SASTA OLIPHANT SCIENCE AWARDS

SOUTH AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Prize Winner

Programming, Apps & Robotics

Year 3-4

Chengyuan Yu

Linden Park Primary School

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Australian Government
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SASTA South Australian Science Teachers Association

Reduce, Reuse, Recycle and Recover to Save the Environment (4RSE)

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0319-094

The issue

According to the United Nations Environment Programme[1], every year the whole world generates more than 2 billion tonnes of garbage. By 2050 we would have more than 10 billion people and also by then we would create about 3.4 billion tonnes of garbage per year. People think that when they put garbage in the bin then it magically disappears, but they are wrong or they have forgotten what they learned in primary school.

Photo by Tom Fisk from Pexels

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The truth is:

- When garbage decomposes it produces methane, a greenhouse gas that is 28 times more potent than carbon dioxide and a major accelerator of climate change.
- Open waste burning causes the release of black carbon that penetrates deep into the lungs and bloodstreams with critical health impacts. About 7 million people die every year from exposure to it.
- High income countries contribute about 34% of the waste produced worldwide, even though they only represent 16 percent of the world's population.

My solution

My idea is to discourage residents from creating lots of waste that ends up in landfills. I am doing this by charging a fee depending on how much the waste weighs. Because when people need to pay fees they will think twice before dumping anything into the bin. This will encourage people to reduce waste by reducing consumption, reusing items, recycling materials and

[1] https://www.unep.org/news-and-stories/story/waste-not-heavy-toll-our-trash (accessed on 27 June 2021).

recovering resources.The ultimate result is to save the environment by reducing human waste.

I have developed a prototype of a bin lifting arm that demonstrates a bin being weighed and the house owner being charged by the weight of the garbage. My solution can be scaled up and used on real garbage trucks. Please watch my video demonstration.

Scan to watch my demonstration	Click to watch my demonstration
	https://youtu.be/GMW85uvoS48

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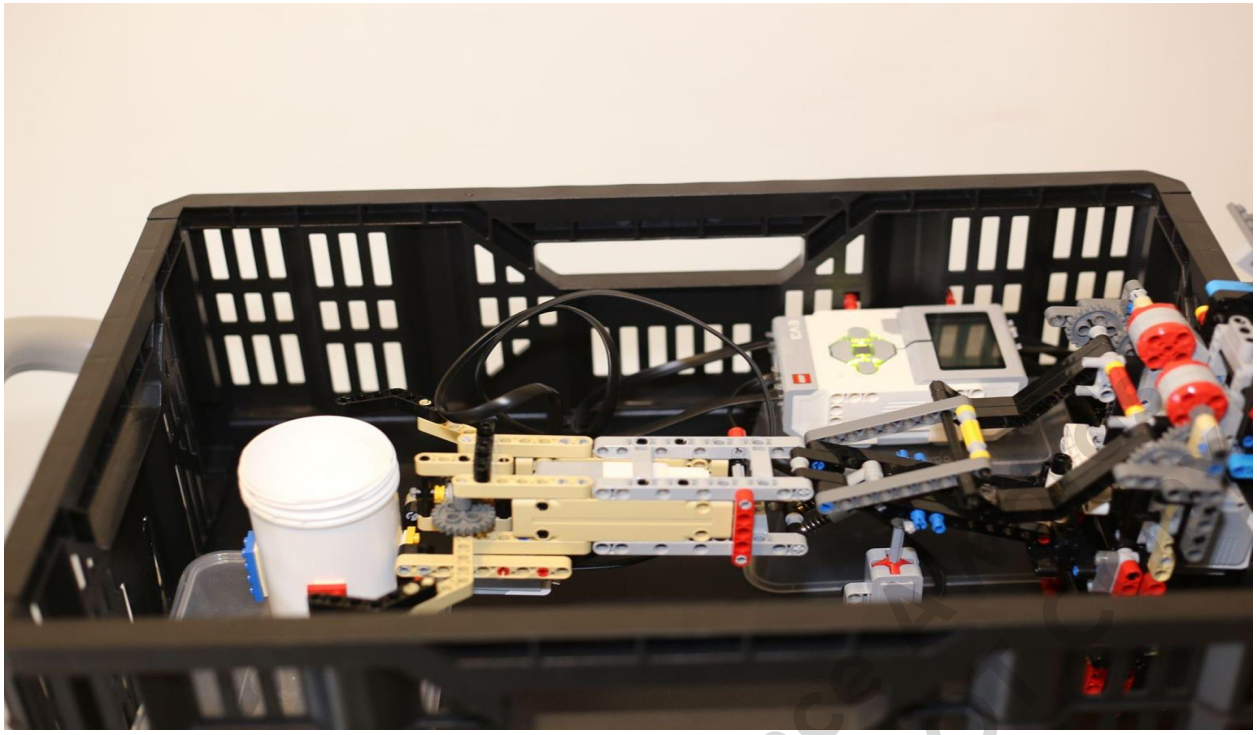
How I got the idea

I have been learning coding since I was 6 years old. I got my Lego Mindstorm EV3 when I was 8 years old and I started coding in Python under my dad's guidance at the same year. We did a few projects together including a robot that could avoid obstacles, a website for myself and an app for my rugby club.

About two months ago, my dad asked me if I wanted to join the 2021 Oliphant Science Competition. I said yes. I understood that my parents could not do anything but guide me through. For the next few days I was thinking about a project to do. Then one day when I saw the garbage truck picking up our bins, a question suddenly came to my mind. I asked my dad, 'Dad, how much do you pay the council to get the bins emptied?' He said he doesn't know how much because he pays all of the fees together with the bins service but he also said: 'I don't know how much I have to pay for it but I do know that everyone pays the council quarterly.' Then I asked, 'So does that mean that it doesn't matter if the bin is full or not but people still have to pay the same price?' He said yes. I thought it is unfair to charge a fee without considering the weight and that people don't care how much waste they produce.

After school I had an idea that I could make a garbage truck arm that would weigh and charge the bin owner by the weight of the waste. My parents thought it was a good idea, so I started working on it. If my idea was implemented then it would make people think twice before wasting because it charges by the weight. Below is a picture of the finished prototype:



What was required for this project

1. Lego Mindstorms EV3
    1.1. One Lego Mindstorms EV3 brick
    1.2. One Touch Sensor
    1.3. One Color Sensor
    1.4. One Ultrasonic Sensor
    1.5. Two Large Motors
    1.6. One Medium Motor
    1.7. Lots of Lego technic pieces
2. Six AA rechargeable batteries (with a battery charger)
3. One rigid large plastic box
4. A small old plastic vitamin bottle (to represent a bin)
5. A computer
6. Visual Studio Code
7. USB Cable
8. Micro SD card (new)
9. Round lead fishing sinkers or any other small heavy balls to represent waste

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How I made it

1. Making the arm

1.1. First I drew sketches of the arm on a sketchbook (see Figure 1). Then I took out my Lego Mindstorms EV3 and started building what I sketched.

1.2. I got 2 gears and a worm gear (see Figure 2), and 2 claws and a medium motor (see Figure 3). These are parts of my grabbing system. It took me a long time to figure out how to make the worm gear to stay in one place. The problem was that every time I turned the shaft right the worm gear went forward, and every time I turned left it went backwards. It did not turn the gear wheels.

1.3. I put bars in various places to try to stop the bar from going forward or backward and made sure that the worm gear won't pop out. After a lot of tries I got it working.

1.4. Once I figured out how to make the worm gear to stay in one place, I started building a stronger and lighter structure using box frames (see Figure 4).

2. Making the lifting motors

2.1. Again, I first used my sketches (see Figure 5) to build the lifting mechanism. It didn't work because it didn't have enough force to lift the arm up.

2.2. Then I googled how to increase motor force and found inspiration from the video called *What's a Gear To Do?*[2] by Children's Museum Houston. So I used gears to gear down to increase force even though it will slow down the lifting machine.

2.3. I first made a gearbox that would increase the force by 3 times. But it did not have enough force to lift up the arm. So I added more gears to increase the force by another 3 times. To add more gears I had to turn the motors around and rebuild the structure holding the motors. It increased the force by 9 times. This was enough force for it to lift up the arm.

2.4. The gear ratios:

- 8 tooth driver gear wheel #1 to turns a 24 tooth follower gear wheel #1.
- 24 tooth follower gear #1 is connected by a shaft to another 8 tooth gear #2 making it a driver gear.
- The 8 tooth driver gear #2 is driving the 24 tooth follower gear #2.
- The 24 tooth follower gear#2 drives a long shaft which is connected to the lifting arms.

[2] https://www.youtube.com/watch?v=vX1-9C58-VM (accessed on 5 June 2021)

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- The force is increased by 3 times then another 3 times makes the force increase 9 times.

3. Adding the weighing system and connecting the arm to the lifting motors

3.1. Because Lego Mindstorms EV3 does not have a weighing sensor, I had to use other items. Then I remembered that normal weighing scales use springs and I could use some.

3.2. From my other Lego technic sets, I got 2 pullback motors to act like springs because they had springs inside so it would work. But it was hard to connect them and they were too heavy.

3.3. After that I remembered that I had 2 Lego springs (see Figure 6) so I used those instead. They were much lighter and easier to connect and disconnect.

3.4. Even though I had springs, I still needed a way to measure the weight. I thought for a while. Then I remembered that I had an Ultrasonic Sensor. After all of that I figured out I could use the Ultrasonic Sensor to see the distance to the ground because the springs will go down on different weights and it will have different distances from the sensor to the box.

3.5. I attached a box frame to make it longer to connect it. Then I attached 4 Lego arms around the box frame to make it wider and longer. Then I attached the arms to the bars that were connected to the gearing system on the lifting motors.

3.6. It works like this:

- The weight in the bin decides how much the bin lifting arm goes down;
- Then using the distance of how much it goes down to calculate the weight.

3.7. It took a long time to get the weighing system to work correctly due to gear slippage, inconsistent spring tension and battery charge. I tested it over 50 times to get an accurate distance range that could be converted to weight.

4. Using Class 3 Lever

4.1. When I tested the bin lifting arm, it was very bulky and had jerky movements because it had to lift up a lot of weight.

4.2. I searched how to lift things easily on Youtube and found a program that was discussing about 3 types of levers[3].

4.3. I watched the video and it concluded as that different types of levers have the fulcrum, load and force in different places. It showed that class 3 levers were the

[3] https://youtu.be/jtk2V0M6k3M

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only one that will work in my system. The solution to this was to add a class 3 lever to reduce the jerky movements (see Figure 7).

4.4. Once I built the class 3 lever, I got another problem. I needed a place where I could connect the force and the fulcrum so the whole movement happens in one smooth movement. I tried connecting the force and the fulcrum in many places and finally I found the correct place. It took me more the 11 times to get it right.

5. Adding the house recognizing sensor or colour sensor

5.1. I used a Colour Sensor because the Lego Mindstorms EV3 does not have a barcode reader. I had to use different colours to represent different houses. In real life we can use barcode sensors to recognise individual houses.

5.2. To get the Colour Sensor working, I had to experiment in many different ways because if I put it too far it might not read any colours or it might read to many colours. Also if I put it too close to the bin it cannot read any colours.

5.3. I first used toy coloured bins to see if the Colour Sensor could recognise the colour of the bin but it did not work because the bins were too shiny and they were not in Lego colours. Then on the next day I printed out some Lego colours and stuck them to an old vitamin bottle to see if the Colour Sensor would sense the coloured paper. It worked but it kept on recognising green as blue. So finally I thought just sticking actual Lego pieces onto the vitamin bottle that was used as a bin.

6. Touch Sensor to stop

6.1. Even though the system was working, it was not accurate when the arm came down due to gear slippage. It was very accurate when going up.

6.2. I experimented with different variables to bring the arm down to the bottom. But it never returned to the starting position.

6.3. To solve this problem I set the arm to keep on going down until the touch sensor gets pressed by the arm.

6.4. If I had another Touch Sensor I would have used it at the top to stop the bin lifting arm when it went up to tip the bin. I couldn't do this because the Lego Mindstorms EV3 kit I have only has one Touch Sensor.

7. Coding

7.1. I did a lot of coding and tested it many times. I read books, websites and watched

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relevent videos[4] on Youtube to solve some coding problems.

7.2. I wrote code seperately in this order:

- I wrote code for the claws to open and close. I had to experiment with many variables to get it open and close correctly to grab the bin. If the bin size changes, I'll have to change the variables.
- I wrote code for the lifting motors to move the arm up and down. I had to drive 2 motors together and I found a specialized command that would drive multiple motors at the same time.
- I wrote code for the Colour Sensor to identify if there is a red, blue, yellow or green bin which represents different households. I had to limit it to 4 colours so if there is no bin then it should not do anything. It also identifies the colour so it can charge a fee to the bin owner.
- I wrote code for the Ultrasonic Sensor to measure the distance to calculate the weight. I had to experiment a lot of times until I could get a range of numbers to calculate the weight.
- I wrote code for the Touch Sensor to stop the arm from going down. I had to put a loop to keep on checking if the touch sensor had been pressed.
- Then I combined the code for the lifting motors and the claws to make them work together.
- Then I combined that code with the code of the Colour Sensor to make sure it will sense the colour and then pick up the bin to dump it.
- Then I put this combined code together with the code for the Ultrasonic Sensor so it will identify the colour, grip the bin, lift it up a bit to measure the distance and calculate the weight, and then dump it.
- After that I added the Touch Sensor code so it will identify the colour, pick up the bin, measure the distance to calculate the weight, dump the bin, and then keep on going down until the arm presses on the Touch Sensor.
- I wrote code for the brick to give warnings such as "to move out of the way to lift", and to tell the colour, the weight and the fee. I made the machine talk because the Lego Mindstorm EV3's screen was to small to display all of the text. It is much easier to hear the machine talk than try to read words off a tiny screen.

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[4] https://youtube.com/playlist?list=PLfZDz4HU7SLzQlsfXlfziaOhODz3eHCGo

- I wrote comments for the code to tell what each line does in English.

7.3. My final piece of code is shown in the next section.

Scan to watch how I built my robot	Click to watch how I built my robot
	https://youtu.be/dFjzQS6WSYA

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Code

```
#!/usr/bin/env pybricks-micropython

#Importing functions and classes
from pybricks.hubs import EV3Brick
from pybricks.ev3devices import (Motor, Touch Sensor, ColorSensor,
InfraredSensor, Ultrasonic Sensor , GyroSensor)
from pybricks.parameters import Port, Stop, Direction, Button, Color
from pybricks.tools import wait, StopWatch, DataLog
from pybricks.robotics import DriveBase
from pybricks.media.ev3dev import SoundFile, ImageFile


# Creating objects
ev3 = EV3Brick() # Lego mindstorm brick

ussensor = Ultrasonic Sensor (Port.S1)
stop_switch = Touch Sensor(Port.S3) # initiate Touch sensor and assign it to
port S3
my_bin = ColorSensor(Port.S4) # initiate Color sensor and assign it to port S4
gear1 = Motor(Port.B) # initiate the first large motor and assign it to port B
gear2 = Motor(Port.C) # initiate the second large motor and assign it to port C
claw = Motor(Port.A) # initiate the one and only medium motor and assign it to
port A

#Code for R4SE
while True: #Starting an infinite loop to keep on checking if the button is
```

```
pressed
    pressed = Button.CENTER in ev3.buttons.pressed() #making a variable that is
assigned to the middle button on the brick
    if pressed == True: # If the middle button is pressed then...
        color = my_bin.color() # assign 'color' to the colorsensor and check the
current color the colorsensor is reading
        if color == Color.YELLOW or color == Color.GREEN or color == Color.BLUE
or color == Color.RED: # If the color is yellow, green, blue or red then...
            ev3.speaker.say('Warning! claws closing') # give a warning
            claw.run_angle(3600, -1250) # Close the claws/Grab the bin
            gt = DriveBase(gear1, gear2, 7, 114) # setting up the motor and
giving requirements for lifting
            ev3.speaker.say('Beware Lifting arm up to weigh')# give a warning
            gt.drive_time(-100, 0, 800 ) # lift the arm a little bit
            wait(3000) # Wait 3 seconds or 3000 milliseconds

            distance = ussensor.distance() # using the Ultrasonic Sensor  to
check the distance of the ground so it can estimate the weight
            color = str(color) # converting color into a string

            if distance > 76: # checking weight and how much
                ev3.speaker.say("{} bin 40 kilograms pay 45 dollars. Consider
reducing waste".format(color)) # tell the weight
            else: # if it is even heavier than say bin 40kg ...
                ev3.speaker.say("{} bin 120 kilograms pay 200 dollars. Stop
destroying the Earth!".format(color)) # tell the weight
            wait(1000) # wait 1.5 seconds

            ev3.speaker.say('Keep out! lifting up for dumping')
            gt.drive_time(-100, 0, 1300 ) # lifting up to dump the garbage
            wait(3000) # Wait 3 seconds or 3000 milliseconds

            switch = stop_switch.pressed()# if the Touch Sensor is pressed then
stop the motor from going more down
            ev3.speaker.say('Move Out of the way! going down')
            while switch == False: # while the Touch Sensor is not bumped
                gt.drive_time(100, 0, 100 )# keep on going down
                switch = stop_switch.pressed()# keep on checking is the Touch
Sensor bumped
            else:# or if the touch sensor is bumped
```

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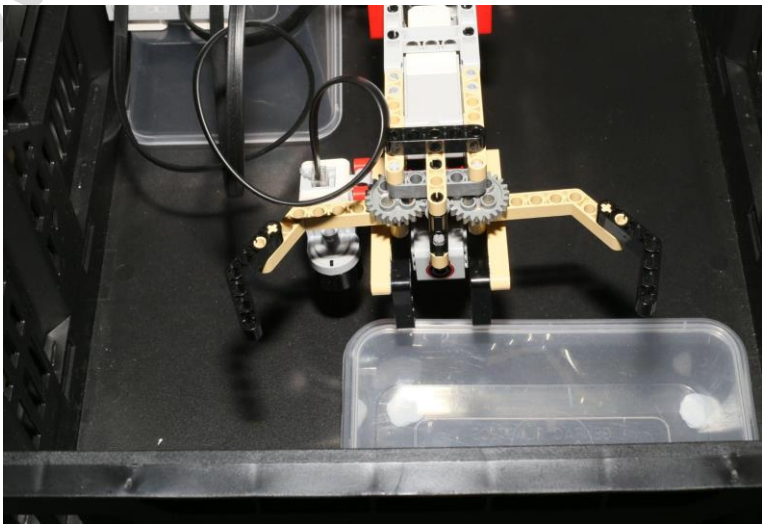
```
                ev3.speaker.beep(2) #make beep sound and because the Touch
Sensor was bumped the while loop broke and it stopped going down
            ev3.speaker.say('No going near! Letting go of bin')# warning sign
            claw.run_angle(3600, 1250) #let go of the bin/open the claws
```

Problems and solutions

The table below summarises the problems I encountered and my solutions:

Problems	Solutions
1. Can't write long programs in the normal Lego Mindstorms EV3 software	Download the EV3 MicroPython MicroSD card image[5] and install it in a microSD card. I write the code in micropython using Visual Studio code.
2. Can't get the claws to close	Use worm gears and gear wheels to open and close the claws. To drive the worm gear I used the Lego Mindstorms EV3 Medium motor. 

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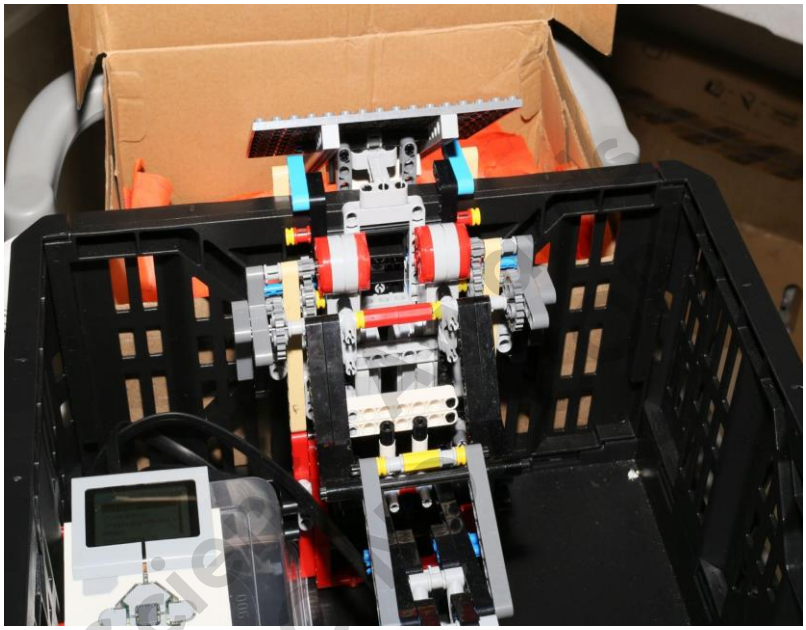
[5]. https://education.lego.com/en-us/product-resources/mindstorms-ev3/teacher-resources/python-for-ev3

Problems	Solutions
3. Arm is too heavy to lift	Use a box frame and a hollow lattice structure to strengthen it and reduce the structure weight. 
4. Not enough force to lift arm up using motors	Use a gearing system to increase force even though it will decrease the speed. 

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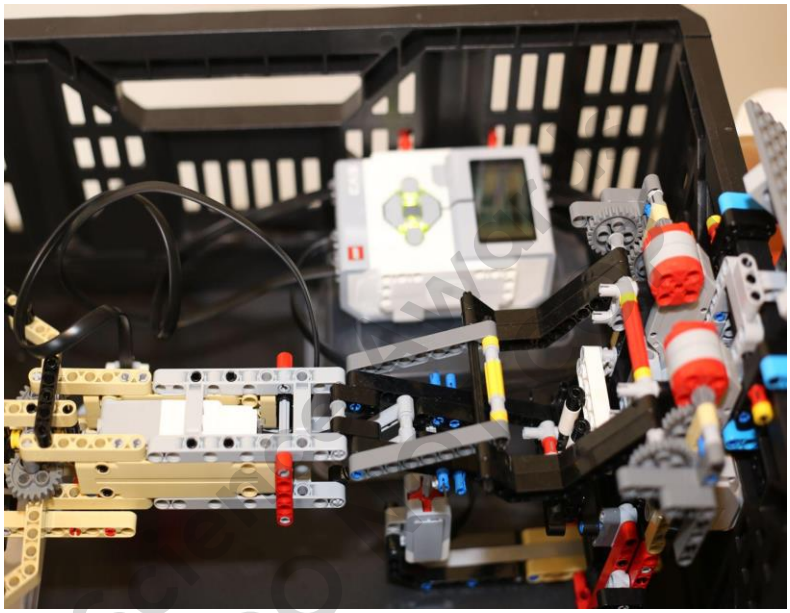
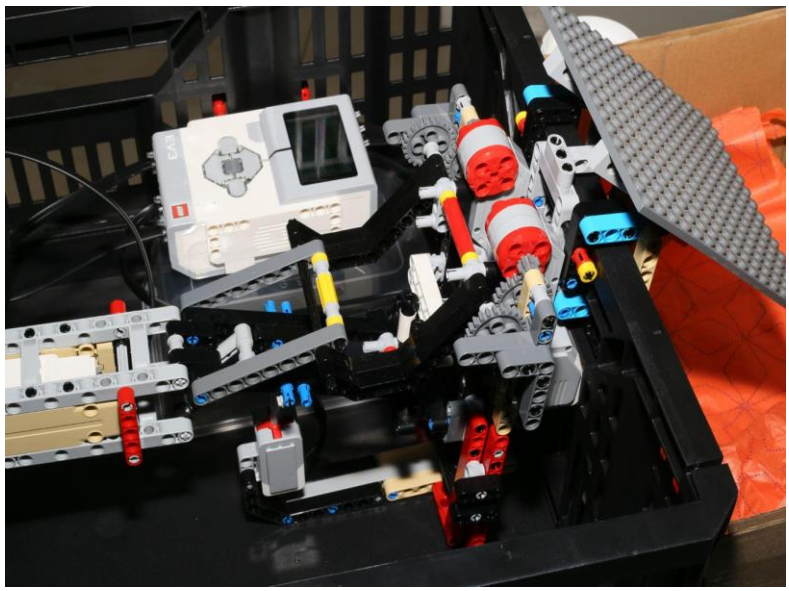
Problems	Solutions
5. Can't get the gears to stay together	Make a box frame securing it from all sides. 
6. Very jerky movement	Use a Class 3 lever to reduce the jerky movement by taking the strain of the lifting arm. 

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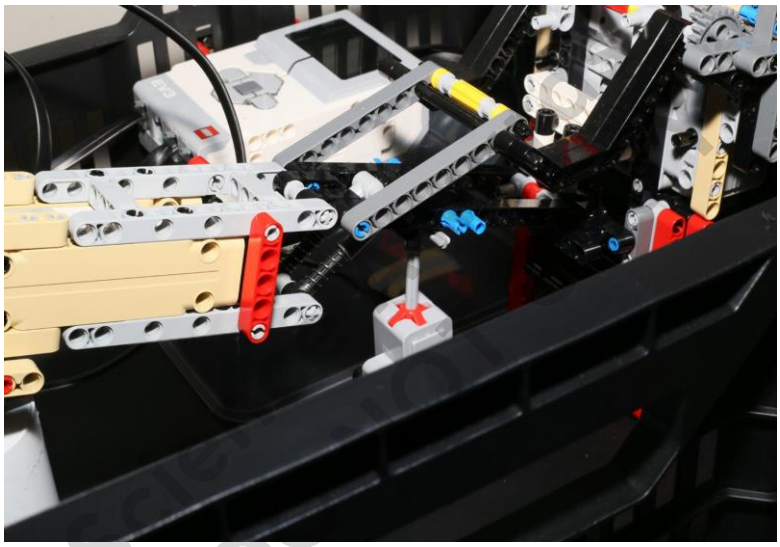
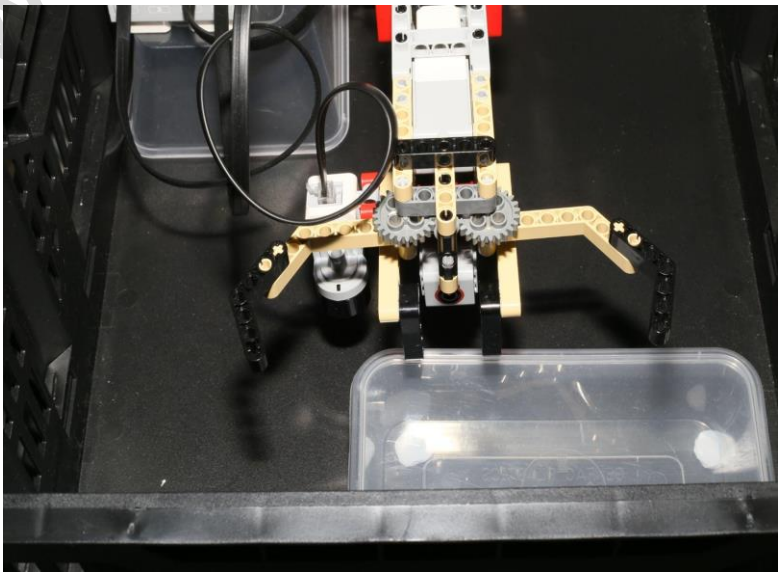
Problems	Solutions
7. Can't weigh because Lego Mindstorms EV3 does not have a weight sensor	Use springs and the Ultrasonic Sensor to calculate the weight. The arm gets lower as the weight increases so by measuring how much it goes down it can calculate the weight. 
8. Lego Mindstorms EV3 does not have a barcode reader so it can't sense the bin or identify the bin owner	Use a Colour Sensor because each color represents a house. E.g. yellow colour means yellow house, red color means red house, etc. 

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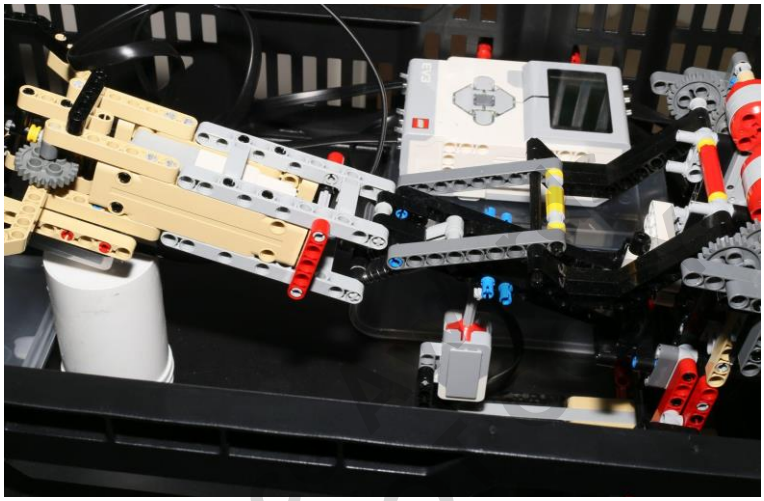
Problems	Solutions
9. Can't accurately control the descending movement of the arm	I used a Touch Sensor so it will keep on going down until the arm touches the Touch Sensor. 
10. Can't fit the text on the EV3 Brick	Read the text out loud using the micropython code

Parent involvement

My dad helped me in a number of ways. I discussed my ideas with him from the beginning. He separated the Lego pieces that were stuck and I was not strong enough to separate them. He also found appropriate websites for me to find solutions for the problems. He held up structures that wouldn't stand up by themselves so I could build legs for the structures to stand up. When the code was not working my dad read through it and pointed out some errors that I didn't see. He bought the equipment for me, cleaned the glue off the old vitamin bottle's label, and found Lego pieces for me. He filmed the whole process that I was constructing and coding. He also uploaded (but unlisted) my videos on Youtube because it doesn't allow me due to age restrictions. He also taught me how to generate a QR code for my videos.

My mum pointed out the grammar and spelling mistakes in my document. She gave me some feedback when I was demonstrating the bin lifting arm. She helped me edit this document too. She also kept an eye on my brother so he wouldn't destroy my robot (he is only 3 years old but extremely interested in robotics especially what I am doing). Both my parents encouraged me to stay on task.

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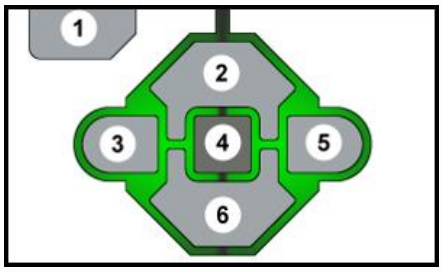
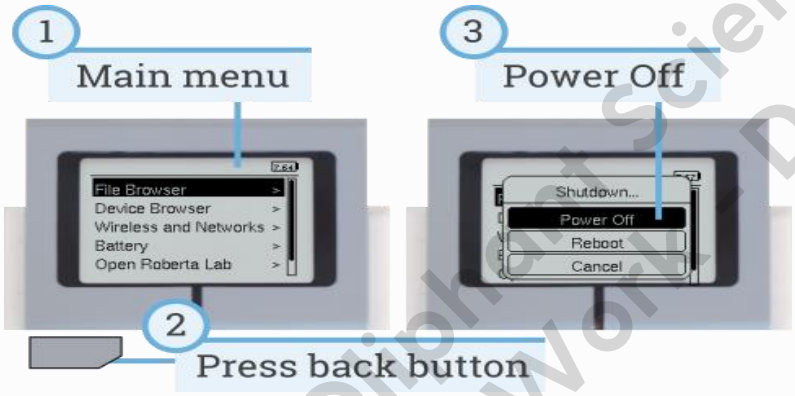
How to operate it

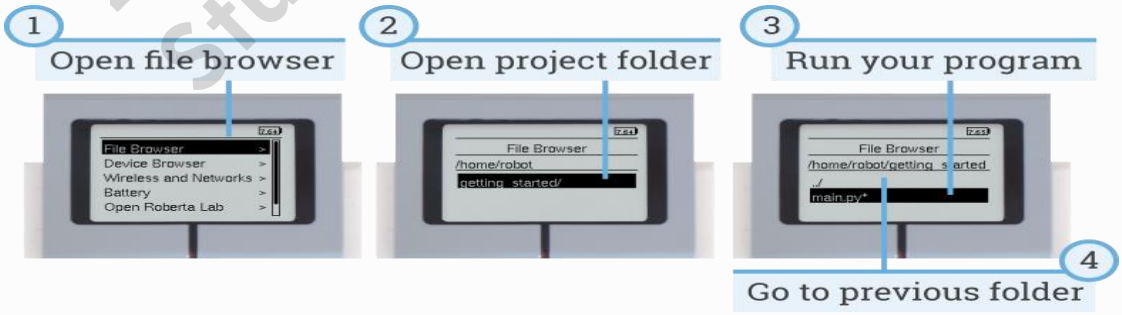
1. Turn on the EV3 Brick by pressing the dark gray center button (Button No. 4 in the picture below).



2. The boot process may take several minutes. While booting, the EV3 Brick status light turns orange and blinks intermittently, and you'll see a lot of text on the EV3 screen. The EV3 Brick is ready for use when the status light turns green.
3. To turn the EV3 Brick off, you need to open the shutdown menu with the back button, and then select *Power Off* using the center button, as shown in the picture below[6].



4. You can run previously downloaded programs directly from the EV3 Brick.To do so, find the program using the *file browser* on the EV3 screen and press the center button key to start the program as shown in the picture below[7]



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[6] The picture is adopted from https://pybricks.com/ev3-micropython/startbrick.html (accessed on 12 June 2021).
[7] The picture is adopted from https://pybricks.com/ev3-micropython/startbrick.html (accessed on 12 June 2021).

5. The folder name for this project is R4SE. Once you are inside the folder, press on main.py and press the dark grey center button to run the project as much as you want. But wait! It will only run the project if there is a green, blue, yellow or red colored bin in front of it!

Figures

Figure 1.

Figure 2.

Figure 3.

Figure 4.

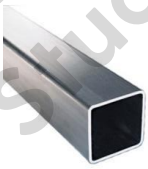

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Figure 5.

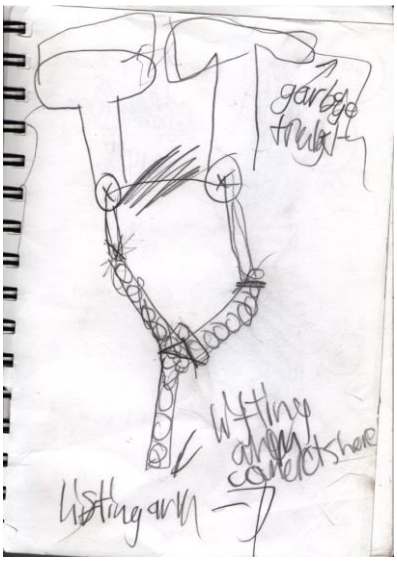
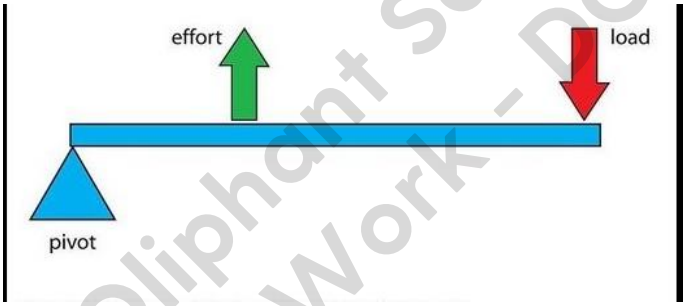


Figure 6.

Figure 7.



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