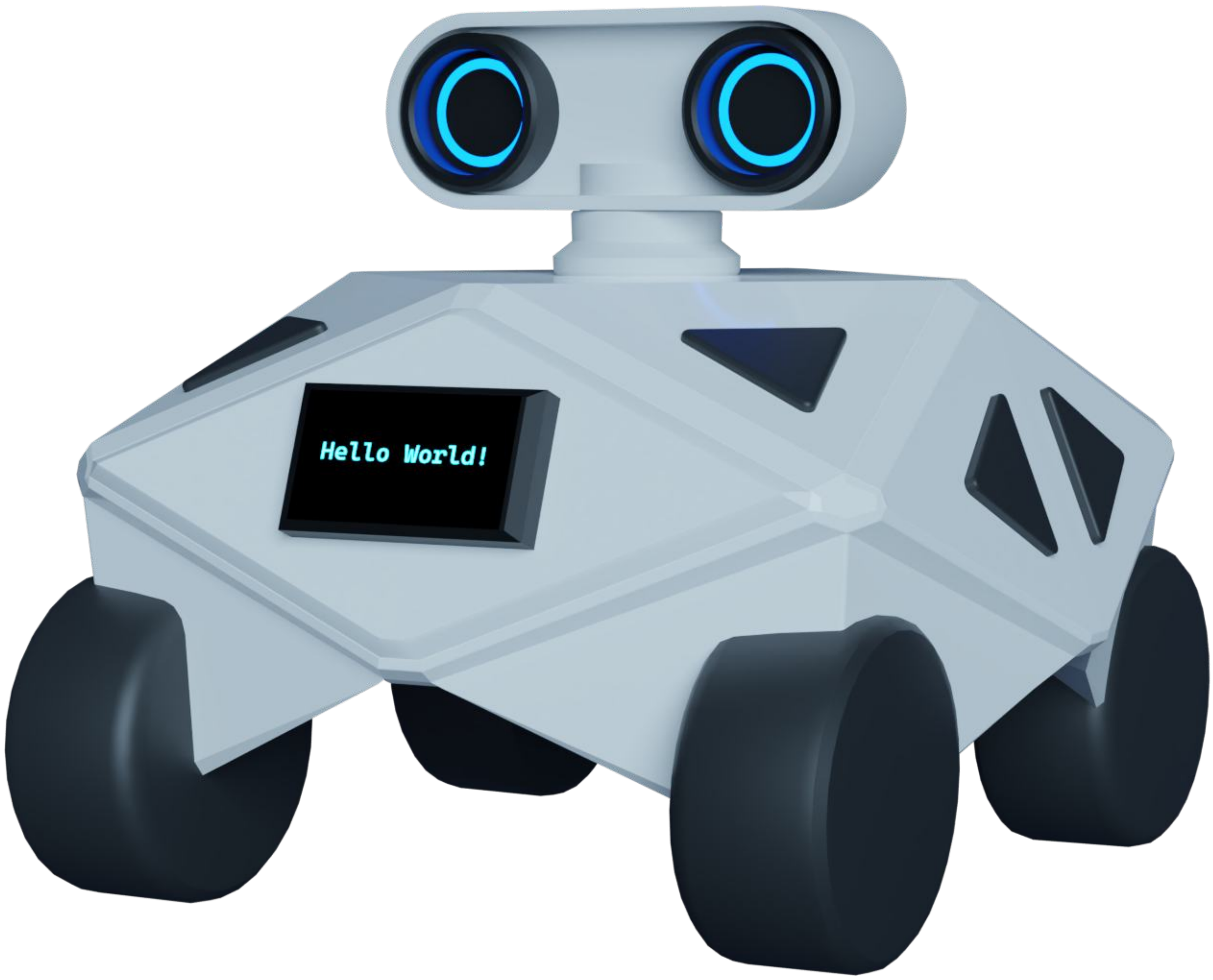

ROBO-LINK

the **CREATIVITY** machine

zask8052, ptam7853, aesp2102, lfor8727

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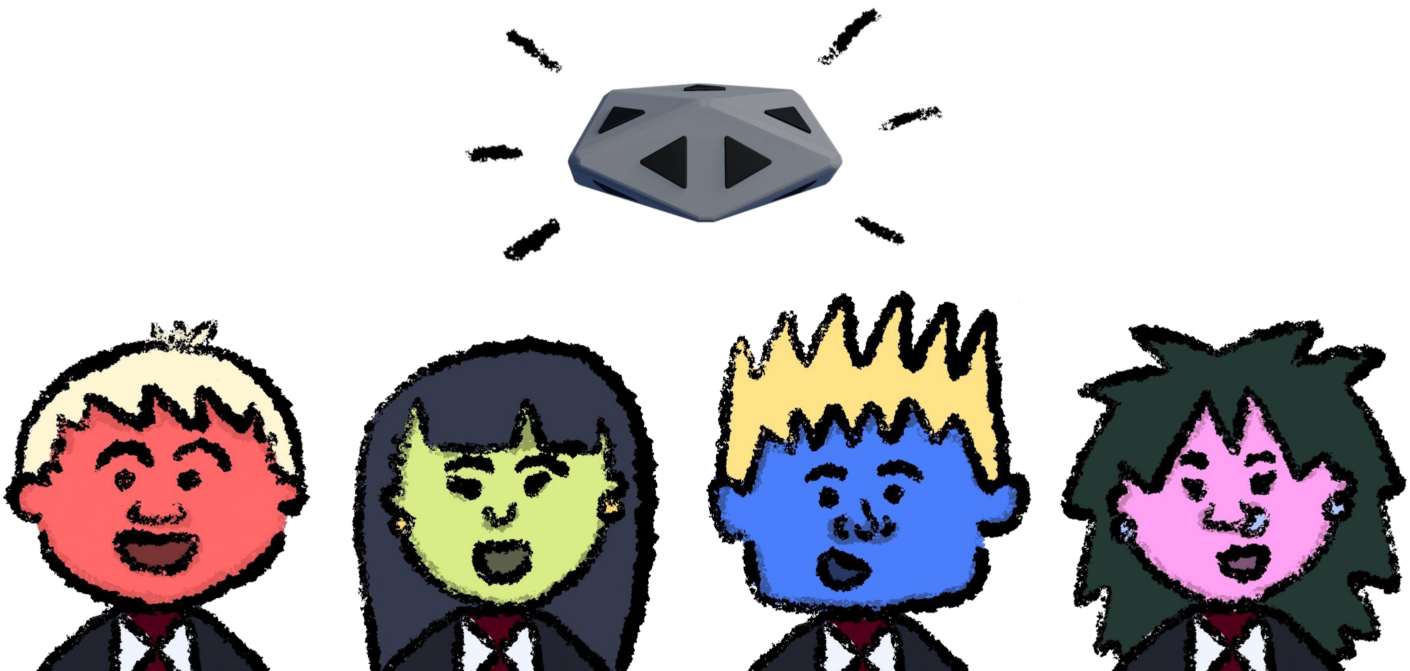


1. Introduction

Background Research

Our motivation for creating Robo-Link was to address the disconnection students experienced during the COVID-19 Lockdowns and the long-lasting impact it had on schools. Through our research we identified feelings of disconnection and anxiety from students transitioning into on-campus classes from online classes.

These feelings have negatively contributed to the overall quality of education in the class room. Our team offers a solution to the lingering effects of prolonged remote learning to current students and teachers affected from this transition, as well as those potentially suffering from future prolonged remote-learning.

Problem Statement

From there we formulated our problem statement:

"Improving social development in on-campus environments after prolonged remote learning."

The Product

Robo-Link is a customisable, modular robotic system designed to reconnect students through collaborative, interactive play. Our aim for Robo-Link is to introduce STEM education to early high school students and teachers through an affordable, hands-on approach that fosters creativity.

Our product has two components, the physical modular body and the Robo-Link companion app. While the physical component fosters collaborative learning, the app introduced basic programming through our block coding system that acts as an entry point into STEM learning.

2. Overview of the Design Process

Summary of Process

The Robo-Link is a culmination of months of planning, researching, prototyping, evaluating, and developing, over and over again until we arrived at our final design. This design is the product of in-depth research into the topic of COVID-19 and education, and as we arrived at the end point, we decided to focus more on increasing the freedom of expression in our product, not just the functionality.

Iteration Process

Designing the Robo-Link was a process filled with many layers of researching, prototyping, evaluating, and developing, until we arrived at our final design. From the beginning, we wanted to design something that fit our chosen design problem, and created a number of **product aims:**

- *Bridge the gap for remote students with hands-on learning activities*
- *Low-cost, easy-access solution for integrated teaching*
- *Target early high school students and their teachers*
- *Address classroom challenges and external factors affecting learning*

We then performed various forms of background research (literature review, competitor analysis, interviews, survey, online ethnography), taking in mind a number of pre-established **research questions** to guide our development:

What impact did remote learning have on students' social interactions and how do these changes influence peer and student relationships? 1

How does the physical learning environment of class rooms impact productive class discussions and engagement 2

How has prolonged remote learning affected student engagement and participation with hands-on learning activities? 3

How has the transition to hybrid learning influenced students' academic performance across different subjects? 4

What challenges did teachers face after the transition from remote to inperson learning? Where new strategies implemented? 5

After conducting our research we analysed our data through an affinity diagram and empathy mapping, with the use of these allowing us to synthesise data points from all of our research methods, into cohesive diagrams, of which we could learn from moving forward, directly aiding in the generation **three key insights** that helped us in developing some ideas for the design:

Flexibility vs Engagement

Many students were dissatisfied by the lack of flexibility on campus learning offered. Students who suffered from long commute times and poor scheduling resulted in poor attendance and engagement.

Importance of Social Connection

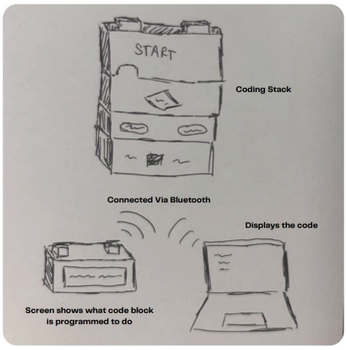
Social connection is vastly important for establishing a healthy learning environment for students.

Student Anxiety After Remote

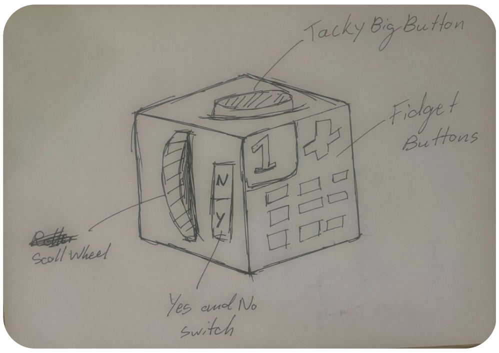
Students identified that asking questions talking to students after remote learning was a considerable concern.

Taking in our product aims, background research, and insights, we utilised the 'Crazy 8s' method to ideate and explore various concepts we felt could be appropriate solutions to the chosen problem.

Alternative Concepts



Idea 1: Code Blocks



Idea 2: Educational Fidget Cube

Idea 3: Virtual Pet

We generated these three ideas, which contended against the Robo-Link for the product we would move forward with in our design process. Using a **decision matrix**, we determined that these ideas did not make the cut for a variety of reasons.

Idea 1: Code Blocks

A physical block coding system that encourages an educational, collaborative learning environment. The blocks are connected to a user's device where they're translated from the physical code blocks into digital blocks where the game or program can be seen and played. **Wasn't chosen as it did not address the issues of anxiety or flexibility.**

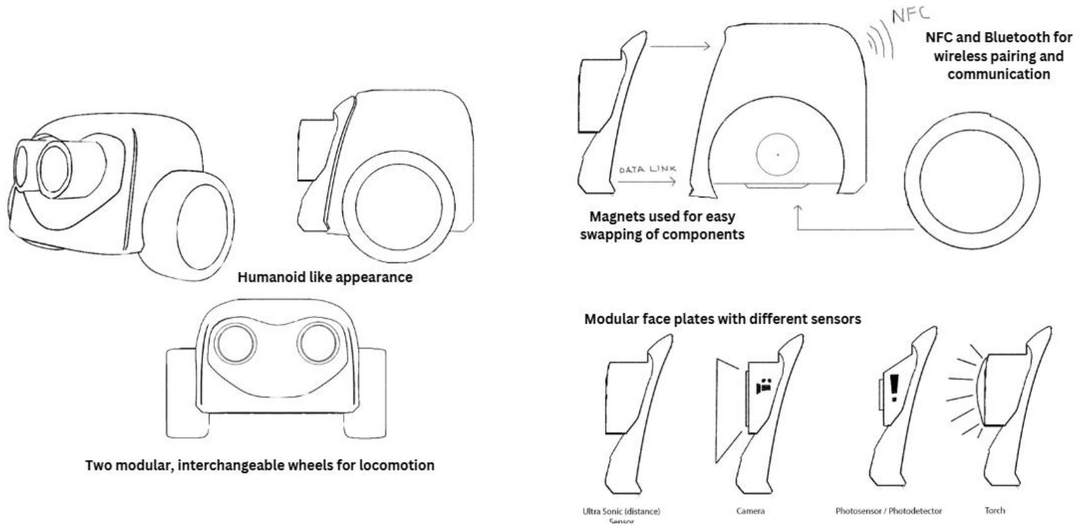
Idea 2: Educational Fidget Cube

A small, portable device with multiple tactile exercises on each side that is intended to aid with focus in pupils. The cube features moving sliders, turnable knobs, or pushable buttons that all incorporate educational features including memory tests, mathematical problems, etc. **Wasn't chosen as it did not address the issues of social connection or engagement.**

Idea 3: Virtual Pets

A virtual pet that students can play with and socialise with each other by adding each other as friends, sending virtual snacks to each other's pets, set up play dates for their pets. **Seemingly fits all criteria for a fitting design, however does not implement any meaningful level of education into its design.**

Why did we choose the Robo-Link?



Original Pitch

> *With a focus on STEM education, "Robo-Link" aims to create a fun and engaging hands-on activity for students. Robo-Link aims to improve social development in class rooms. Through it's modular design, it encourages sharing amongst students to achieve a common goal.*

The Robo-Link was the winner of our decision matrix, as it **encompassed all three of our key insights**, and had the potential to **fulfil all of our product aims.**

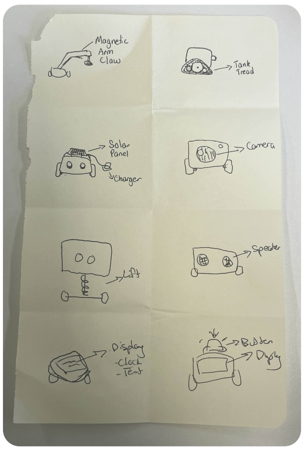
Addressed anxiety and social connection concerns through its focus on inter-student connection.
Addressed engagement issues with providing a physical hands-on activity.

The designs' focus on inter-student connection addressed issues of **anxiety** and **a lack of social connection** in the classroom, and its hands-on nature and modular design addressed issues with **student engagement in learning**, as the modular design encourages sharing and group-thinking.

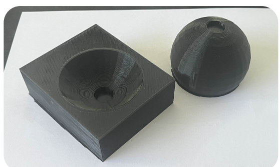
Developing a chosen concept

We developed the chosen concept in a variety of ways, including Sketching, 3D Modelling, 3D Printing, Crazy 8s, and Physical Prototyping (new attachments, base design, level of customisability).

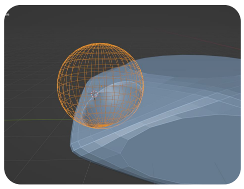
Physical Prototyping



Crazy 8s



3D Printing



3D Modelling

Physical Prototyping

Sketching

Sketched ideas for various attachments for the base, discussing their possible uses, and how relevant they would be to our problem area. During this stage we also began discussing how the base shape of the robot would function, opening up discussions on changing its initial design from a rather simple, cylindrical shape, to a more angular, visually unique one. This process helped us develop our emphasis on **Play** as a major aspect of the learning abilities of the Robo-Link, breeding creativity through limitations (similar to the LEGO Brick System).

3D Modelling

Utilised 3D modelling software Blender to begin forming our initial concepts for the base shape.

3D Printing

As we chose magnets for our attachment system to inter-lock, we wanted to test this method physically. We modelled and 3D printed a test for our magnets, which ended up being a success.

Crazy 8s

Brainstormed ideas for possible attachments for the base model, discussing each ones relevance and analysing its effectiveness in achieving our established product goals. Each attachment also had to be fun.

Physical Prototyping

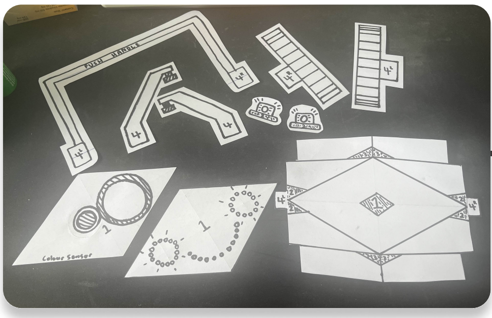
Created a Physical Prototype of the base model, equipped with standard wheels. This was constructed using cardboard, tape, and markers to better understand the design's form in a physical space.

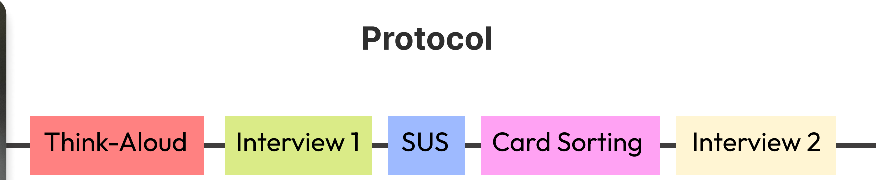
User Testing Fair

As part of our unit, we participated in a User Testing Fair which would allow us to show off our product to our cohort on a wide-scale for the first time. This was a crucial point in the development of the Robo-Link, as the data collected from this testing would directly influence not only the design itself, but our design process as a whole moving forward. We each developed Evaluation Protocols to test both our physical and digital components of the product. Participants included University Students and Teachers.

For the fair, we developed a number of prototypes to be tested, including:

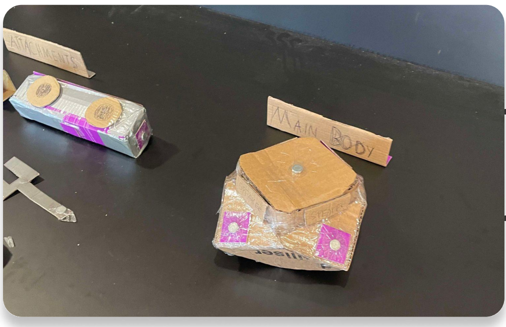
Paper Prototype





This procedure consisted of a 2D paper prototype model representative of the Robo-Link model, as well as a collection of attachments. Users were asked a series of questions to evaluate the relevance of each attachment, and the effectiveness of the attachment system, this prototype covering a key component of the entire concept: customization. This low-fidelity recreation of how users will react with the final product allowed for a simple, easy to understand activity, which was received well by those who tested it, appreciating the level of customisation, and simplicity in its base function.

Cardboard Attachment Prototype



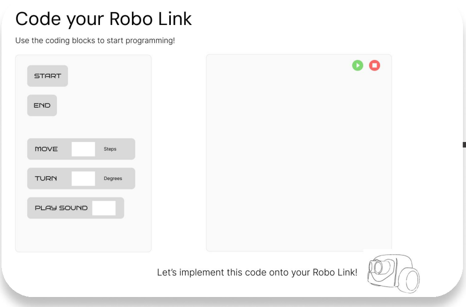
Protocols

Think-Aloud — SUS

Think-Aloud — Co-Design

This procedure consisted of a 3D cardboard model of the Robo-Link model, as well as a collection of attachments. Users were given three suggestions to construct various robot kinds utilising the model and the surrounding attachments, these acted as tests of users' adaptability and creativity within the modular system, as well as an evaluation of Robo-Link's versatility, flexibility, and inventiveness. Responses to the System Usability Scale (SUS) survey on this design were mainly positive. Even though every participant was confident in using the system and said they would buy it, most participants thought the system was unnecessarily complex. However, all participants agreed that the prototype was usually simple to use despite this, and none of them felt the need to ask for external help when using the product. 80% of participants reported not seeing any inconsistent functionality or design in the system, supporting the idea that it was generally coherent and easy to use.

User Interface Prototype



Protocol

Think-Aloud — SUS

This procedure consisted of a digital prototype of the product's User Interface, created to test the functionality of our coding block system, as well as the Information Architecture of our digital component. Users were tasked with various activities such as pairing the Robo-Link to the device, selecting which attachments to assemble onto the Robo-Link, and coding functionality into the Robo-Link. Users found this low-fidelity version of the UI to be quite clunky and difficult to use, stating that the idea was interesting, but was not executed in a way that could be understood and used clearly.

After our testing had concluded, we evaluated each procedure through a wide range of evaluation methods (Affinity Diagram, "How might we?" Statements, Empathy Mapping, Quadrant Graph).

1. Affinity Diagram

Our Affinity Diagram was used to inform us of the possible design flaws and strengths present in our prototypes, and thus, our designs. From this we took away **two** key points:

Users should be able to learn how to use the design through playing with it alone, not by being told

The transition between Physical and Digital should be seamless, flowing naturally through a sharp User Interface

2. “How might we?” Statements

After synthesising our data in an Affinity Diagram, we decided to generate a few “How might we?” statements, in order to further innovate on core needs, or discover any we may be yet to find. These statements were then used to influence our core needs for our final design.

HMW make users feel comfortable during their first time using RoboLink?

HMW allow users of different backgrounds to enjoy RoboLink?

HMW encourage users to experiment freely with RoboLink?

HMW encourage learning through play?

HMW create a UI that makes sense to everyone?

HMW teach users how to use RoboLink through play alone?

HMW tailor specific attachments to specific user wants?

HMW challenge users to make something that’s their own creation?

HMW help to foster social connections between people?

From this we took away **two** key points:

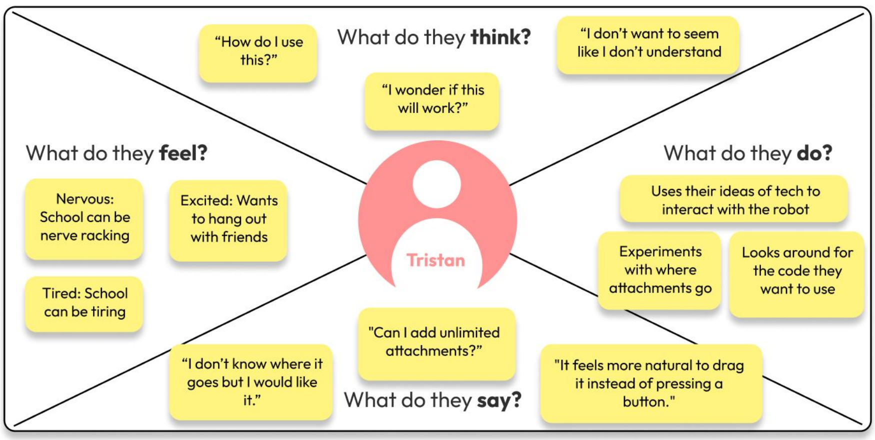
The design should allow users of all backgrounds and languages to use it

The design should encourage users to make connections with others through play

3. Empathy Mapping

We utilised an Empathy Map for our core user, High School Students:

Tristan - High School Student



Through the exploration of what these users Think, Feel, Say, and Do, we were able to bridge more of an understanding of how our users interact with the design.

User needs we discovered from the creation of this Empathy Map include:

The design should cater to those whose assumed knowledge of technology is low

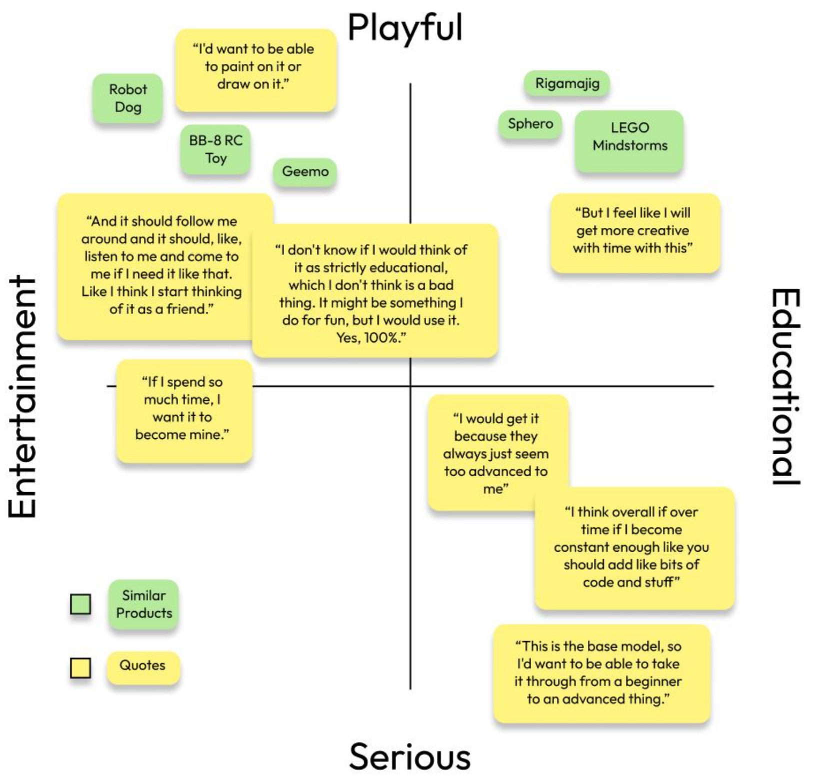
Users should not feel pressured to use RoboLink in a certain way

Users should feel safe to experiment with RoboLink, learning as they do so

The design should be fun and relaxing to use

4. Quadrant Graph

We created a Quadrant Graph to get a better understanding of how relevant our design ideas were to our Problem Area. The scale flows between Entertainment/Education on the Y-axis, and Playful/Serious. We placed both quotes from our Prototype Evaluations, as well as the names of similar systems onto this graph to get a better idea of where we wanted our idea to sit.



Through the implementation of both quotes, and similar products, we discovered a skew leaning heavily towards **play**, with the educational elements of the design fitting more into the 'Serious' side of the quadrant. This is to be expected though, as education is often thought of as a serious endeavour, however, we wanted to try and remove this stigma around Secondary Education, as we feel very strongly that the act of **play** is just as valuable for teens, as it is for children.

This graph helped us focus our design more towards the **play** aspect overall. User needs we discovered include:

The design should have a focus on playfulness, whilst not forgetting its educational purpose

The design should aim to de-stigmatise the act of play as a learning tool for teens

Refined Problem Area

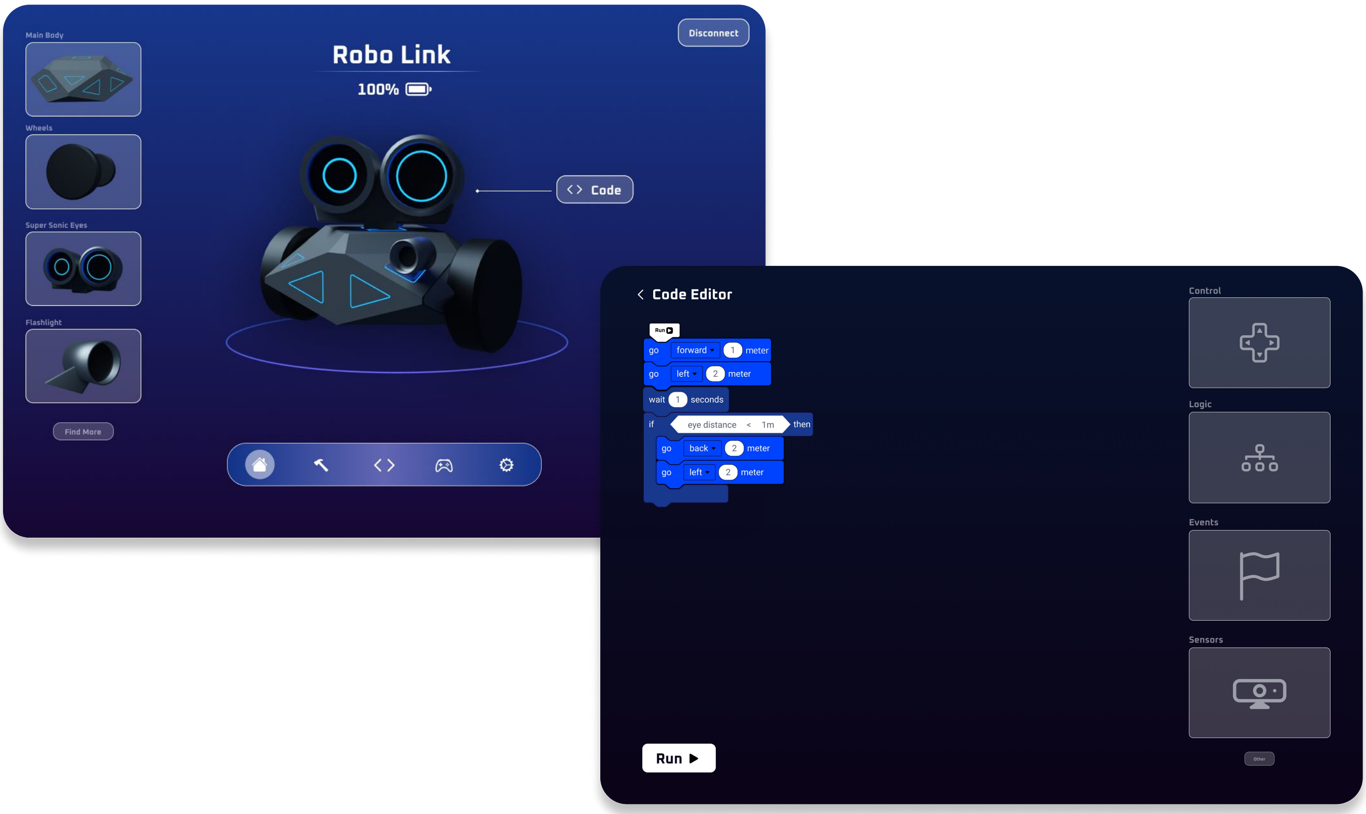
In order to get a better sense of what we were trying to solve moving forward, we chose to refine our Problem Area. We focused in on and reintroduced our problem area of improving social development in on-campus environments after prolonged remote learning.

"Though the use of interactive, hands-on learning activities that promote engagement and cooperation, our system seeks to enable more seamless transitions. Though hands-on-learning, these activities give students a concrete means of re-establishing connections with their teachers and peers while strengthening important STEM concepts. [...] Our approach bridges the gap between remote and in-person education by offering an affordable, interactive learning tool that tackles these intersecting problems. By encouraging active learning, this tool aids in reestablishing participation and teamwork in both contexts. In line with the Sustainable Development Goals (SDGs), it promotes meaningful social interactions while offering flexibility for unforeseen disruptions in the future."

"a more resilient educational system that can adapt to the challenges of hybrid learning environment."

Mid-Fidelity Prototypes

Taking in everything we learned from this design process so far, we created our Mid-Fidelity Prototypes of the Robo-Link model and UI.



In our Mid-Fidelity model, we decided to expand on the design's modular building system by adding more attachment points to each side of the object's body, which was done to give the user more creative freedom. The navigation system was also changed to follow non-linear steps, so users could jump straight between the coding and modifying stages of the user interface, without having to travel through each individual parts of the system. This allowed for ease of access which we found was an important part of why our prototype UI discouraged users initially. The improved UI includes a controller feature directly accessible through the navigation system due to feedback that the user interface did not directly relate to the product enough and they felt like two different products.

Users found that the code editor had limited functionality with the code blocks, which ended up impacting creative freedom and control. To fix this we added four different types of code blocks:

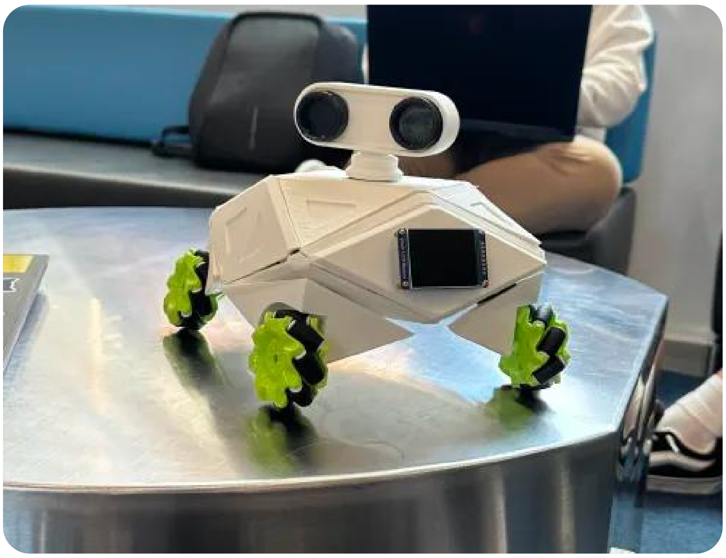
Control: Movement of the robot
Logic: Logical operators e.g. If statements
Events: Different triggers e.g. when colour changes
Sensors: Access information from different attachments e.g. depth sensor / eyes

We also removed the END block because it was too confusing for users and turned the **START** block into "**Run**" which also acts as a button. This was because some users were confused about pressing the green start button seen in the previous prototype.

Final Development Phase

After finishing development on the Mid-Fidelity Prototype, we immediately began tweaking the product, getting it ready for our pitch presentation, where it needed to be in a higher fidelity. The first thing we did in this process was aim to address the main goal missed in the timeframe of our Mid-Fidelity Prototype's development.

A 3D Printed Model of the Robo-Link with functioning magnetic attachments



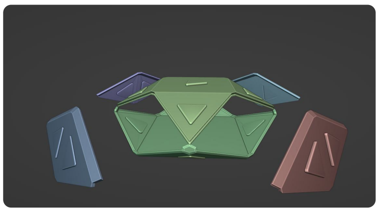
We developed a physical High-Fidelity Prototype using Blender and 3D Printing.

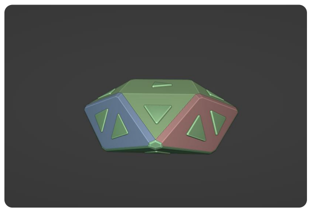
Assembly

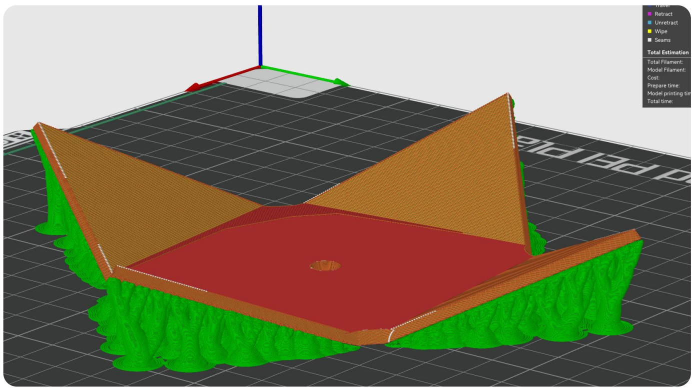
Because the shape of the object has overhangs and angles, we opted to build the object as individual components.

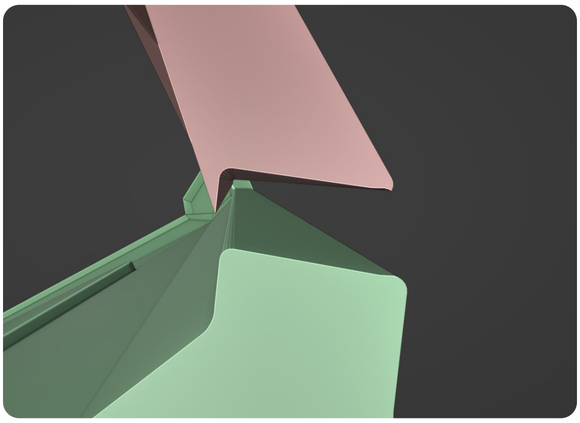
In some cases where prints could not be oriented to avoid overhangs, tree supports were used for any surface over a 30 degree angle.

From our testing, we chose to only use tree supports for prints because they lowered print time, allow for a smoother finish and produce less material waste than linear supports.









The main body was joined together using the tensile strength of PLA plastic. All connections were interlocked with friction (see left).

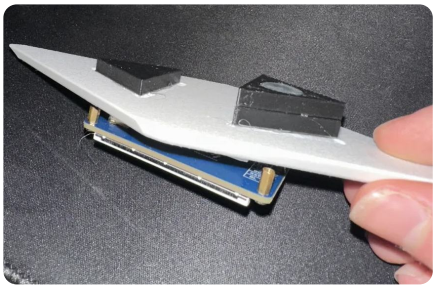
In future, we would like to use threaded screws to hold the components together to be more secure.

Connectors

For the magnetic connection interface we printed triangles in TPU which contained fridge magnets.

We chose TPU because it is more durable and less brittle than PLA. Making it ideal for a connective surface which may constantly experience changes in force and friction e.g. adding / removing attachments.

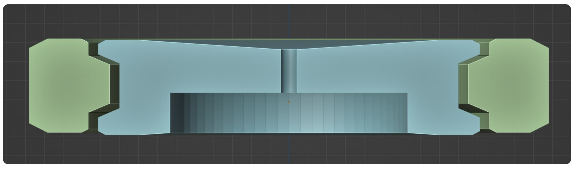
The flexible nature of TPU also made securing the fridge magnets easy and did not require an adhesive.



3D Printed Bearings

Instead of using a manufactured bearing for the head movement, we opted to 3D print the bearing in place. This allowed us to rapidly prototype faster as it let us change the shape and size of the attachment easily.

From our testing, we found a 4mm tolerance was most effective for rotational movement. This was to emulate the servo movement of the head, which was not technically implemented.



Programming

We used a Raspberry Pi Pico as the main microcontroller board for the robot. We wrote a simple microPython script to demonstrate the driving and digital display functionality for the prototype.

For the display, we controlled in via SPI interface using the ST7789 Python library. Motors are controlled via GPIO pins which interface with the DC motor controller board.

```python
from machine import Pin, SPI
import st7789
import time

# Motor control pins
left_motor_forward = Pin(18, Pin.OUT)
left_motor_backward = Pin(19, Pin.OUT)
right_motor_forward = Pin(22, Pin.OUT)
right_motor_backward = Pin(23, Pin.OUT)

# Initialize display
spi = SPI(1, baudrate=20000000, polarity=1, phase=1, sck=Pin(14), mosi=Pin(13))
display = st7789.ST7789(spi, 240, 240, reset=Pin(12, Pin.OUT), dc=Pin(11, Pin.OUT), cs=Pin(10, Pin.OUT), rotation=0)

# Function to display text on the screen
def display_text(text):
    display.fill(st7789.BLACK)  # Clear the display
    display.text(text, 0, 0, st7789.WHITE)  # Display text at the top-left corner
    display.show()

# Motor control functions
def stop():
    left_motor_forward.value(0)
    left_motor_backward.value(0)
    right_motor_forward.value(0)
    right_motor_backward.value(0)
    display_text("Stopped")

def move_forward():
    left_motor_forward.value(1)
    left_motor_backward.value(0)
    right_motor_forward.value(1)
    right_motor_backward.value(0)
    display_text("Moving Forward")

def move_backward():
    left_motor_forward.value(0)
    left_motor_backward.value(1)
    right_motor_forward.value(0)
    right_motor_backward.value(1)
    display_text("Moving Backward")

def turn_left():
    left_motor_forward.value(0)
    left_motor_backward.value(1)
    right_motor_forward.value(1)
    right_motor_backward.value(0)
    display_text("Turning Left")

def turn_right():
    left_motor_forward.value(1)
    left_motor_backward.value(0)
    right_motor_forward.value(0)
    right_motor_backward.value(1)
    display_text("Turning Right")

# Test movement
try:
    while True:
        move_forward()
        time.sleep(2)
        stop()
        time.sleep(1)

        move_backward()
        time.sleep(2)
        stop()
        time.sleep(1)

        turn_left()
        time.sleep(2)
        stop()
        time.sleep(1)

        turn_right()
        time.sleep(2)
        stop()
        time.sleep(1)

except KeyboardInterrupt:
    stop()
```

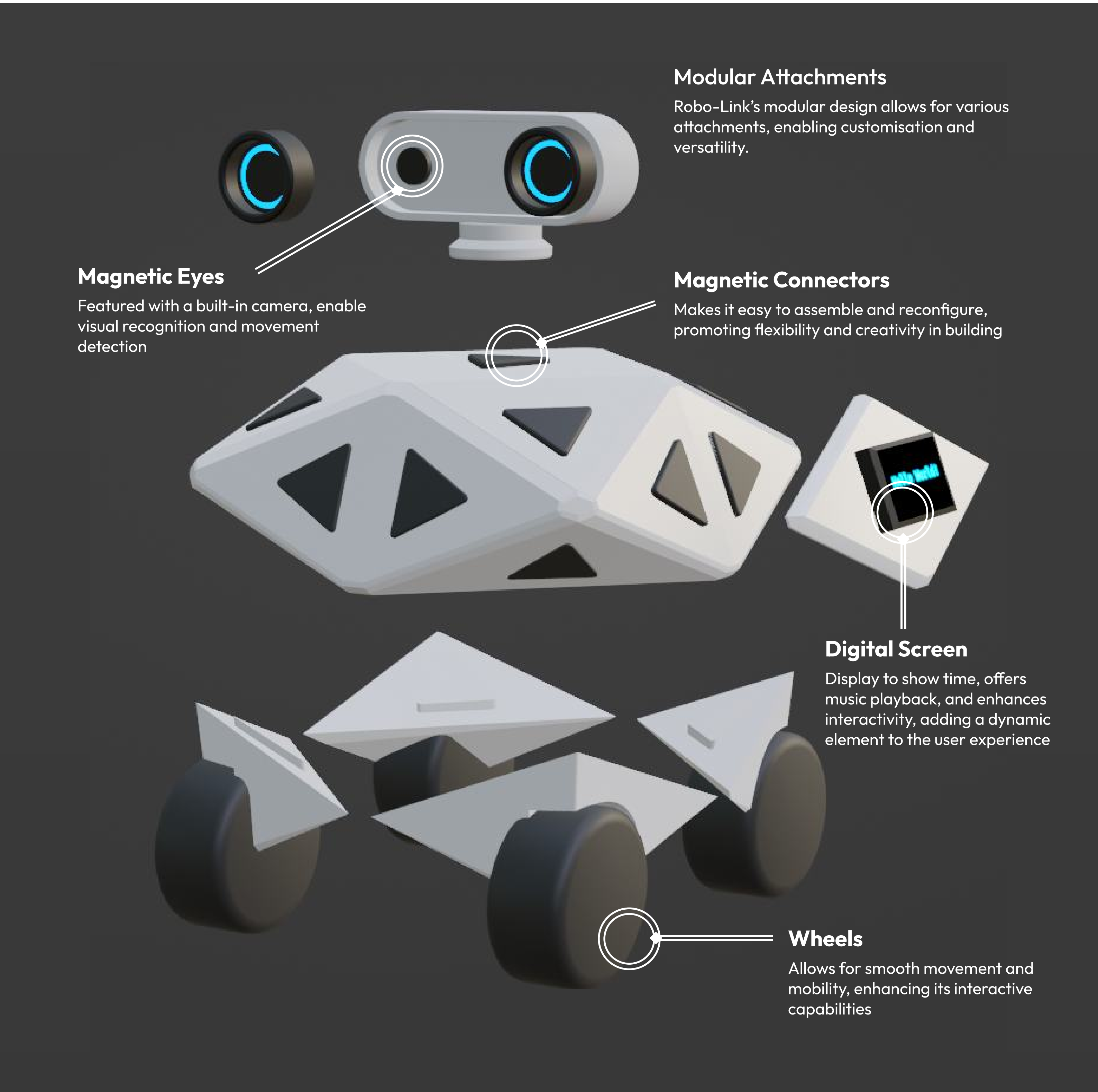
3. Core Functionality

Features:

To optimise engagement and learning outcomes, RoboLink's two features - a physical component and a digital companion app - are made to function in unison.

Physical Features

Student can experiment with real-world applications of STEM principles in a tactile, engaging way thanks to this hands-on components, which promotes cooperation and collaborative problem solving.

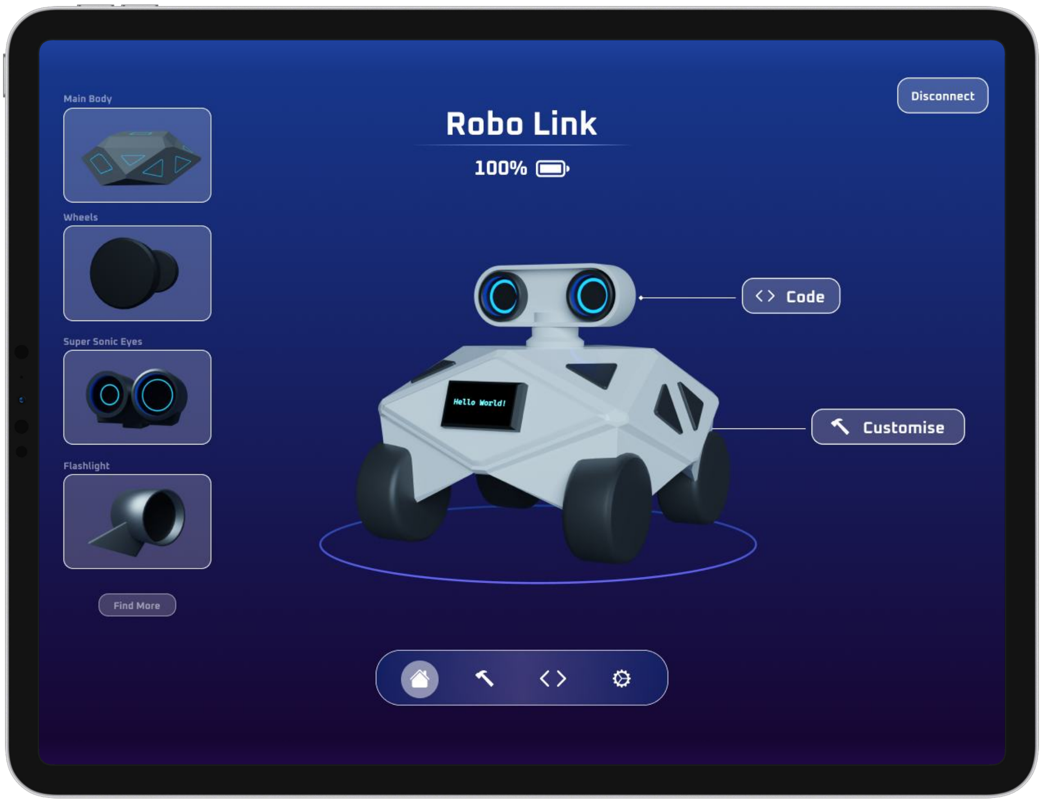


Digital Features

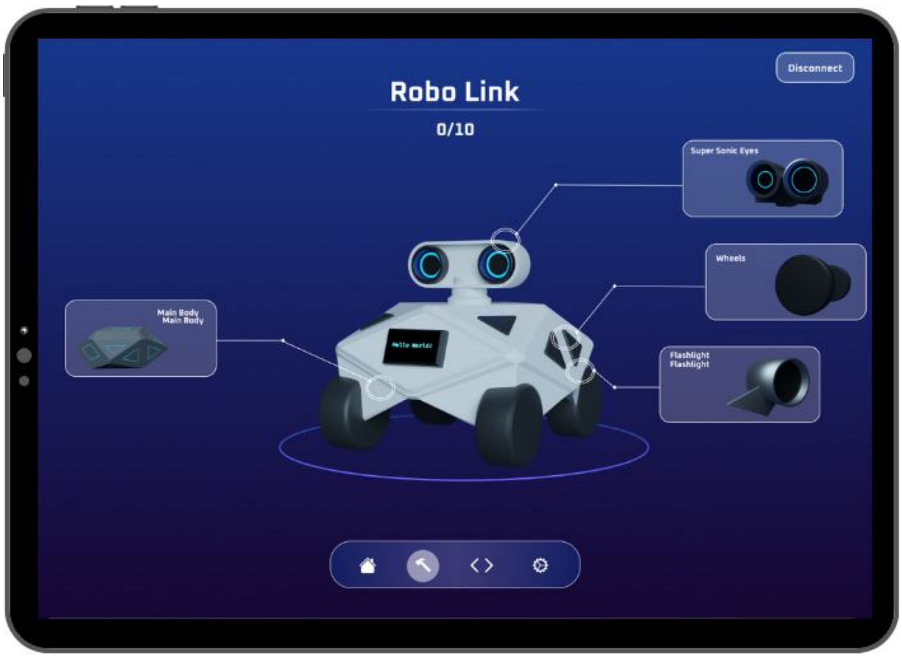
RoboLink's digital features include a companion app with tutorials and social sharing, plus a screen for time display, music, and interactions, enhancing engagement and versatility.

Home Page

The app includes a homepage, providing a quick access to tutorials, challenges, and customisation features, making navigation intuitive and user-friendly.



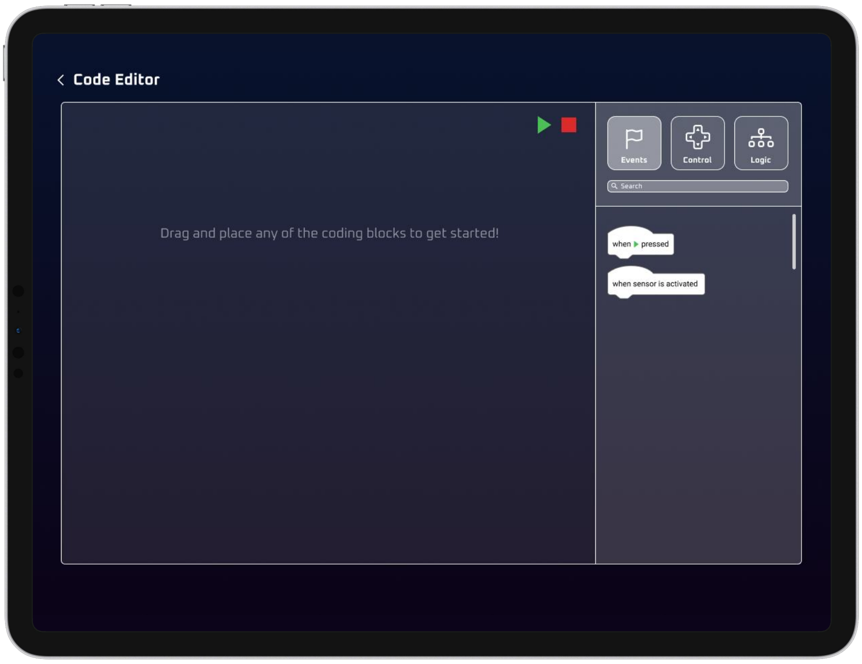
Home Page



Customisation Page

Customisation Page

The app includes a customisation feature which allows the user to visually design RoboLink's modular attachments. Users can directly modify attachments, settings, and code interactions to customise the robot's performance for particular jobs.



Code Editor

Coding Editor

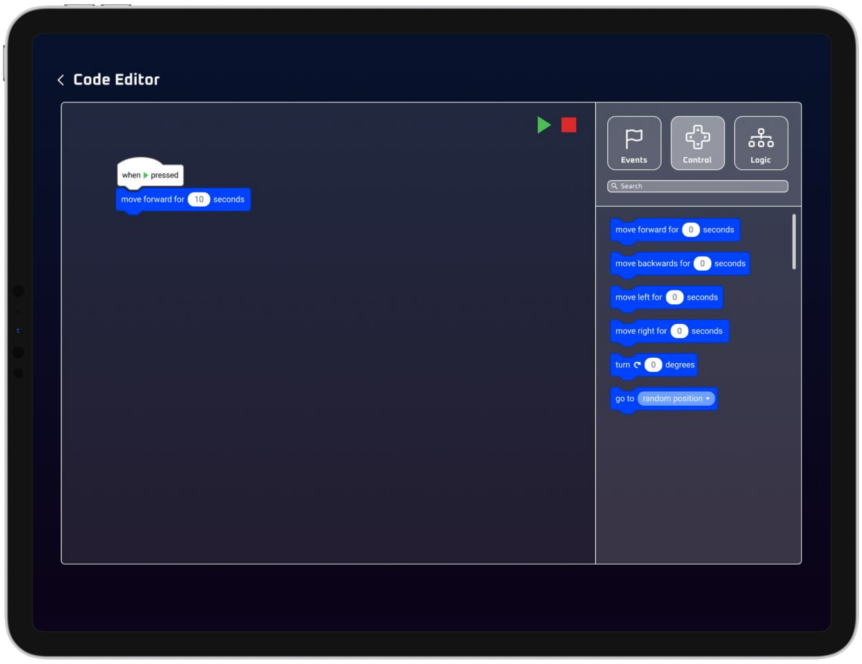
The Coding Editor provides users with the ability to program basic functions.

By giving the ability for users to be able to program their Robo-Link, it fosters a deeper interest in STEM education while keeping it fun and engaging.

Block Coding System

The use of a Block Coding system is to familiarise users with coding fundamentals without the complex nature of traditional text-based coding.

The drag and drop pre-made code blocks are essential in keeping the programming entry-level.



Code Editor (Block Coding)

Hardware/Software Requirements

In order to use the Physical Component of Robo-Link, users do not have to use any external means, unless they want to expand their use of the product with the digital companion app. In the context of a school, faculty would have to order the Robo-Link for use in the classroom.

In order to interact with the digital companion app. Users are required to have a digital device such as an iPad. This enables the users to interact further with RoboLink which can enable them to dive deeper into STEM, as it allows them to personally customise each attachment, and build on their knowledge of STEM and robotics.

4. Known issues & Future work/ versions.

Print Quality

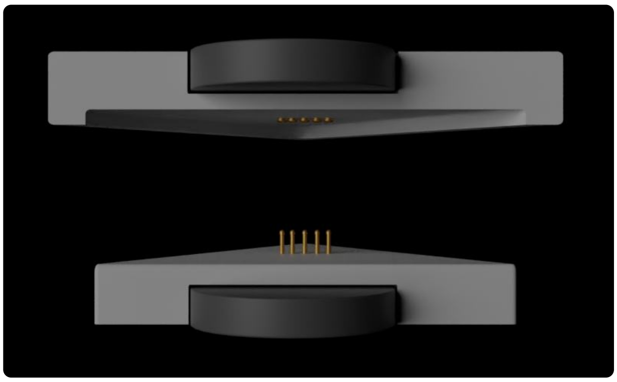
Due to time constraints a lot of prints suffered from layer shift. This could be corrected at the slicing phase by reducing the print speed the of the model and using more support material.

Other printing methods could be used to improve quality e.g. SLA printing because they can produce highly dimensional accuracy

Remove Cables Using Magnetic Connectors

Our initial design for the magnetic interface was going to provide power and data through small push pins on each magnetic surface. This would be essential for a low barrier of entry for users, but we did not technically execute this idea due to its complexity.

Not only would it require precision manufacturing for the metal pins, each component may need its own integrated circuit to correctly identify each component and its requirements.



Screwed Assembly

Printed components could be held together with threaded screws rather using friction and tension. This would help create a more robust and secure physical prototype. This is a key area of concern because our product is indented for an younger audience, who may be more likely to break the product.

Additional Attachments

Due to time constraints, the attachment selection is limit. We only focused on designing 3 of our many concepts of attachments (motors, graphic display and eye sensor). Having additional attachments would greatly benefit the creative control and freedom of our design, which we outlined to be essential for tackling our design problem.

If we were to further develop this idea, we would work on creating more sensor modules for the robot. E.g. an IR / LED sensor which can detect white vs black lines, an ultra sonic distance sensor and camera. These sensor modules would allow for more interactivity and dynamic play with the robot e.g. designing a robot to avoid obstacles and follow a black and white line on the ground.

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