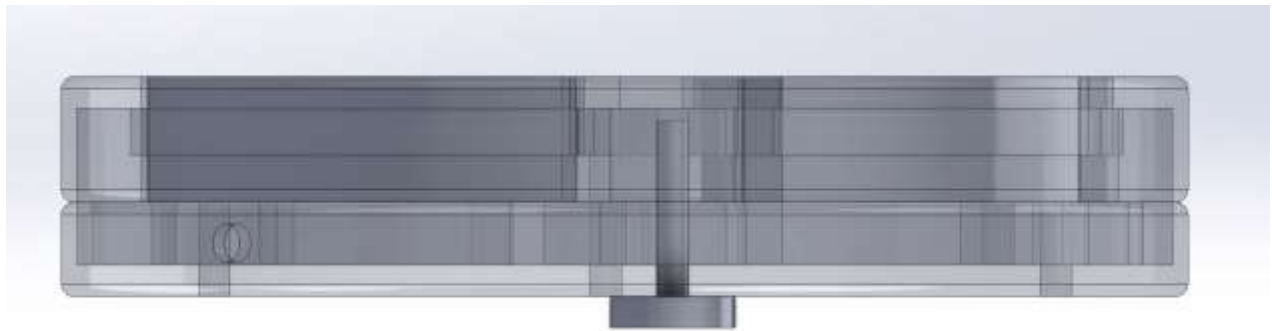
The device has a square center for the screen and 4(four) button arc holes.



Both top and base is held together with 4(four) screws around the base.



This screw will pass through the base and join in the top

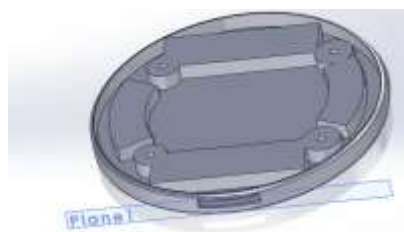


Put the screen in the middle box and push buttons to the circles underneath it. Put two springs between each of the side buttons. Finally, properly put the two parts together and put screens in from the lower part to hold the two parts together

The button has side jaws to hold it in place and screw sitting on the base so it can bounce upward and downward



The wires pass through the inner walls of the toy and exit through a rectangular hole on the base.



6.4 Testing & Validation

6.4.1 Prototype Test

#	Metric	Imp	Unit	Comment
1	Number of Games	1	Numeric Rating	Rating equal to number of games owns by the pad
2	Game Functionality	1	Numeric Rating	Rating equal to number of games function as instructed
3	Dimension (Size)	1	cm*cm	Diameter*Height

4	Weight	2	Gram	/
5	Material	2	Numeric Rating	1 for using PLA-free plastic, 0 for not
6	Comfort Level for Using the Pad	2	Numeric Rating	Rate from 0 to 10. Higher value for higher comfort level
7	Usability of the web	1	Numeric Rating	Rate from 0 to 10. Higher value for higher usability
8	Button Size	3	Centimeter	/
9	Button Function	3	Numeric Rating	1 for all buttons function correctly, 0 for not
10	Screen Size	2	inches	/
11	Start time	2	Second	/
12	Game loading time	2	Second	/
13	Response time	2	Second	/
14	Safety Level (Outer shell Design)	1	Numeric Rating	Rate from 0 to 10. Higher value for higher safety level
15	Texture of outer shell	2	Numeric Rating	Rate from 0 to 10. Higher value for better texture
16	Durability of outer shell	2	Numeric Rating	Rate from 0 to 10. Higher value for better durability
17	Functionality Test on Cloud Storage	1	Numeric Rating	1 for all games stored in cloud and 0 for not
18	Functionality Test on	1	Numeric Rating	1 for able to update firmware wirelessly and 0 for not

	update of firmware wirelessly			
19	Functionality Test on uploading files	1	Numeric Rating	1 for able to upload files to SD card through web app and 0 for not
20	Functionality Test on viewing files	1	Numeric Rating	1 for able to view files in SD card through web app and 0 for not

Table 2 List of Test Cases

6.4.2 Test Results

#	Metric	Target Specification	Final Test Results	Comment
1	Number of Games	10	2	Counting number & Navigate through Alphabet
2	Game Functionality	10	2	/
3	Dimension (Size)	20cm*5cm	18.7cm*3.5cm	Within target size
4	Weight	500g	/	Not sure of the exact weight but holdable for young kids.
5	Material	1	1	PLA Plastic is used for 3D printing in makerspace
6	Comfort Level for Using the Pad	8/10	6.8/10	Not bad. But numbers of volunteer mentioned use of

				button is bad.
7	Usability of the web	8/10	8.3/10	Easy to use. User complained with few buttons don't have functionality. One father of a kid complained it might be too hard for kids.
8	Button Size	1.5 cm ²	12mm Diameter	Big enough for child
9	Button Function	1	1	/
10	Screen Size	5 inches	2'2 inches	/
11	Start time	5 seconds	3 mins	It can start the game within 2 seconds. But the opening of web app and loading games take a long period of time.
12	Game loading time	15 seconds	20 seconds	/
13	Response time	100 milliseconds	/	The response time is acceptable
14	Safety Level (Outer shell Design)	8/10	7.4/10	Some edges are not rounded, and the box inside can show wires which makes our volunteer felt insecure
15	Texture of outer shell	8/10	6.7/10	/
16	Durability of outer shell	8/10	6.1/10	/
17	Functionality Test on Cloud Storage	1	1	/

18	Functionality Test on update of firmware wirelessly	1	1	/
19	Functionality Test on uploading files	1	1	
20	Functionality test on viewing files	1	1	
21	File uploading time	5-30 seconds	/	Depend on the file size. Files under 10 mb can be uploaded within 20 seconds.

Table 3 Average Test Results

For tests (6), (7), (14), (15), and (16), we collected feedback from ten users and calculated the average response. The results of other tests are consistent and unlikely to vary significantly with different testers. For the aforementioned tests, the recorded results reflect the average feedback. The testers, aged between 4 and 43 years old with an average age of 25.5, included 7 males and 3 females.

7 Conclusions and Recommendations for Future Work

7.1 Conclusion

To conclude with, this user manual guide will provide an individual to get familiar with the product and how to use it. Moreover, this guide provides a brief overview of the toy, how to get started with the toy and also how to get start to build the same exact product from the scratch. Also, it elaborates on the system use on what kind of features that has been implemented and how an individual can access them. In addition, the whole build process has been elaborated for the new production of the toy. At the end, List of material, cost of the material, equipment list and brief instruction is also given for seamless understanding of the product.

7.2 Future Recommendations

This prototype still has several issues to address. First, the firmware update process (uploading a game) takes nearly a minute, despite the code being only a few hundred KB. Second, using SDIO for data transfer to the SD card would be faster than the current SPI method. Third, the layout of the web app, especially the file management page, is poorly designed and difficult for users without electronics experience. Additionally, the Wi-Fi configuration process takes too long. The outer shell design also has multiple issues. First, the edges are not rounded, which could potentially harm a child. Second, while PLA plastic is environmentally unfriendly, we chose it for 3D printing since it's free in the makerspace. Third, the screw design is inadequate; because the screws are made of the same material as the other parts, they don't hold the components together firmly. Furthermore, the box in the middle doesn't fit the screen properly, failing to secure it in place. Finally, the side button design is flawed, as the springs lack proper seating, making assembly difficult and causing the buttons to be hard for children to press.

8 Bibliography

8.1 Adafruit Learning Platform: “[Adafruit ES32-S3 Setup](#)”

8.2 Arduino Uno Libraries: “[Libraries to Install](#)”

9 APPENDICES

9.1 APPENDIX I: Design Files

All the relevant document file that are needed to build this product is available on the MakerRepo Project section, for which the link is given below.

Document Name	Document Location and/or URL	Issuance Date
MakerRepo	MakerRepo Link	20 th Nov, 2024

Table 4 Referenced Documents