Eatsy

Final report Engineering Design (4WBB0)

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Figure 1: Eastsy Logo

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1 Group effectiveness

1.1 Group Composition

In this Engineering Design group there are seven total members. As is typical for such a group, all members represent a different Major as a bachelor student. Within this group we have an Industrial Design student, an Architecture student, an Electrical Engineering student, a Computer Science and Engineering student, an Industrial Engineering student, a Chemical Engineering student, and an Applied Physics student. Moreover, in terms of nationalities the group is mostly Dutch, with one student from Bulgaria. Ideally, a group with such diverse academic backgrounds would have a variety of different strengths and weaknesses which will help to complete the assigned project.

1.2 Group Strengths

From the vary beginning of the project it was clear that every group member had a unique set of skills which would impact the course of the project. To begin with, the group had several group members who were interested, and skilled, at designing and modelling potential products. Creativity with this regard was a strength to the group, and this is reflected in both the choice of special topics, namely Design sketching and CAD design, as well as in the general design and concept sketches which were made. Over the course of the project sketches became more clear as more ideas were incorporated, and it was clearly a strength of ours to express our ideas in this way. This strength in modelling and designing most likely came from some students' majors, which undoubtedly linked to their personal interests as well. Nevertheless, as the project developed it became clear that this was a real strength for the group.

As well as design modelling and sketching, another strength in the group was coding, relating to both smartphone app design and Arduino. Several group members had experience with different aspects of coding in many languages, be it basic experience or robust knowledge. Having experience related to the Arduino was a strength for our group, because that made the implementation of it somewhat easier. Having experience with regards to smartphone app design was also an important strength. What this allowed us to do as a group was develop a product in which the user could connect to it with his/her smartphone and engage with it in that way. This added versatility to our group, and not doubt made developing ideas significantly easier. The skills with this regard again may have come somewhat from the students' majors however, with the initiative shown by some group members it was clear that it was also an area of interest for them. In order to take full advantage of this strength we again chose to dedicate a special topic towards it, and incorporate it in the design.

Finally, many of the group members expressed competence with regards to organization, planning and communication skills. Although these skills may seem somewhat vague, many group members showed that they were truly competent in this aspect. Whether it be while leading a meeting, taking notes or simply working together in a group environment, every group member had some of these qualities. What this allowed us to do as well was easily switch between tasks on a weekly basis. If a group member had no real technical skill in a certain week, or was simply not able to work on other aspects, he/she could always work on something to do with communication or on an aspect of the final report. Generally, the active group participation and versatile skill set meant that we could easily share tasks as we wanted, and that we could complete the entire project in a complete timely manner.

1.3 Group Weaknesses

With such a diverse group of students we faced a number of challenges as well. Firstly, we oftentimes struggled with working in such an inter-disciplinary group. Prior to this project, our experience in working in multi-disciplinary groups was quite limited. This brought a unique set of challenges with it. For example, certain disciplines were better suited to certain parts of the project by nature, for example Industrial Design students may be better at developing concepts than others. What this meant for the group was that at certain times we had to adapt to each other, sometimes becoming more active, sometimes less. Allowing everyone to use their strengths and hiding their weaknesses was difficult, and certainly a weakness at the beginning, but as the project went on and we became more comfortable with each other it became second nature. For example, initially many members of the group did not participate as much in the discussions, but as the project went on everyone found their strength and area of interest, hereby solving the issue we had.

Another weakness we had as a group was communication. Despite it also being a strength of ours, some aspects of communication were clear weaknesses. Oftentimes, we struggled to communicate effectively, especially at the beginning of the project. In the first few meetings, some members were more active than others, as stated previously, however what this meant was that it became very difficult to follow the design process for members who were less active. The note-taking had not developed to a point where it was clear what exactly the assigned tasks were. This meant that for the first few meetings, many group members were unsure of their task. This issue was a significant one, but thankfully it was mostly fixed quickly. A clear action plan and action points were included in every meeting's notes making it easier for members to go back and check what their task and other's tasks were. Also, meetings were slowed down a bit, allowing everyone to follow the discussion and involve more group members.

Finally, our group had a weakness with the development of feasible ideas, as well as splitting the workload easily. When we met as group during the first few meetings, we struggled with keeping our ideas small enough and feasible enough to work. Many of us had fantastic ideas which simply weren't possible with the budget or time-frame which we had. Eventually, we had developed a concept which we believed to be feasible, but then the issue became splitting workloads. We had a significant problem with allocating assignments evenly at the beginning of the project. Group members who were very passionate about their idea would often spend significantly longer sketching and prototyping their ideas than other group members. Moreover, certain group members would voluntarily take on extremely large tasks while others had relatively little to do. This issue was a certain weakness, however by the middle of the project we better developed our roles in the group, allowing everyone to more or less spend an equal amount of time on the project.

Overall, our multi-disciplinary group faced a number of challenges and had a number of weaknesses. However, over the course of the project all of us certainly learned from each other and grew as people and future product developers. The skills we developed during the course of this project and the weaknesses and challenges we overcame will undoubtedly help us in our future endeavours.

2 Design goal

Most adults with Cerebral Palsy, also known simply as CP, experience fatigue and a lot of stiffness and pain. [6] With the right treatment and information at a young age some of this pain, stiffness and fatigue could have been prevented. Adhering to this fact, children with CP also experience difficulties with communication and fine motor skills. [8]

Cerebral palsy is one of the most common motor disabilities amongst children. About 1 in 323 suffers from CP and around 80 percent of these children have spastic CP, which means that their muscles are stiff and movement can be awkward or even painful. [2]

In fact, according to an article written by S. Rudebeck, "Many children with cerebral palsy face considerable challenges in their day to day life. Some will be highly dependent on those around them. While motor deficits are most commonly reported, children with cerebral palsy also experience higher rates of challenging behavior, attention difficulties, social communication problems and to a lesser extent mood disorders in comparison to the general population. Personal risk factors for psychological distress include normal intellect, communication problems and less functional disability. Due to their need for higher levels of care and support, their parent's emotional state and parenting style also highly impacts on the child's development." [8]

Much like the experience for children, adults suffer many of the similar problems as children. "Experiences of pain, stiffness, and fatigue also made participants aware of their need for physiotherapy, although many complained about lack of funded services as adults: "They pretty much let you go with pretty much no resources ... once I was 18 ... they cut you loose and said 'we can't do anything for you now, and you're on your own,' and that was it..." [6]. As such, it is vital that a product be developed which can aid and teach children vital tasks to ensure that they can live somewhat independently in society.

"Most had not anticipated these changes at such young ages, wishing that they had been informed sooner to take preventive measures." It is clear that the effects of CP on children are highly influential to their development and later their ability to live independently. As such, a device which aids children in their attempts to perform day to day tasks which their CP can be vital to their further development. [6]

Children with CP typically struggle with many day to day tasks, especially those suffering from Spastic CP. This is especially true for tasks requiring fine motor skills including brushing their teeth and eating. The later of the two is especially interesting to us, as we think eating is one of the most important daily tasks, and is of course essential to survival. Fine motor control is essential to these tasks and the improvement of this fine motor control can lead to greater independence for a child suffering of CP. Fine motor control "...Improves hand dexterity by working on hand muscle strength, finger isolations, in-hand manipulations, arching the palm of the hand, thumb opposition and pincer grasp. Activities include squeezing a clothespin, playing with water squirt toys and pushing coins into the slot of a piggy bank." [5]. Taking this into account it is clear that the action of eating is a fine motor skill which can be improved by tasks which build up the previously mentioned aspects.

Based on the background of the group, several possibilities are available for our design. Having both a computer science and electrical engineering student offers the chance to have interaction between physical electronics and for example a smartphone app. This can be done for example through the use of an Arduino. Moreover, having an industrial design student as well as an architecture student allows our group to develop physical models, as well as potentially allowing us to make a physical product. Finally, we also have a Chemistry, industrial design and Physics student, which will be able to assist with all tasks in some way, be it error-analysis or building the product. With these things in mind, it is clear that the interaction between sensors on our final product will be easy to implement. Because we have the majority of the possibilities covered by strengths in the group, we are able to come up with several diverse design concepts, which will each play to group members stengths in different ways.

To summarize the findings of this section, we have identified that the challenges faced by children with Cerebral Palsy, in particular spastic Cerebral Palsy should be addressed. We found this disease to be the most significant from our initial ideas, and we believed it is the most unique issue to address. From the various challenged faced by the children who suffer from spastic CP the control over fine motor tasks was identified as a significant issue. The issue of being able to eat independently resonated with the group and as such it was decided that our final design goal would be to develop a product which in some way will aid children who suffer from spastic cerebral palsy to eat, or practice eating, independently.

3 Functional design and solutions

The functional specifications, along with the solutions encyclopedia and the technical specifications come for the most part from the previously established design goal. As well as the functional specifications created from the design goal, the given assignment also created a number of functional specifications.

Table 1: Functional Specifications

Functional Specifications	
Must Have	**Should Have**
Fit in a box of 0.34 x 0.23 x 0.31 m^3	Aesthetically pleasing
Be built from parts that do not have a complete function	User-friendly
Must have sensors and actuators	Comfortable to use
Be usable in-house	Usable with visual impairment
Help the user eat or to hold items	Light and Durbale
Safely Usable by people with CP	

Table 2: Functional Specifications Continued.

Functional Specifications cont.	
Could Have	**Won't Have**
Not make the user feel different/discriminated	Function to rehabilitate CP
Most people with CP can use it safely	Overall balance
Adjustable height/size	Overall posture correction
Adjustable strength/difficulty	
Easy to carry	
Fun if used by children and motivating to practice	

Based on the above functional specifications, a number of different solutions were developed within the context of a solution encyclopedia. Many of the ideas listed below fulfill many of the suggested specifications. In the interest of brevity, ideas are only listed for the Must and should have function(s) they fulfill.

Table 3: 'Must have' Proposed Solutions

Must Have Specifications				
Help the user eat or hold items	**Fit in a box 0.34 x 0.23 x 0.31 m^3**	**Be safe to use**	**Be usable by people with CP**	**Be usable in-house**
Eating-game which trains motor skills	Foldable Sleeve	Special-covered cutlery	Slide on cutlery cover	Eating-game
Electromagnetic gloves	Detachable cutlery	Soft spoon/-fork	Interchangeable cutlery	Eating sleeve
Arm sleeve with stabilizing motor	Normal plate size	No medical data collected	Differently sized sleeve	Electromagnetic glove
Inflateable cutlery		Easy to remove from user	Multi-sized glove	
Velcro Wrist Brace				
Table stabilizer				
Mechanized Cutlery				

Below a table containing solutions for the should have functional specifications can be found.

Table 4: 'Should Have' Proposed Solutions

Should Have Specifications			
Aesthetically Pleasing	**User-friendly**	**Easy to use**	**Usable with Visual impairment**
Small Electronics	Easy to wear	Soft or elastic material	Uses bright colors
3D Printed covers	Usable Independently	Large Buttons	Large components
Different Colors	Hidden Electronics	Big screen	Colorful Components
Minimal use of batteries		Light Cutlery	Audio Cues
Wires managed		Few options	Full Color range available

4 Design concepts

The first design concept is, a glove which helps the user hold items by adding a magnetic strip to the item because cerebral palsy often impacts fine motor skills, many people are unable to easily use cutlery, hold a cup, or transfer food from a plate to their mouth using their hands.The glove would be able to sense the user trying to hold the item with the use of pressure sensors and then activate an electromagnet which with help of the magnetic strip helps the user hold the item. It would also have a mechanism for the user to stop holding the cutlery/cup. This helps patients with for example eating and drinking whilst still using normal cutlery/cups (with a magnet strip attached).

Figure 2: Magnetic Gloves Design Concept

In figure 2 the the exploratory prototype we made can be seen. We pictured to use a material which is quit tight to the skin so a natural feeling would be maximized, furthermore we looked into a light type of material to use to not further weight the prototype. With these ideas in mind we came to the conclusion that a combination of nylon and polyester would be a good solution. Moreover, the magnets are placed in rows, which results in a optimal range of motion and maximum effectiveness.

This would help the user hold items without having to get a special version of everything. Therefore, the patients can train their fine motor skills while also being able to eat and drink with a decrease in effort.

The premise of such an idea is to have a way for which people who suffer from CP have a safe way to use their utensils. Ideally, the magnets within the glove would function to hold and stabilize the cutlery so that eating would become much easier.

The second design concept is an eating game with a special set of utensils, teaching the children how to hold a fork and knife and how to use precise motor skills.

The device would consist of a plate and different shaped plastic foods. It would also consist of a knife and fork. The parent can place different foods on the plate. Inside of the plate would be a magnetic ring revolving. The foods on the outside would be placed on the ring and slowly spin around. In the center of the plate would be a hole, a speaker and LED light would tell the child what type of food to pick with the fork and knife. The child then must pick up the food and put it in the plate. At the end the child could also try to remember what he/she put into the pate, actively triggering the memory and communication skills. The initial concept can be seen in figure 3.

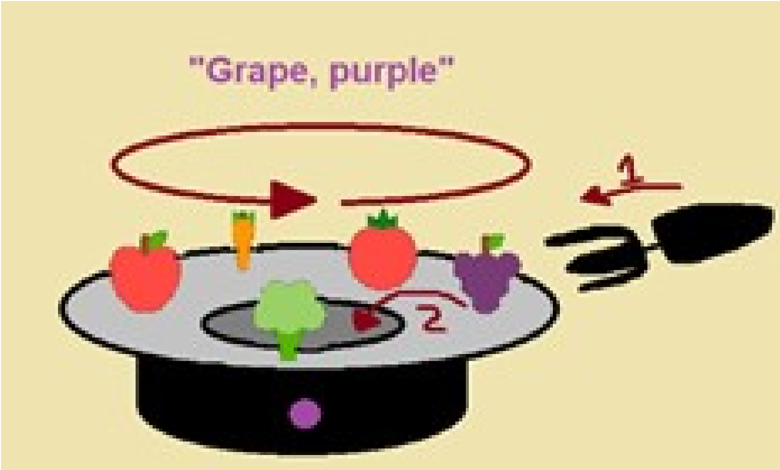
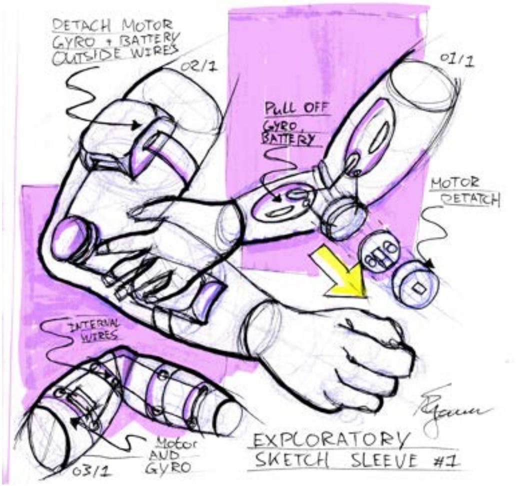
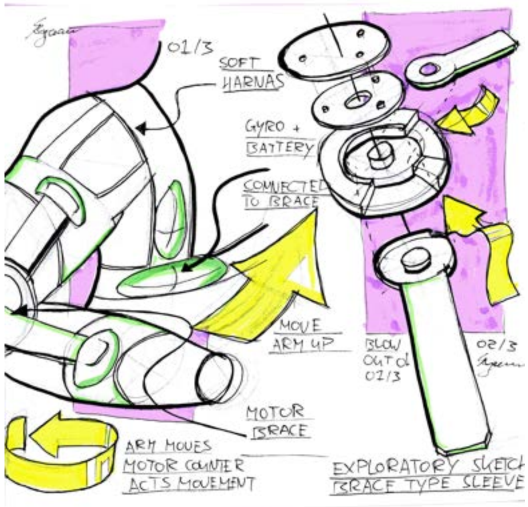


Figure 3: Eating Game Design Concept

The third design concept is a brace for the entire arm. It would help stabilize the arm as the individual would be eating. The idea would be to create a product which, through the use of the a gyroscope and some sort of battery connected motor, the spasms caused by spastic CP could be counteracted specifically while eating. Like with the glove idea, much thought was given to the material to be used by such a design and it was again agreed that a light-weight material such as nylon and polyester would be good to use. Exploratory prototypes were made from several different materials and the mechanism to counteract the spasm was also explored further through the means of prototyping and design sketching. Below in figure 4 the exploratory design sketches and prototypes further explain the idea.



(a) Arm Brace Design Sketch



(b) Arm Brace Design Sketch

(c) Cloth Prototype

(d) Exploratory Prototype

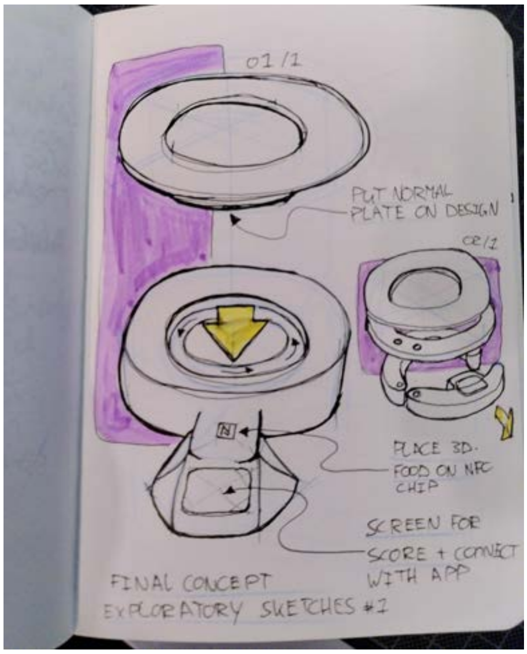
Figure 4: Arm Brace Exploratory Designs

These exploratory prototypes show the concept, being that the user would have their wrist controlled some mechanism attached further up the arm. This mechanism would ideally counteract the spastic CP and aid the user while eating.

5 Final design concept

In a meeting in which we discussed the three design concepts it became apparent that the idea for the game was the most valuable. This decision was based to some extent on a shortened version of a risk-analysis, in which we identified that the other two concepts simply had too much risk involved, compared to the value they would have. This design will help the child who suffers from spastic CP to practice eating independently, as well as practicing to hold items. Moreover, such a design is safe and usable by people with CP, meeting the must have functional specification. This device will also meet the majority of the should have functional specifications as it will be aesthetically pleasing, user-friendly, and generally durable. The device will be user-friendly because of the easy to use spork, modified fruit and the well-designed app, which includes a progress tracker, in which the user can feel rewarded for completing the game progressively better. The app will communicate with the Arduino as well as the users smartphone via Bluetooth. Ideally, the app will be able to tell the user how fast he/she was, as well as whether the correct food was placed on the scanner. Below are several images of the preliminary design, found in figure 5, both in sketch and cardboard form.

(a) Initial Design Sketch



(b) Adapted Design Sketch

(c) Cardboard Model

(d) Cardboard Model Being Used

Figure 5: Design Concept Sketches and Cardboard Model

As can be seen from the preliminary design, the concept is a game in which the child suffering from any form of CP is to place a model food onto an NFC scanner to earn points, practicing his/her fine motor skills in the process.

6 Technical specification

Below in the tables, the technical specifications are presented. The item, the items details and to which function the item relates is shown. The must haves, should haves and could haves are presented in table format. The won't haves are presented below the tables with a justification. All technical specifications are classified using the MoSCoW method.

Table 5: ‘Must’ Have Technical Specifications

Must Have Technical Specifications		
Specification	**Detail**	**Functional Specification**
Arduino	Arduino Uno R3	Will allow for the controlling of sensors and actuators
Magnets	8x2 mm, magnetization N45, holding force 1.1 kg	Will hold the product together & allow the user to open the product
On/Off Switch	12x19 mm, 250V AC, 6A	Will allow the user to turn on and off the product
Resistors	6x 330 Ω, 1x 10 kΩ	Without resistors the circuit will not function.
Wires	1 black, 1 red, 1.5 diameter, $0.33m^2$ core thickness	Like resistors, these are paramount to any circuit
Bluetooth Module	4.0 HM-10, C2541, operational at 5V	Will be necessary in order to link an app and the Arduino

Table 6: ‘Should’ Have Technical Specifications

Should Have Technical Specifications		
Specification	**Detail**	**Functional Specification**
Power Adaptor	9V, 1A Adapter With DC jack	Will ensure that the circuit and arduino are constantly powered.
Modelled Food	Food models made from cloth	Without these, the user will not be able to simulate eating
NFC reader	RC522, 40x60 mm, operational at 3.3 V, 13.56 MHz	Will allow for the Arduino to process whether or not the food placed on the reader is correct
LEDs	2 RGB LEDs	Will give visual confirmation whether or not selected item is correct.

Table 7: 'Could' Have Technical Specifications

Could Have Technical Specifications		
Specification	**Detail**	**Functional Specification**
Solar Charged Batteries	5.5V 100mA - 55x70mm	Will offer a renewable way to power the circuit
Pressure sensing plate	18mm Round weight sensor	This would be able to tell whether something has been placed on the product.
NFC reader	RC522, 40x60 mm, operational at 3.3 V, 13.56 MHz	Will allow for the Arduino to process whether or not the food placed on the reader is correct
OLED Display	0.91 inch OLED Display 128*32 pixels	Could show the user visually whether they were correct.

Aside from what the product will have, there are also a number of things the product will not have. Firstly, the product will not have completely wireless charging. This is because it would cost us too much, and seems unrealistic to implement in a product which will not be transported much. Furthermore, the product will not be made of any other material other than plastic as we would not be able to make it without 3D printing. Other manufacturing methods are not available readily to us, as such it will not be made of any other material. Finally, the product will not contain a speaker, as it it would be very difficult to implement in such a small product. Also, there was a limited budget and the group decided this was something that was not needed.

7 Detailing

Our system consists of 5 different components: the LEDs, the on/off switch, the NFC reader, the Bluetooth module and the app. The three key components, and most interesting components have been described into more detail below. The full code of the game is added in Appendix A.4. Small snippets of the code for the app are added in this section, while the full code for the app is in Appendix A.5

7.1 NFC reader

This subsystem consists of the Arduino, the NFC reader and the NFC tags. In order to understand how the NFC reader recognizes the NFC tags, we wrote a simple code. To establish a connection between our NFC module (RC522) and the Arduino, we needed to include multiple libraries. The Serial Peripheral Interface (SPI) library we included allows us to communicate with the NFC module. [1] The Arduino then acts as the master device. The NFC module has 4 pins that send or receive the data: the SDA pin, the SCL pin, the MOSI pin and the MISO pin, which can be seen in Figure 20. The SDA pin can be used by the Arduino to enable or disable specific devices. The SCL pin synchronizes data transmission that is generated by the Arduino. The MOSI pin is used to send data from the Arduino to the NFC reader and the MISO pin is used to send data from the NFC reader to the Arduino. We also included the MFRC522 library to read and write the NFC tags. [3] After having seen how the NFC reader detects NFC tags, we were able to start working on the code for the game.

First, we defined all NFC tag IDs and paired them with a color. Next, we made a two dimensional array in which we defined the ID, the name of the color, the score and the RGB values. The Arduino was used to pick a random color after which the RGB LED would light up in that color. Since we don't have a module to make an easy random number generator, we had to be more creative. For the random color generator we used the noise of an empty port in order to generate a random number, and using this number we select a color. The Arduino would then check if the NFC tag ID detected by the NFC reader corresponds to the ID that was randomly picked. If not, the RGB LED will blink red and the user would get another try. If the correct food, and thus the correct ID, was presented to the NFC reader, the Arduino would pick another random color.This can be seen in the code for the Arduino in Appendix A.4.

The RGB LEDs have 2 functions as described above namely, presenting the randomly picked food color and indicating the correctness of the presented food. During testing we noticed that it was difficult to clearly differentiate between both functions, especially when the chosen food was red or green. To make a clear distinction, we build up suspense first, by lighting up the LEDs in all the different color. After that the LED would blink red or green, depending on the correctness. This way the user is able to see that the presented food is processed and that the presented food is correct or not.

7.2 Bluetooth Module

The subsystem of the Bluetooth consists of the Arduino, the Bluetooth module HM-10 C2541 and the app on the phone. The HM-10 Bluetooth module has a Low Energy mode. Since we only exchange small amounts of data periodically, the Low Energy mode is ideal. Bluetooth Low Energy remains in sleep mode except when a connection is initiated, and whilst normal Bluetooth has a connection time of about 100 milliseconds, Bluetooth Low Energy only uses a few milliseconds due to the higher transfer rates at 1 MB/s The HM-10 C2541 module has a level converter built in, which means it can operate on both 3.3 V and 5V. This allowed us to directly connect the RXD and TXD pins of the Bluetooth module to the digital pins on the Arduino. This can also be seen in Figure 20. The TXD pin on the HM-10 sends information to the Arduino, and the RXD pin on the HM-10 receives information from the Arduino.

We included the AltSoftSerial library to communicate with another serial device. When the app starts, it will ask the user to turn on Bluetooth if it is disabled. When Bluetooth is enabled and the user has given the app permission to use it, it starts scanning Bluetooth devices in the vicinity. In our app a filter is setup so that it only connects to the Bluetooth device with the correct address, the address of the HM-10 module we use. When the device is connected, the app waits for the change of a characteristic so it can respond. After the random color was chosen by the Arduino, it writes information associated with that color to the characteristic. This was done via the command "BTserial.print(chosen[0]);". When the phone is connected, it notices a change of the characteristic, it then reads the value of the characteristic and uses the information to respond accordingly.

The Bluetooth module would send relevant information to the app, such as whether a presented food was right. The code for the game can be seen in Appendix A.4.

7.3 App

The app communicates with the Arduino through Bluetooth. First, a scan filter is defined to limit the search for Bluetooth devices to only the devices intended. This is done by defining a scan filter and setting the device address as shown below.

```
private val filter: ScanFilter = ScanFilter.Builder().setDeviceAddress(
    Constants.SCAN_ADDRESS
).build()
```

This ensures that only the intended device with this device address is displayed. After the device with the correct device address has been found, scanning stops and it connects to the device using the connectGatt function as shown below.

```
override fun onScanResult(callbackType: Int, result: ScanResult) {
    with(result.device) {
        Log.i(
            "ScanCallback",
            "Found BLE device! Name: ${name ?: "Unnamed"}, address: $address"
        )
        stopBleScan()
        with(result.device) {
            Log.w("ScanResultAdapter", "Connecting to $address")
            connectGatt(null, false, gattCallback)
        }
    }
}
```

After the connection has been initiated, the `onConnectionStateChange` function of the callback is triggered. The connection stauts is checked, and if the connection was successful, we will discover the services to find the service we want: the one from the bluetooth module on the Arduino. Then, when the services have been discovered, the `onServicesDiscovered` function is triggered. Here we get the service we want using the UUID we have from the bluetooth module. We know that this service only has one characteristic which we can also retrieve using the UUID. Finally, when we have the characteristic, we enable characteristic change notifications. This will trigger the `onCharacteristicChanged` function when this character is changed, for example by the Arduino. Shortened versions of these functions can be found below.

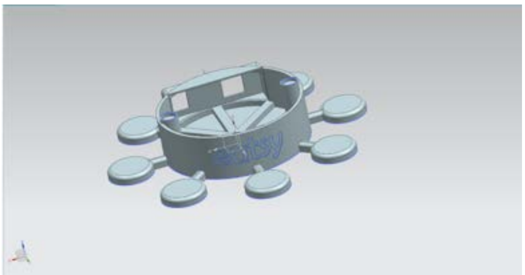
```
override fun onConnectionStateChange(gatt: BluetoothGatt, status: Int, newState: Int) {
    if (status == BluetoothGatt.GATT_SUCCESS) {
        bluetoothGatt.discoverServices()
    }
}

override fun onServicesDiscovered(gatt: BluetoothGatt, status: Int) {
            with(gatt) {
                mService = gatt.getService(UUID.fromString(Constants.SERVICE_UUID))
                val char =
                    mService.getCharacteristic(UUID.fromString("0000ffe1-0000-1000-8000-00805f9b34fb"))
                gatt.setCharacteristicNotification(char, true)
            }
        }
```

Now the function `onCharacteristicChanged` gets triggered everytime the characteristic is changed by the Arduino. So all we have to do is create the `onCharacteristicChanged` function to react accordingly when we receive a new message. The full code of the app can be found in Appendix A.5.

8 Realization

To assemble all the parts into the complete final system, we first had to 3D print two different parts. A detailed assembly drawing can be found in Appendix A.1, Circuit, Testing and Assembly. More precisely as figure, 22c. The first part was the bottom side of our product, this is basically a round formed bowl in which the Arduino including all the wires had to fit, as shown in the picture below,6a. The second part of our 3D print, the top, has as primary function to be a lid. On this 'lid' a smiley face has been engraved in order to stand out and be attractive to the children playing the game. This can be seen below, in figure 6b.



(a) Bottom Part Final Design

(b) Lid for Final Design

Figure 6: Final Design Used

As described above, the inside of the product consisted of an Arduino module with attached to it several different modules. As can be seen in the circuit diagram in Appendix A.1, (Figure 20), a Bluetooth module, an RFID Scanner and several LEDs were attached to the Arduino. Furthermore, a switch and of course several resistors were used to make the circuit function correctly.

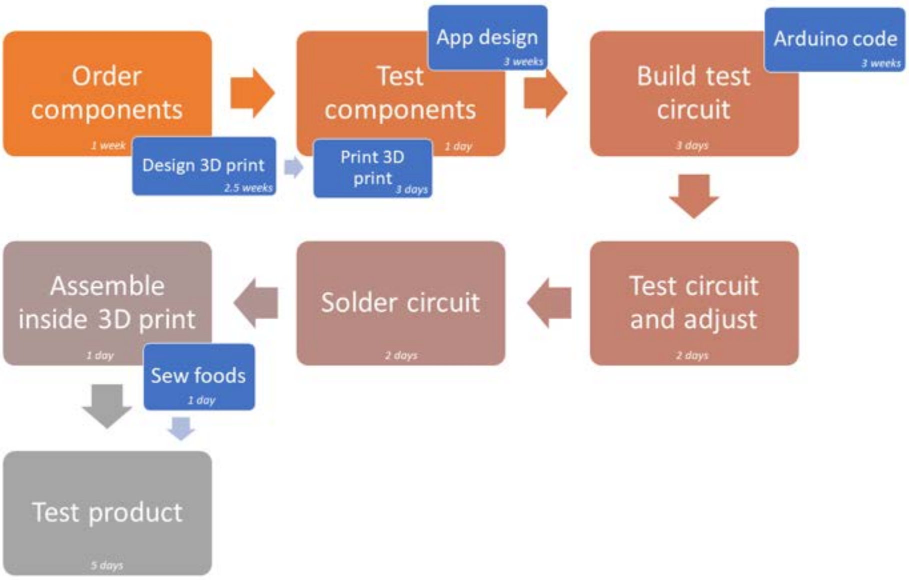


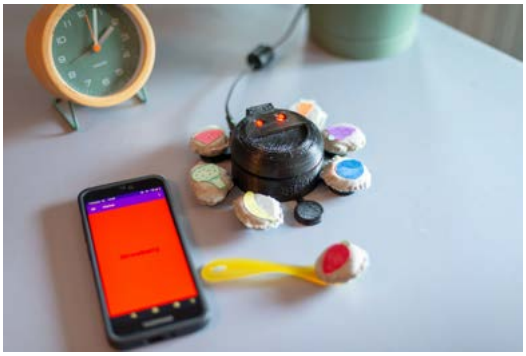
Figure 7: Production Plan

Following our production plan, shown in figure 7, we initially had to order the components needed for the circuit. While doing this, some of the group members had already started on the 3D design for the final product. As described before in this section, and in greater detail in the Special Topics section, Siemens NX© was used to develop a 3D design which would be accommodate the electronics and the core premise of the design itself. Once the components which we had ordered had arrived, they needed to be tested. The electronic parts, including the LEDs and the switch, were tested using a breadboard. This testing can be seen in figure 21a The NFC reader and the Bluetooth module were initially tested to see if they would work, and then later their functionality was reviewed using software tests. Finally, the NFC tags themselves had to be checked, this was also done mostly through software. Data was written to the tag and then was scanned using a smartphone to ensure the functionality of the tags.

Once the testing had been completed, the smartphone app could begin to be developed. At this point the concept of the design was clear, and the NFC and Bluetooth functionality had been confirmed. At this point the app was designed. For more detail regarding the app design refer to the Special Topic section. Knowing all the components were functional, a test circuit could also be developed. This test circuit can be see in figure 21c.

With this in place we could begin to use the Arduino to its fullest, and had to also begin developing code for it. With the software end of the product completed, and the model having been 3D printed out of Polylactic Acid (PLA), the final step was to finalize the circuit and sew the model food. The test circuit was adjusted for any potential issues or hazards, and then promptly soldered using Stannol HS10 tin, as can be seen in figure 22a. Once the circuit was final, it was placed within the product. The model foods were then sewed with NFC tags in them, and after having assembled everything the product was complete. Assembly is shown in figure 22. The final product is shown in figure 8. For more detail regarding the items or electronics used please refer to table 9.

(a) Side-View Final Product



(b) Top View Final Product

Figure 8: Final Product

Further, more detailed photographs can be found in the appendix in figure 23. As is shown in the photographs of the final design, there is a central smiley face which has, within it, the Arduino. The mouth of the smiley functions as the NFC scanner and the LEDs are the smileys eyes. These eyes will instruct the user which color to select, and whether or not the item they placed on the scanner was correct. The smartphone app will further confirm whether or not the item was correct, as well as also instructing the user which item to select. Finally, around the smiley on separate stands are the foods. These model foods are meant to somewhat simulate food, and within them they have an NFC tag. As previously said, the idea is to place the food on top of the smiley's mouth to simulate eating and practice fine motor skills, essential as described in the design goal.

Table 8: Project Budget

Project Budget							
Category	**Specification**		**Price**	**Nr.**		**Expected Cost**	**Realised Cost**
Electronics							
	Arduino		€ 11.50	1		€ 11.50	€ 11.50
	On/Off Switch		€ 0.50	1		€ 0.50	€ 0.50
	NFC Reader		€ 7.78	1		€ 7.78	€ 9.00
	NFC Tags		€ 0.96	1		€ 0.96	€ 0.96
	Resistor						
		330 Ω	€ 0.05	6		€ 0.30	€ 0.30
		10 kΩ	€ 0.05	1		€ 0.05	€ 0.05
	LED						
		RGB	€ 0.25	2		€ 0.50	€ 0.50
	Wires		€ 1.00	3		€ 3.00	€ 2.00
	DC Plug		€ 8.00	1		€ 8.00	€ 8.00
	Bluetooth Module		€ 8.00	1		€ 8.00	€ 8.00
	PCB		€ 0.60	1		€ 0.60	€ 0.60
Other							
	Magnets		€ 9.50	1		€ 9.50	€ 9.50
	Thread		€ 4.00	1		€ 0.00	€ 4.00
3D Printing			€ 5.00	1		€ 5.00	€ 5.00
Shipping			€ 2.50	4		€ 0.00	€10.00
10% Unforeseen						€ 5.57	
Replacements						€ 8.74	
Total						**€70.00**	**€69.91**

Table 9: Purchased Bill of Materials

Bill of Materials			
Item	**Product Code**	**Brand**	**Supplier**
Arduino	ARDUNO 000066	Arduino	TinyTronics
Switch	SWITCHN 000210	TinyTronics	TinyTronics
NFC Reader	MFRC522	NXP Semiconductors	TinyTronics
NFC Tags	NTAG213	Hecere	AliExpress
330 Ω Resistor	330Ω 000137	TinyTronics	TinyTronics
10 KΩ Resistor	10KΩ 000138	TinyTronics	TinyTronics
RGB LED	RGBLED5MMTRANSP 000220	TinyTronics	TinyTronics
Wires	AW3051-1 RED/BLACK 001433/4	TinyTronics	TinyTronics
DC Plug	LS-PW12W-9V1A	ShenZhen LVSUN	TinyTronics
Bluetooth Module	HM-10 C2541 000952	TinyTronics	TinyTronics
PCB	PCB5x7 000075	TinyTronics	TinyTronics
Magnets	NM-ø8-h2	Scope Basics	Bol.com

9 Test plan and results

For our final system test we wanted to test the functionality of the game. That includes testing all the different subsystems of the game:

- Arduino - NFC reader - NFC tag
- Arduino - Bluetooth Module - App
- Arduino - Switch
- Arduino - LEDs

For our final test we focused on the functionality and the software, instead of hardware - we had tested the hardware in previous stages. We designed subtests for each subsystem including switching the game on and off and sending simple commands to the RGB LEDs. For each test we stated the results we wanted beforehand. The subtests can be seen in table 10. After having completed the subtests and adjusting the product accordingly, we were able to do the final test for the whole system: playing the game.

Table 10: Final System Test Plan

Final System Test Plan		
Subsystem	**Test**	**Desired Result**
NFC	Place correct and false tag in front of NFC reader	NFC reader detects false tag and lets the user retry, and NFC reader detects the correct tag and generates a new color.
Bluetooth Module	Send generated color to the app	Screen of the phone lights up in that generated color
On/Off Switch	Switch the game on and off while playing	The system shuts down even during playing
LEDs	Send color values of the generated color to LEDs	LED lights up in the generated color.

To carry out a good test we wanted to imitate a future real-life situation as best as possible. In our case, that would be a situation in which a child with CP tries to play the game. This situation was especially relevant to testing the switch and the NFC subsystems. The switch should be able to be easily controlled and be robust, and the NFC reader should be able to detect the NFC tags even though the might be not directly on top of the NFC reader. This situation was imitated by shakily switching the product on and off, as well as placing the NFC tags on the product at different angles and distances from the reader. To carry out the most accurate testing, we maintained the same circumstances for the test of the whole system.
We had stated a desired result beforehand, but we also stated different criteria:

- Exit criteria for all sub tests;
- Suspension criteria for all sub tests;
- Resumption criteria for all sub tests;

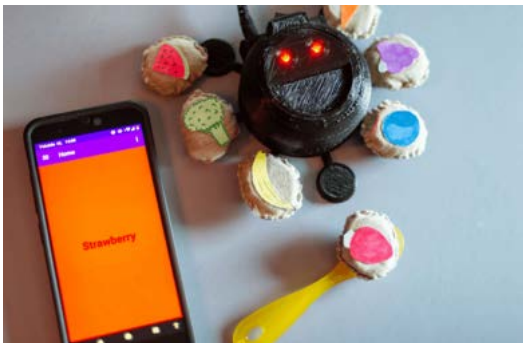
These criteria gave structure to our test plan. The exit criteria for the sub tests were getting the same result as the wanted result. We set the suspension criteria as one part of the test not working. A high bar was set by doing this, however it would result in the most complete system which could be manufactured. After fixing a single bug in the system testing would be resumed. This formed the resumption criteria. By testing again after each adjustment, structure in testing would be maintained.

Finally after having done the subsystem tests, the final system test could be commenced. Again the test and desired result was stated. The whole system was tested by playing the game under similar circumstances the game would be used in real life. The result which was desired was the game to generate colors after presenting the right food, the game to let the user retry after presenting the wrong food, the game to communicate the colors to the app, the game to communicate whether the food was correct or not to the app, the LEDs to light up in the same color as the generated food, the game to switch on and off correctly and finally the game to communicate the score after having presented the correct food 5 times. The exit criterion for the final test was the game to check off all the desired results. Again for this final test, each bug meant adjusting and testing again.

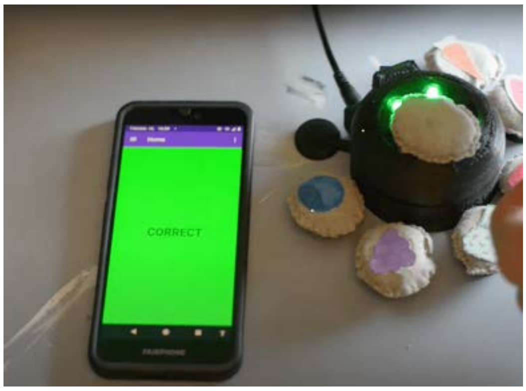
The subsystem tests would be carried out by people that had been working on the electronics and app. The final test would be carried out by the same people, but would also be viewed by several others of the team.

With the tests carried out we tested the functionality of components listed in the technical specifications. For the system to fulfill the conditions, the system must have sensors and actuators. For us, getting those working was the main focus. The sensors used were a switch, which was used as a sensor, and the NFC reader. The actuators were the LEDs and the app, therefore getting the Bluetooth module to work was imperative.

Fortunately, the final system test went quite well. Nevertheless, an unexpected result was encountered. The functionality of all components throughout the development of the system had been tested, and all the components were working. However, during the final subsystem test of the NFC subsystem, the Arduino code was unable to compare the correct NFC tag ID to the generated one. It would always give false. To fix that, we uploaded the simple code we used in the beginning to test the ability of the NFC reader. This code was used to deduce exactly how the NFC reader reads the NFC tag ID. After finding our bug, a space and a 0 in front of the NFC tag ID's, the code was changed and the final system test was carried out. We checked if we checked off all must have and should have functional and technical specifications and were able to check off almost all could have functional specifications too. After having established that, we finished the whole design and system.The initial testing can be found in figure 21, final tests are found in figure 9.



(a) Confirming Bluetooth Connection



(b) Final System Test

Figure 9: Final Testing

10 Design evaluation

The design goal we stated at the beginning of the project was: "to develop a product which in some way will aid children who suffer from spastic cerebral palsy to eat, or practice eating, independently." Purely looking at this stated design goal, our product succeeded in making a creative way for children with CP to train their fine motor skills, especially eating. Hard testing on our targeted audience was not possible, mainly due to the corona virus and the sparse amount of time given for this project. However, the product does for a fact challenge the patient to at least use their fine motor skills and therefore, when used properly, the product has in our eyes a great possibility of truly helping out children with CP to eat independently.

The aesthetics of our final project did not meet our expectations, therefore, one of the three improvements that can be made is: The height of the product. This is calculated wrongly, after putting in the electrical components, the 3D bottom and top part of the product did not fully connect anymore. This causes the product to be less aesthetically pleasing and possibly dangerous (when the inside electronics are damaged the children can get mildly shocked). This should have been implemented at the testing point in the design cycle, unfortunately due to the sparse amount of time and the time it takes to make a new 3D printed product, we did not do this at this stage of the project.

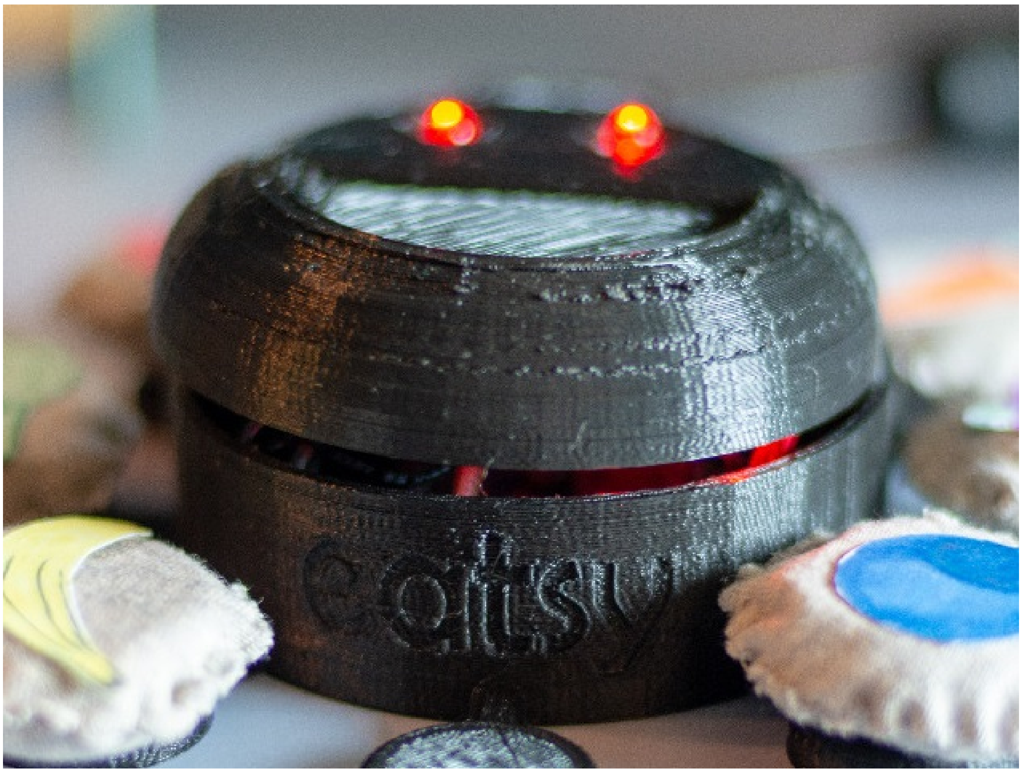


Figure 10: Gap of the device

Another part, which mildly effects the aesthetics of our final product, is that the 3D print did not come out as clean as it should have been. The sides of the products are no complete flat surfaces, which results in a decrease of the aesthetics of the game. This problem should have been implemented in the testing point of the design cycle as well, however due to the reasons mentioned above, we were not able to do this.

The second part which we found lacking in our product, is the fact that when we implemented the LED's of the game, the product Only had two PWM ports left available on the Arduino. Therefore, the LED's are only able to differentiate in two colors, where we wanted it to differentiate in three colors. Not able to make all colors or right tones can possibly result in a little confusion for the user/patient. This could have been prevented during the detailing part of the design process. In the detailing part you look at your components and try to make them more specific with regards to the specifications. We noticed this problem, but since we have a sparse amount of time we decided to only take two lights that could vary in intensity.

Thirdly, the food prototypes we made are not completely operational and ready to use. For example, we had in mind to make the bottom part of the food round shaped, which would result in an object which we could pick up quite easily. However, the foods turned out rather flat, this resulted in the user having to put in a lot of effort and even the need for the user to utilize it's other hand. This problem could have been prevented in the detailing phase of our project, in the detailing phase the calculations, printing time and time measurements are done. If we had more time in this phase of the project we might had been able to come up with a better solution for the "fruits". However, due to a lack in time because of the other time consuming parts of the project we did not completely realize the fruits as we wanted them to be.

The most critical step in the design procedure is the detailing part. This can be easily seen, because most of our improvements come from around this period of time. Furthermore was this also the moment we encountered most of the problems that we had during this project.

11 Special topics

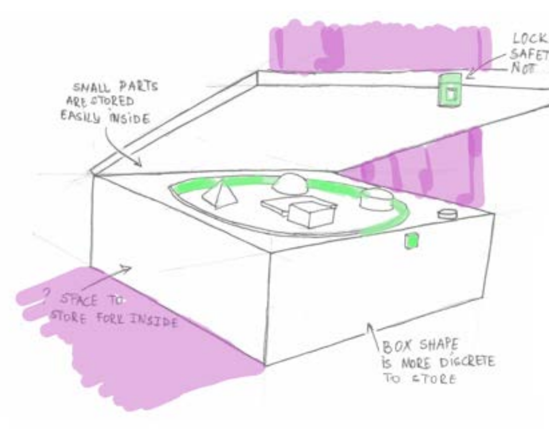
11.1 Design Sketching

The special topic Design sketching was chosen to help the group with visualizing ideas, exploring shapes they could take and communicating between the team members.

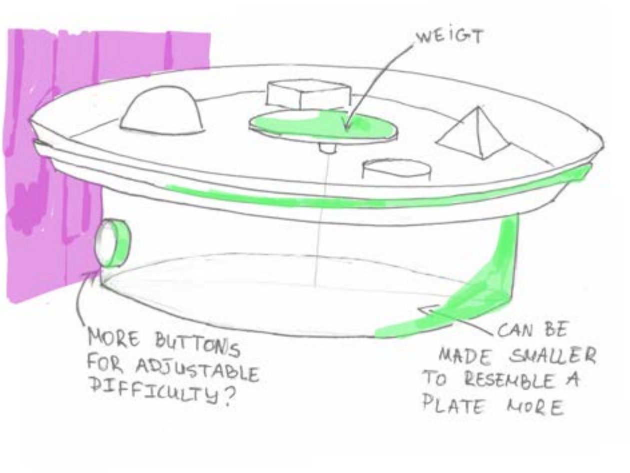
The material in the Sketchdrive module for Design sketching were studied. It distinguished between exploratory sketching and communicative sketching. This highlighted the possibility to use sketching as a tool to both explore new ideas and make decisions on the final form of the product. Figure 4a, 8a and b are a good example of exploratory sketches. They were made to quickly come up with different ideas surrounding different design ideas in the beginning of the project. Comparing this to figure 5a and 9a, which have more detail, they were focused on communicating the more developed idea to the team. The module about communicative sketching was very helpful. It showed ways in which people usually look at sketches and how this can be conveyed through arrows, backgrounds and descriptions.

The module also gave very useful directions on how to show the desired shape accurately and in correct perspective. We started by practicing how to draw lines, shapes and curves. We learned simple ways and rules to develop our sketching skills by using extended lines, suitable materials and reference photos. Such as shown in figure 8c, which was a practice sketch of a printer copied from photos. We practiced how to make communicative drawings by using colors and placing dimensions. We also learned how to show movement of components using different arrows and making sequences of drawings. The skills that we developed to quickly make clear, accurate and appealing sketches made communication of ideas between team members easier.

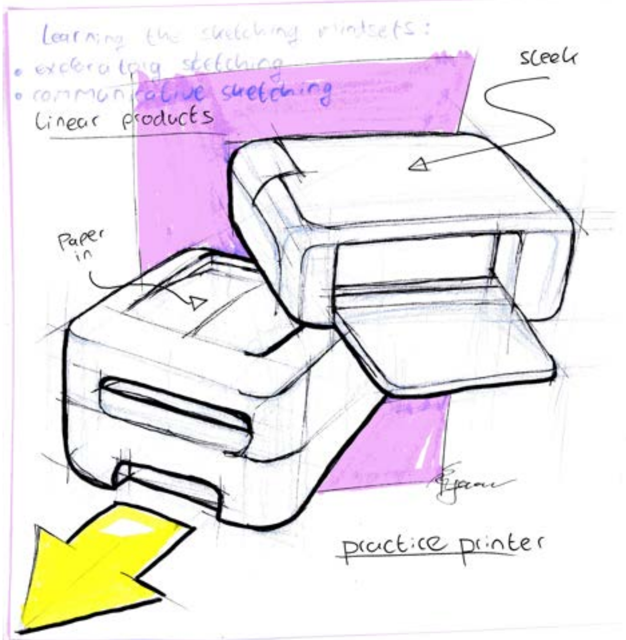
We used exploratory sketches in week 2 to look into different options for executing the three design concepts. Drawing was used to seek solutions by creating many sketchy options for the product as seen bellow. Exploratory sketching was a way investigate, tweak and refine ideas in order to create a meaningful design. Seeking solutions through sketching gave valuable insight on how the designs could be improved. The strong points of these sketches were translated into new solutions for the solutions encyclopedia.



(a) Exploration Game concept



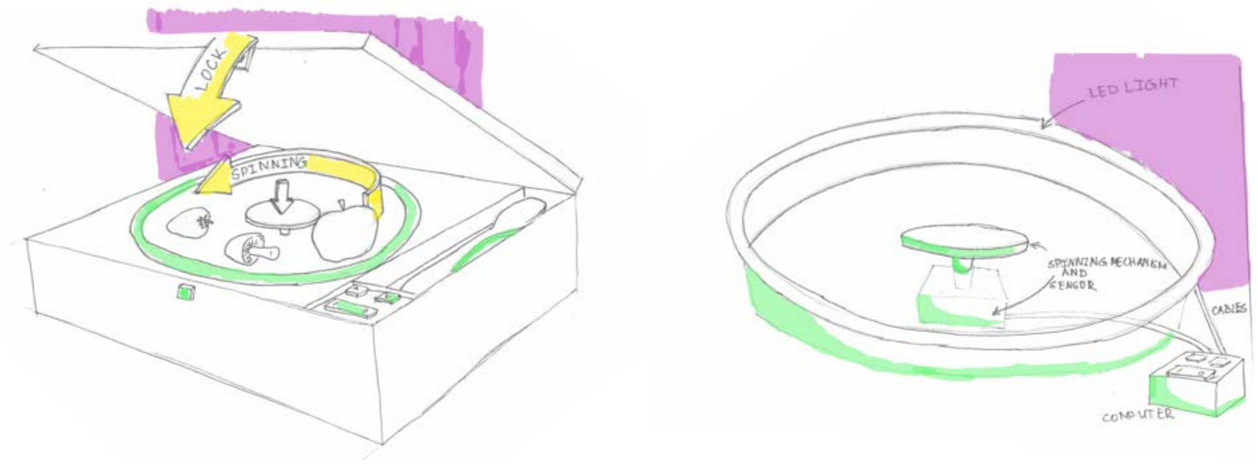
(b) Game Concept Side-View



(c) Skills practice sketch

Figure 11: Exploratory sketches

The best exploratory sketches were elaborated into communicative design sketches, as seen bellow, which were very useful to clearly communicate the ideas between group members and to determine which concept seemed the most feasible and appealing. It was possible for the group to draw conclusions only because of having a means to review, discuss and validate possible design solutions together.



(a) Movement Game concept

(b) Components of Game concept

Figure 12: Design sketches

The skills developed from the Special topic was also used at a later stage in week 5 when defining the final shape of the product. During the discussions we made many design sketches of different shapes in order to find the best shape for the product. It was very useful drawing it from different angles, with sections etc. to determine the positions of all components in the shape, the final dimensions and the placement of openings. These drawings were used later as a basis to create the CAD model.

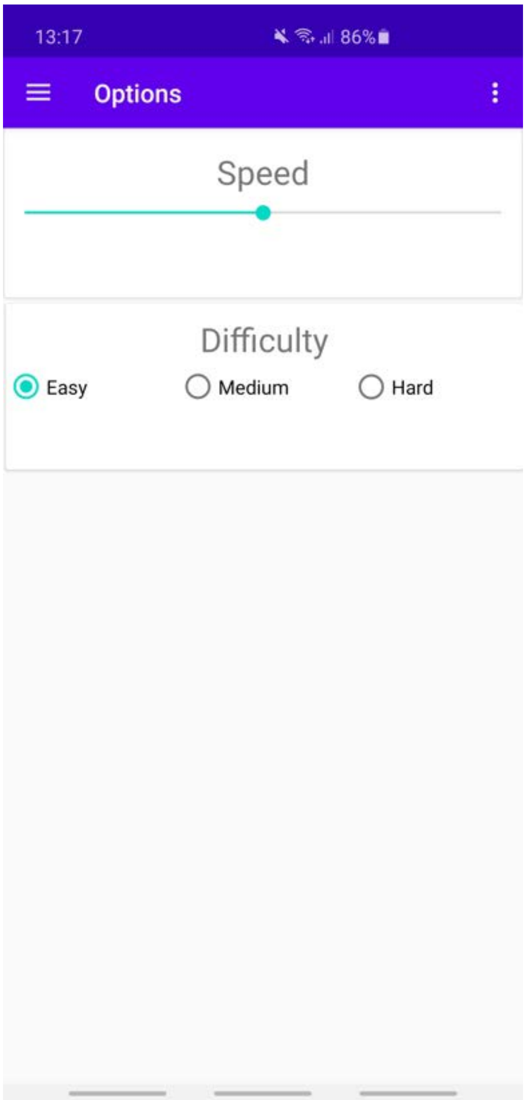
11.2 Smartphone App Design

We decided to integrate an app into our game for several reasons. First of all, we wanted to be able to track scores of the user in order to track improvement. This is not easy or cheap to implement in our physical prototype since we would need at least a screen. We also wanted a better way to visualize the food that has been picked, since RGB LEDs are quite small and one in ten patients of Cerebral Palsy has a severe visual impairment. After discussion we concluded that the best way to implement these ideas was using a smartphone, which almost everyone has, this would be a big improvement for our design since we are limited on budget and a smartphone has no extra costs.

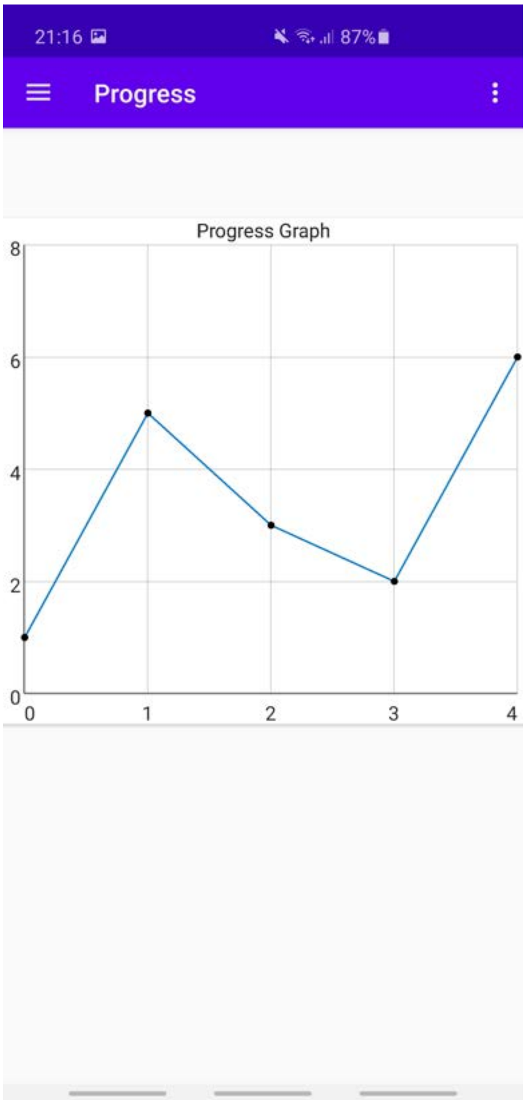
The first major decision in the app development process was which language would be used for the app. We decided to go with Kotlin [7], since it allowed for the most freedom and is not reliant on frameworks. Kotlin is a programming language designed to be the new industry standard for app development. It is designed to fully inter operate with Java, the default Android app programming language. The aim of Kotlin was to improve the app development industry by making the programming more efficient, readable and easier to maintain. This is also why we chose to use Kotlin, we wanted to use a language which is popular in the app development industry and has been designed for app development.

We also had to decide what features we wanted the app to have, we decided to at least try to integrate the NFC tags of the food items and a Bluetooth connection to the game. We also had the idea of adding settings for difficulty which could make the game more challenging.

Now that we had a plan, it was time to learn Kotlin. The first app we made was an app from a tutorial [4], which had a few simple buttons and a text field which changed whenever a button was pressed. Screenshots of this app can be found in figure 24 of the appendix.
After this first app was created, it was time to look into making a mock-up for the prototype app. We developed an app with three screens, first of all we had a home screen which had text on it. Secondly, we had a screen with settings which could be changed, and finally, we had a screen with a graph where we could display scores. This can be seen in figure 13.



(a) Options screen



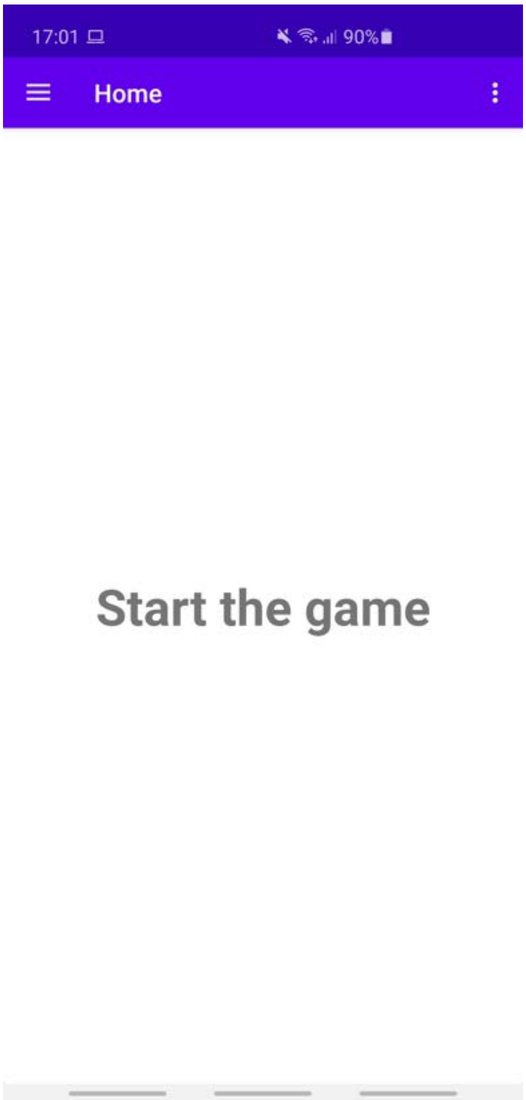
(b) Progress Log screen

Figure 13: Screenshots of app mock-up

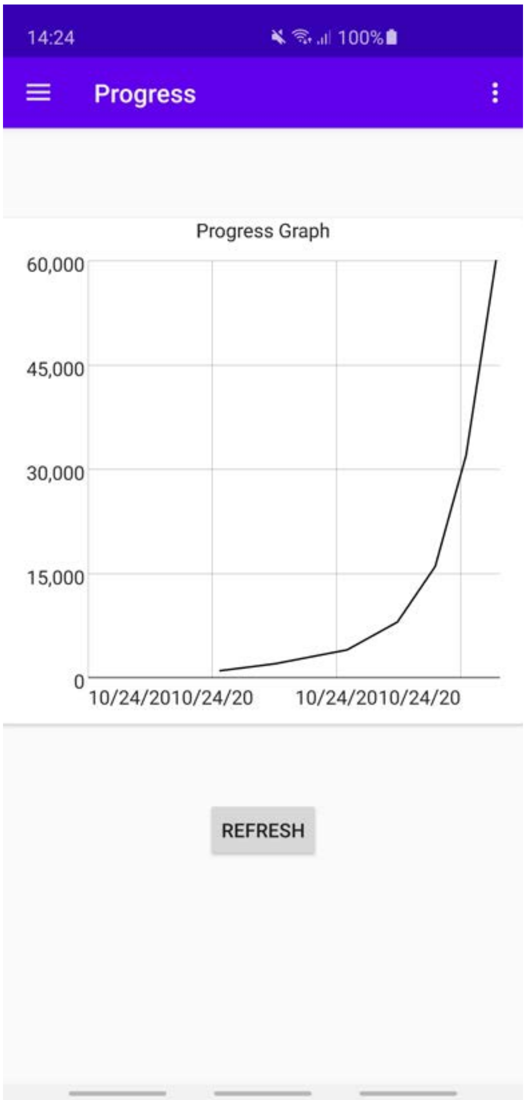
Now it was time to implement NFC and Bluetooth, we first worked on integrating NFC into the app using the default NFC way which took quite a while there are a lot of different methods on the internet which are compatible with all possible data types on the NFC records, but we only needed one. So the final method turned out to be way simpler and because of that it took quite a while to figure out.

Bluetooth was a little harder to get right, since to test it, the person with the Arduino had to meet up with the person doing the app development, so we had limited development time. After a lot of struggling we got Bluetooth to work. We then had to make sure the right messages were sent at the right moment and setup what happens when we receive a message. We decided to just use one word messages since that was easiest. If we receive a string with a color, we set the screen color to that and set the text to the name of the fruit. After a user puts a fruit in front of the NFC scanner, we get the message "correct" or "wrong" from the Arduino, dependant on which one we receive we change the color of the screen to red or green and display if it is correct or not. When 5 games are completed, the Arduino sends a number through Bluetooth. When we receive this message we store the score together with the Date object of when we receive it, we use this for our log. Due to the nature of the game, we could not figure out a way to nicely implement options, so unfortunately we had to leave it out.

Screenshots of the final app can be found below in figure 14. The source of this app can also be found in section A.5



(a) Game Screen



(b) Final Progress Screen

Figure 14: Screenshots of final app

After this was completed, the app was finished. It was a great learning experience since we did not have experience creating an app before. Not only did we learn how to develop an app, but we also learned how Bluetooth Low Energy works and how to integrate it into an Android app, together with reading data on an NFC tag and using it.

11.3 CAD Design

We studied the Special topic CAD design in order to create our product using 3d printing. That allowed the shape of the product to be original and innovative but also appealing and entertaining in order to fulfill the set of functional requirements.

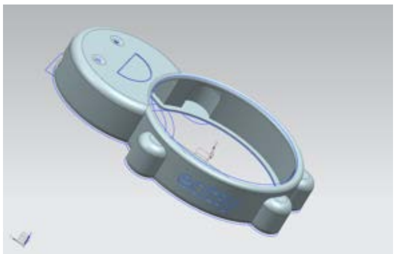
The topic was studied in week 4 when the first steps in creating the CAD model were taken. Firstly, we examined the uses of different programs for CAD modelling that could be used for creating files for 3d printing. We studied how AutoCAD, Sketchup and Siemens NX could be used for that purpose, what were the advantages and restrictions of each program and in what field they are commonly used and decided to use Siemens NX for the model.

The instructions in the module 4ONL00 Training technical design skills were studied in week 5. It provided general information on the basics of technical drawing. The importance of drawing organization, the use of scaling in digital drawing and the switching between different views and representations of the drawings were studied. We learned how to read and how to make basic technical drawings using CAD software which is applicable in many fields of engineering.

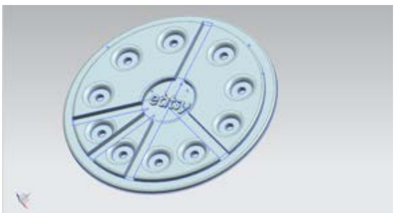
The exercises in the module were made in order to learn how to use the basic tools in NX for creating a model. We combined acquiring the basic skills of using NX with exploring different shapes the product could take. The exercises were initially done by two people in the group independently who put them into practice by creating different variants for the shape of the product. This was very useful to determine the desired shape of the product since the NX renders are easily read and the group could communicate and discuss different characteristics using them. Another advantage of using CAD design is the precision of the drawing in terms if dimensions which allowed to determine which design ideas are appropriate and which look attractive when made in scale. This feature of CAD design also allowed to use the model for finding exact placement and size of all components and openings.

With the skills from the exercises, two sets of prototypes were made and analysed (figure 15a, 15b and 15c). The prototypes were made by first drawing up quick sketches (figure 15d), which made it easy to communicate the shapes to the other team members, and then the model was based upon those sketches with preliminary dimensions. The goal of these sketches and models was to figure out how to make the prototype fun and aesthetically pleasing as well as how to fit in all of the electronics in such a way that the prototype would be safe for the children to interact with. With the sketches the models could be made with much detail. This made troubleshooting and analysing the prototype easy and effective.

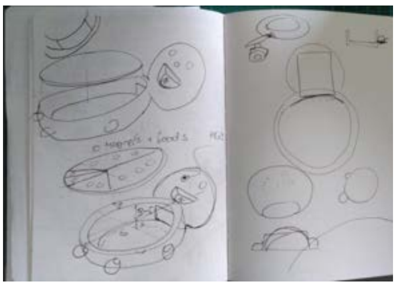
(a) Initial Prototype



(b) Second Prototype



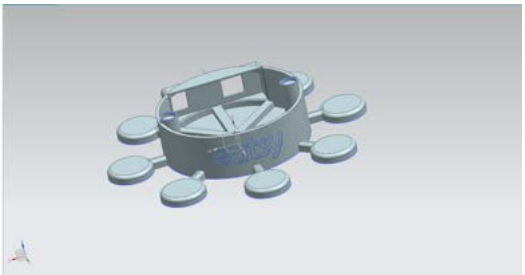
(c) Game Lid



(d) Basic Sketch Used

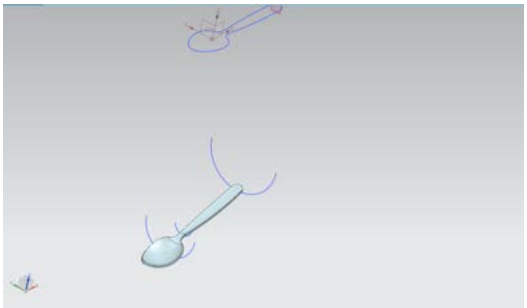
Figure 15: CAD Special Topic Initial Concept

In week 6 the final model for 3d printing of the product was created using NX. This model was the first prototype, which was determined to be the more fun and easy to make one. The module Training technical design skills was studied again in order to test the CAD model and prepare the file for 3d printing. The module was useful in finding out the possibilities, restrictions and requirements of 3d printing. We found out how to test a 3d model before printing it and how the time for printing is dependent on the shape. Some changes were required due to these technical restrictions. The findings from this preparation completely changed the way the prototype would look. However, due to the acquired skills, changes could be made quickly without sacrificing the 'fun' and 'aesthetically pleasing' functional specifications. This was managed by letting the prototype consist of three separate parts (figure 16). The CAD model was used to create the 3D print of the final product in week 7. In the end the exercises that were done have made the process of 3D modeling, although time consuming, very effective and have resulted in a fun and good looking prototype with which the intended user can interact in a safe way.



(a) Final Design

(b) Lid for Final Design



(c) Spoon For Game

Figure 16: CAD Special Topic Final Design

11.4 Project Risk

The reason for tackling this project already has been answered in section design goal. To quote this section: "We have identified that the challenges faced by children with Cerebral Palsy, in particular spastic Cerebral Palsy should be addressed. We found this disease to be the most significant from our initial ideas, and we believed it is the most unique issue to address."

The section of what specific goals must be reaches is also answered earlier in the report, namely, in the section design goal. To quote this section: "to develop a product which in some way will aid children who suffer from spastic cerebral palsy to eat, or practice eating, independently."

When looking at the phenomenon succes from an academic point of view, the project can be seen as a succes when everyone in our project group is satisfied with the grade he/she gained. Furthemore, to increase this feeling of succes, the product has to be completely functional and operative, this is of course related to the academic grade we will gain, because it is partly dependent of the functionality of the product.

What parties are affected?

- Children with CP
- Parents of the children with CP
- The people that grade our project
- Doctors that rehabilitate the children
- Retailer of product
- Retailer of our product
- Governement (law)
- Certifying bodies (it needs to be testedand approved)
- Possibly charity funds

The above mentioned parties will also modify our expectation of succed, as these parties can impact our grade and the functionality of the product.

First of all the people that grade our project naturally modify our defenition of succes in the way that we want a good grade for our project to feel succeeded.

Parents buy the product, and children on the other hand, should like the product, by this is meant that the parents buy things that their children tend to enjoy. This modifies our defenition of succes in the way that we need to make the product fun to use, to convince the parents to buy the product. Furthermore, this will increase the effectiveness of the product, because the children like the way the product works and will therefore use the project much more often.

Certifying bodies and the governement strive to make the product 100% safe and especially the governement will try to assure that the product delivers what it promises to deliver. The governement will use the certifying bodies to proof whether or not the product is safe and delivers what it promises.

Furthermore, the doctors will only prescribe this product to people who suffer from this impariment, if they believe that it is effective and safe to use. The prescription of doctors is ofcourse valueable and profitable for us as the makers of the product. Because doctors help us sell the product by prescribing it, we need to convince doctors that this product is effective safe and easy to use. This modifies our defenition of succes, because we now also need to strive to a high effectiveness. Moreover, the docters are also linked to the certifying bodies, because the docter can only prescribe products when the effectiveness is proven by independ parties. **What factors necessarily limits the things that can be achieved:**

- budget of 70 euros
- Time of 8 weeks
- Little expertise in a design project
- Corona virus (possibility of one or more students gaining the virus).
- The assignment (technical specifications).
- Some students have more input in the technical aspects of the project than others.
- A maximum of 5 hours 3D printing time.

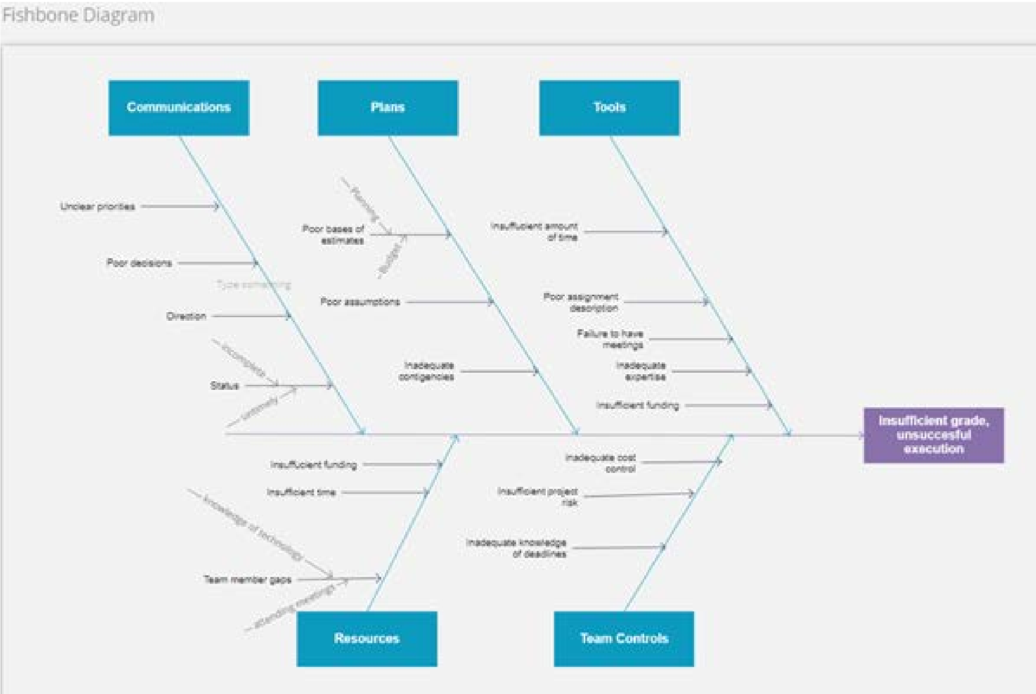


Figure 17: Fishbone diagram

With expertise of the chief transformation officer of GKN aerospace and the fishbove diagram, given above, we came up with 14 main risks. These risks are added in Appendix A.6, the risks are supplemented with matching objectives impacted, the impact, the likely hood, the severity, a fitting prevention and the cost of response. Furthermore, the figure below gives a nice and clear visual overview of the severity factor, with a being the first risk of the table and b the second etc.

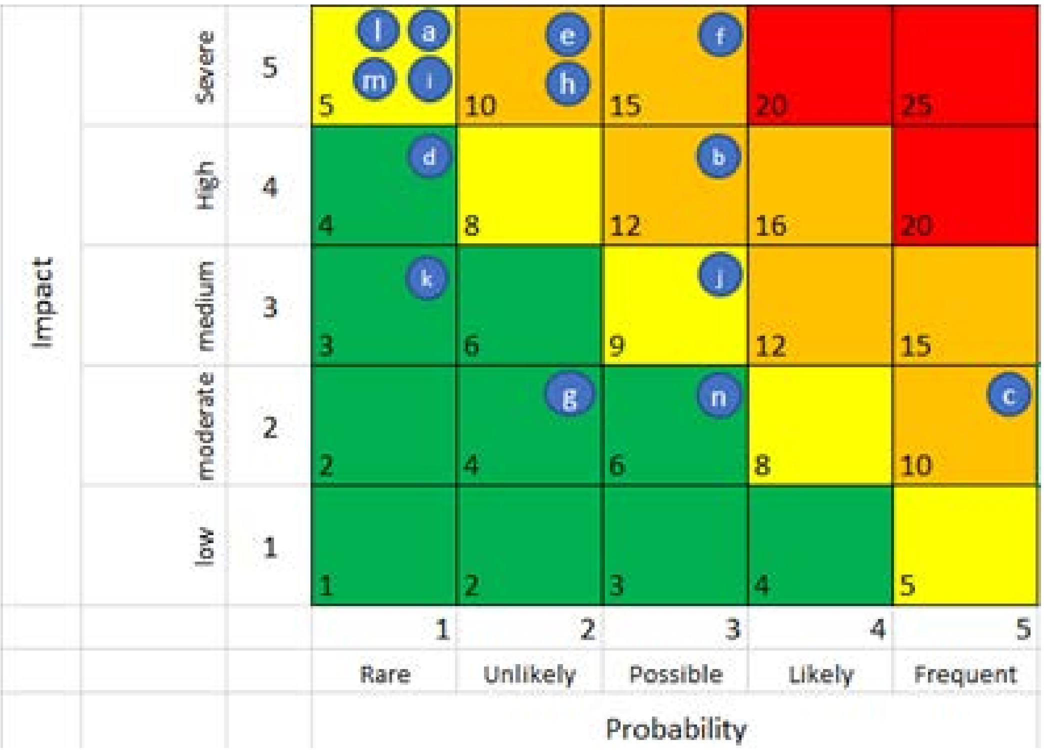


Figure 18: Risk matrix

References

[1] Arduino. Spi library.

[2] D. Christensen, K. Van Naarden Braun, N. S. Doernberg, M. J. Maenner, C. L. Arneson, M. S. Durkin, R. E. Benedict, R. S. Kirby, M. S. Wingate, R. Fitzgerald, et al. Prevalence of cerebral palsy, co-occurring autism spectrum disorders, and motor functioning–autism and developmental disabilities monitoring network, usa, 2008. *Developmental Medicine & Child Neurology*, 56(1):59–65, 2014.

[3] GithubCommunity. Mfrc522 library.

[4] Google. Build your first android app in kotlin.

[5] C. P. Guide. Occupational therapy for cerebral palsy.

[6] M. Horsman, M. Suto, B. Dudgeon, and S. R. Harris. Ageing with cerebral palsy: psychosocial issues. *Age and ageing*, 39(3):294–299, 2010.

[7] JetBrains. Kotlin programming language.

[8] S. R. Rudebeck. The psychological experience of children with cerebral palsy. *Paediatrics and Child Health*, 2020.

A Appendices

A.1 Circuit, Testing and Assembly

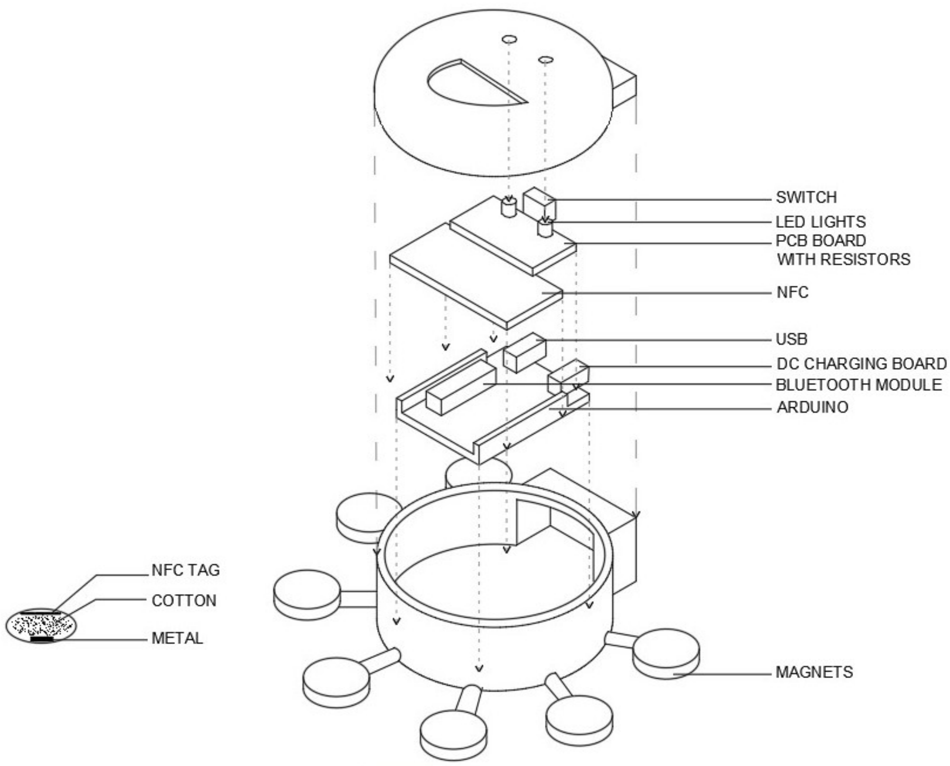


Figure 19: Assembly drawing

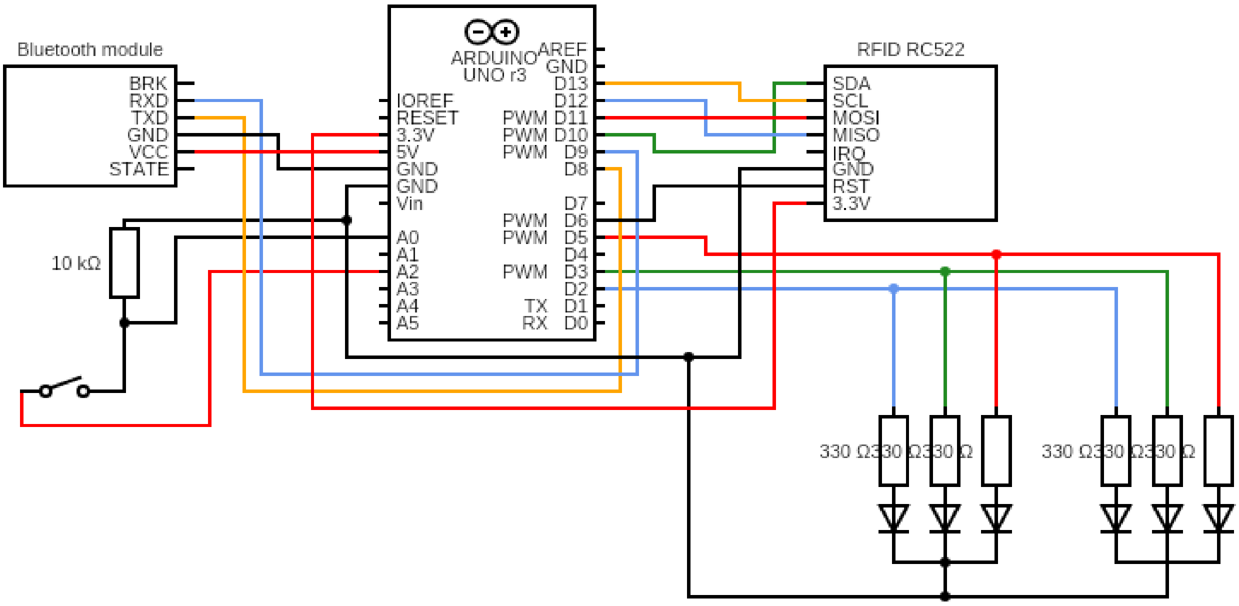
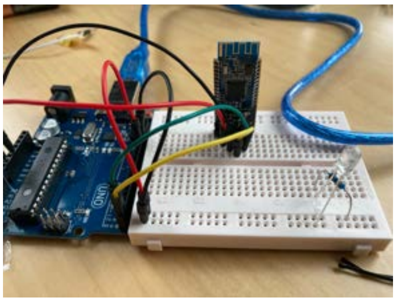
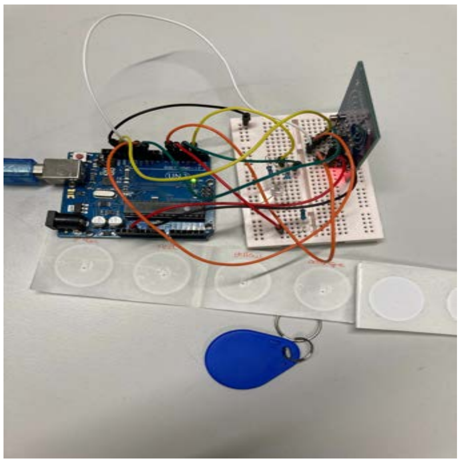


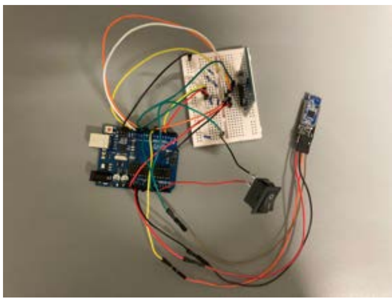
Figure 20: Final Circuit Diagram



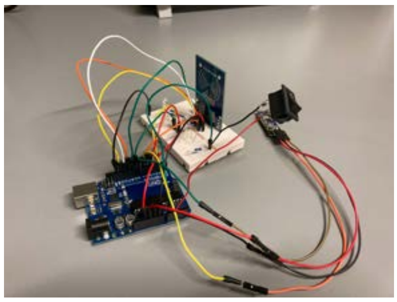
(a) Testing Bluetooth Functionality



(b) Testing NFC Functionality

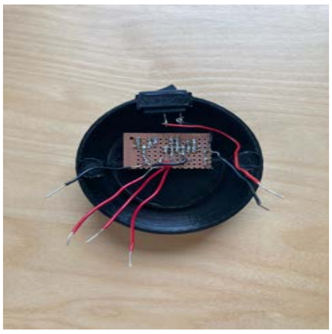


(c) Circuit Testing

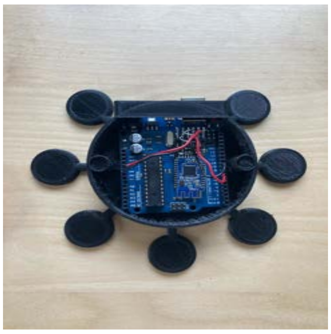


(d) Circuit Testing

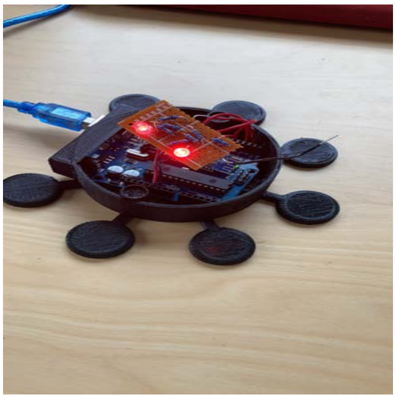
Figure 21: Circuit Testing



(a) Soldering



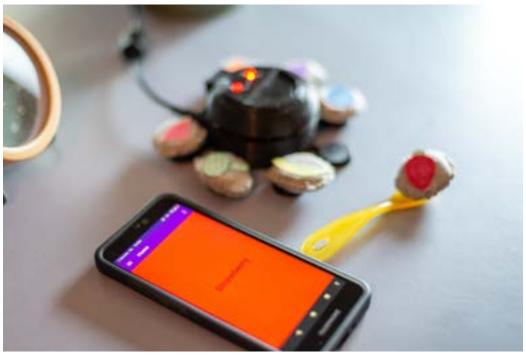
(b) Circuit Assembled



(c) Assembly

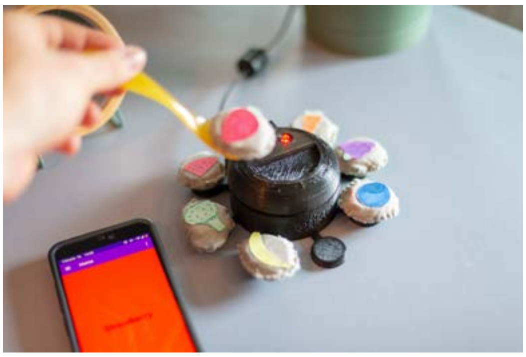
Figure 22: Assembly and Soldering

A.2 Final Product



(a) Smartphone App

(b) Front View

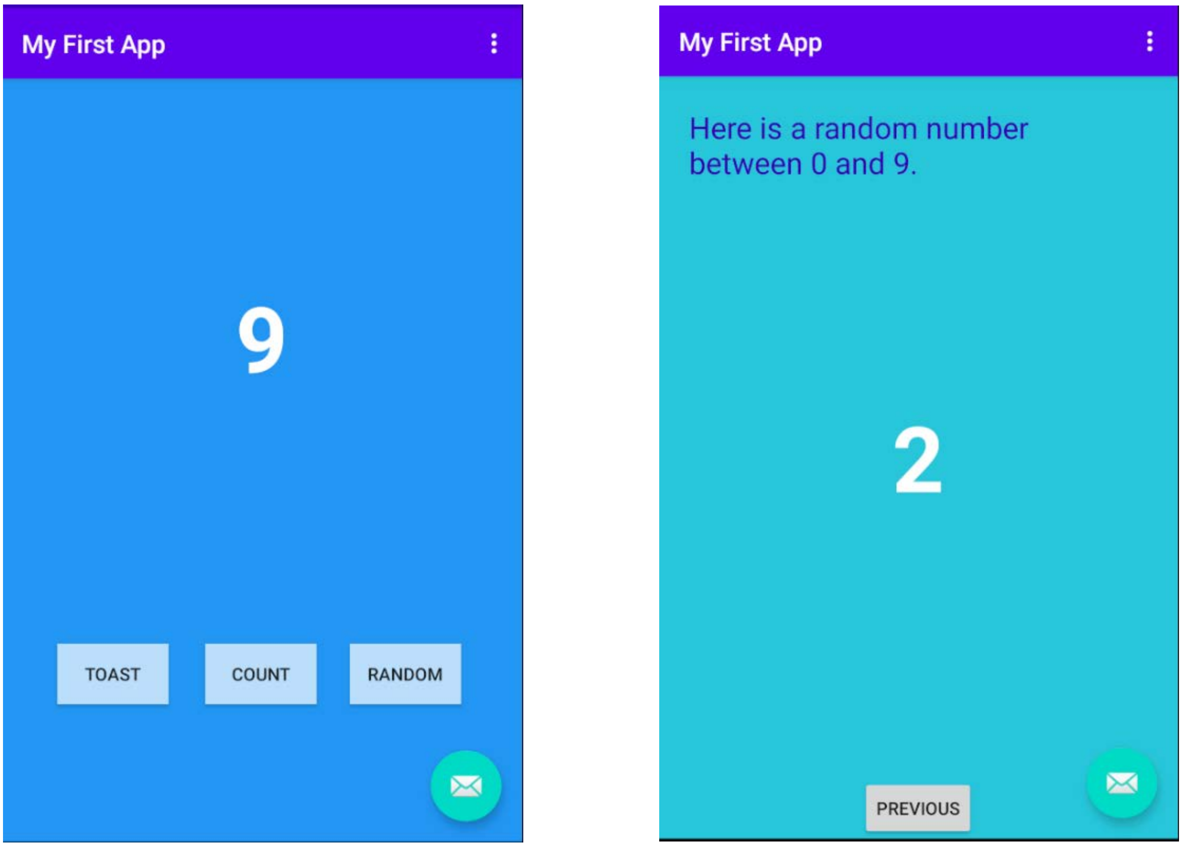


(c) Foods on Utensil

(d) Top-down View

Figure 23: Final Product Detailed

A.3 App Design



(a) Main screen

(b) Screen after clicking button

Figure 24: Screenshots of first app

A.4 Arduino Code

```
#include <SPI.h>
#include <MFRC522.h>
#include <AltSoftSerial.h>
AltSoftSerial BTserial;

const int pinRST = 6;
const int pinSDA = 10;

int redlight = 5;
int greenlight = 3;
int bluelight = 2;
int Switch = A0;
int Switchin = A2;
int reading;
int sendBT;

char c=' ';
boolean NL = true;

float speed = 1;

String startTag = "D8 E0 72 4A";

String green = "4 FB 7E FA 86 52 80";
String red = "4 01 7E FA 86 52 81";
```

```
String orange = "4 09 7E FA 86 52 81";
String blue = "4 0C 7F FA 86 52 81";
String purple = "4 10 7F FA 86 52 81";
String pink = "4 14 7F FA 86 52 81";
String yellow = "4 1C 7F FA 86 52 81";

String white = "4 18 7F FA 86 52 81";
String grey = "4 1C 7F FA 86 52 81";
String black = "4 20 7F FA 86 52 81";

String colors[][6] = {
  {"green", green, "200", "0", "255", "0"},
  {"red", red, "100", "255", "0", "0"},
  {"yellow", yellow, "50", "200", "50", "0"},
  {"orange", orange, "150", "235", "25", "0"},
  {"blue", blue, "100", "0", "0", "255"},
  {"purple", purple, "150", "255", "0", "255"},
  {"pink", pink, "200", "255", "180", "255"}
};

unsigned long int startTime;

int wrongCount = 0;
int gameCount = 0;

String chosen[] = {"", "", "", "", "", ""}; // Chosen variable

bool active = true; // Is game active

MFRC522 mfrc522(pinSDA, pinRST); // Set up mfrc522 on the Arduino

int getRandomSeed() {
  int rand1 = analogRead(A2) & 0x7 ;
  delay (10) ;
  int rand2 = (analogRead(A2) & 0x7) << 3 ;
  delay (10) ;
  int rand3 = (analogRead(A2) & 0x7) << 6 ;
  delay (10) ;
  return rand1 + rand2 + rand3;
}


void setRandomColor() {
  int randomfruit = random(0, 7);
  if(colors[randomfruit][0] == chosen[0]) return setRandomColor();
  for (int i = 0; i < 6; i++) {
    chosen[i] = colors[randomfruit][i];
  }

  Serial.println(chosen[0]);
  BTserial.print(chosen[0]);

  gameCount++;
  if (gameCount == 1) {
    wrongCount = 0;
    startTime = millis();
  }

  Serial.println(chosen[0]);

  active = true;
}

void colorful(int red, int green, int blue) {
```

```
  for (int r = 0; r < 256; r+= 255) {
    for (int g = 0; g < 256; g +=255) {
      for (int b = 0; b < 256; b+=255) {
        RGB_color(r, g, b);
        delay(100);
      }
    }
  }
  for (int i = 0; i < 3; i++) {
    RGB_color(red, green, blue);
    delay(600);
    RGB_color(0, 0, 0);
    delay(300);
  }
}

void RGB_color(int redlightval, int greenlightval, int bluelightval)
 {
  analogWrite(redlight, redlightval);
  analogWrite(greenlight, greenlightval);
  analogWrite(bluelight, bluelightval);
 }


void setup()
{
  SPI.begin(); // open SPI connection
  mfrc522.PCD_Init(); // Initialize Proximity Coupling Device (PCD)
  Serial.begin(9600); // open serial connection
  randomSeed(getRandomSeed());
  pinMode(redlight, OUTPUT);
  pinMode(greenlight, OUTPUT);
  pinMode(bluelight, OUTPUT);
  pinMode(Switchin, OUTPUT);
  pinMode(Switch, INPUT);

  BTserial.begin(9600);
  BTserial.print(10);
}

void loop() {
  digitalWrite(Switchin, HIGH);
  reading = analogRead(Switch);
  if(reading > 0) {
    sendBT = 0;
    if(!active) {
      setRandomColor();
      RGB_color(chosen[3].toInt(), chosen[4].toInt(), chosen[5].toInt());
      delay(500);
      if(reading == 0) return;

    }

    // Look for new cards
    if ( ! mfrc522.PICC_IsNewCardPresent()) {
      return;
    }
    // Select one of the cards
    if ( ! mfrc522.PICC_ReadCardSerial()) {
      return;
    }
    //Show ID on serial monitor
    Serial.print("ID tag :");
    String content= "";
```

```
    byte letter;
    for (byte i = 0; i < mfrc522.uid.size; i++) {
      Serial.print(mfrc522.uid.uidByte[i] < 0x10 ? " 0" : " ");
      Serial.print(mfrc522.uid.uidByte[i], HEX);
      if (i != 0) content.concat(String(mfrc522.uid.uidByte[i] < 0x10 ? " 0" : " "));
      content.concat(String(mfrc522.uid.uidByte[i], HEX));
    }
    Serial.println();
    Serial.print("Message : ");
    content.toUpperCase();
    if(reading == 0) return;
    if (active && content == chosen[1])
    {
      // Checks if serial is equal to the chosen serial
      unsigned long int timeTaken = millis() - startTime;
      Serial.println("Correct");
      Serial.print("Wrong count: ");
      Serial.println(wrongCount);
      Serial.print("Time taken: ");
      Serial.println(timeTaken);
      Serial.println();
      BTserial.print("correct");
      if (gameCount == 5)
      {
        int score = max(0, round(60000 - (timeTaken + wrongCount * 5000)/1000));
        Serial.println("Game ended");
        BTserial.print(score);
        gameCount = 0;
      }
      active = false; // Sets active to false so new game starts.
      colorful(0, 255, 0);
    }
    else if (startTag == content)
    {
      active = false;
      Serial.println("Start tag");
    }
    else if (active)
    {
      Serial.println();
      Serial.println(content);
      Serial.println();
      Serial.println("False");
      BTserial.print("wrong");
      wrongCount++;
      colorful(255, 0, 0);
      RGB_color(chosen[3].toInt(), chosen[4].toInt(), chosen[5].toInt());
      BTserial.print(chosen[0]);
    }
  } else
  {
    active = false;
    RGB_color(0,0,0);
    if(sendBT == 0)
    {
      sendBT = 1;
      BTserial.print("off");
    }
  }
  delay(100);
}
```

A.5 App Code

The source code of the android app can be accessed through the URL:
https://tuenl-my.sharepoint.com/:u:/g/personal/s_p_jordaan_student_tue_nl/EcebEjWAv0RC
qlNBfoAQrlgBqepKarkrR6AOFNl3FkQQHA?e=U5HsQz

A.6 Project Risk

Risk	Objectives Impacted	Impact	Likelihood	Severity	Prevention	Cost of response
a. Not having the report finished in time	All	5	1	5	A good and clear planning, in combination with a weekly check on whether it is achievable	10 weeks (re-attending the course)
b. Electrical components breaking	Success of the product	4	3	12	Keeping a close eye on the components and put them in place with care	1 day (delivery time)
c. Team member gets coronavirus/has to test	Passing grade	2	5	10	Obey the Covid-19 rules set by the RIVM and TU/E	10 days (quarantine time)
d. Electronic parts stop working while the user is using the device	Success of the product	4	1	4	Keeping a close eye on the components and put them in place with care	1 day (delivery time)
e. The device doesn't help the user train their muscles	All	5	2	10	A continuous check on the efficiency of the product, supported by a good literature review with correct research.	10 weeks (making a new design)
f. The device isn't fun to use	Success of the product	5	3	15	Do literature research on what makes a game a game and implement this in the design.	4 weeks (adjustments to the product and extra research)
g. The tutor/teachers are not satisfied with the prototype	Passing grade	2	2	4	Being on track with the planning, keeping a close eye on the assignment descriptions	2 weeks (redesign of the prototype + new brainstorm sessions)
h. Certifying bodies do not approve the product	All	5	2	10	-	10 weeks (making a new design)
i. A consisting law which makes it illegal to use	All	5	1	5	Do a literature search to find laws that might make our product illegal, then adept our product to make it legal	4 weeks (adjustments to the product)
j. The 3D printing will take longer than 5 hours	Planning	3	3	9	The design should not be too complicated	1 day (make the concept smaller)
k. The 3D printing costs are too high	Planning	3	1	3	The 3D printer should not use a lot of material so the design should be small.	1 day (make the concept smaller)
l. Not having the video for the final presentation in time	All	5	1	5	A good and clear planning, in combination with a weekly check on whether it is achievable	10 weeks (re-attending the course)
m. Not having the video for the intermediate presentation in time	Passing grade	5	1	5	A good and clear planning, in combination with a weekly check on whether it is achievable	-
n. Bluetooth function does not work to expectation	Success of the product	2	3	6	Contacting a person with expertise, enough research on the topic	1 week

Table 11: Risks