Interactive Playground Toy

By James Spofforth

Selecting the contextual challenge:

How can products be used to make playtime in the primary school playground more interactive and fun?

- Safety features
  - No sharp corners
  - No Exposed wiring
  - Should be secured
- Themes/colours
  - Animals
  - Vines
  - Bright Colours
  - Jungle
- What environment will it be in?
  - Fully Exposed
  - Partially covered
  - Outside
  - Floor usually concrete or rubber
- Sustainability
  - Must abide by legislation
  - Recyclable materials
- Requiments due to environment
  - Water proof
  - Temperature resistant
  - Wear proof(durable
- Target audience
  - Children in primary school will be aged from 4-11
  - Clients could be parents, councils and head teachers
  - What are the user groups / interests between the users?
  - What percentile should I use for the users?
- anthropometric data
  - Sizes hands/arms and legs/feet
  - Height of users
- Materials/componenets
  - Wood (perhaps cedar)
  - Plastic (perhaps ABS)
  - Electronic components
- Existing products
  - Giant connect 4
  - Jenga
  - see-saw
  - Puzzles
  - swing set
  - Movement

How can products be used to create a relaxing environment?

- Safety features
  - Grip to prevent sliding
  - Smooth edges
  - No exposed wiring
- Shapes
  - Natural shapes (eg water drops or leaves).
  - Cylinder
  - Indoors
  - A hotel lobby
  - Sphere
  - A hotel room
- What environment will it be in?
  - Needs to abide by environmental regulations
- Sustainability
  - All recyclable
  - Wood
  - Plastic
  - Metal
- Possible materials
  - What's the best plastic to use?
  - Metal
  - LEDs
  - Wood (ash)
- Target audience
  - Are people staying in hotels more likely to be stressed?
  - What does the target audience find the most relaxing?
  - 46% of guests are aged 18-36, what about the rest?
- anthropometric data
  - Volume data (how big overall)
  - Size of fingers
- Relaxing things
  - ocean noices
  - Sounds of nature
  - Classical music
  - Blue/Orange lighting
- Existing products
  - White noise machines
  - Scented Candles
  - Colour changing lights
  - Oil defusers

My Decision:
After initial brainstorming into these preferred contextual challenges, I **have chosen theme 1B**: “How can products be used to make playtime in the primary school playground more interactive and fun?” because I believe it has a greater variety then theme 2A.

Investigation/Research:

Who are the users?

With this particular contextual challenge it is important to note that the clients for this product will be different from the users.
The following is a list of potential users and clients:

Users:
- **Children in primary schools**
- **People that may have learning difficulties or a condition**

Clients:
- Kids clubs
- **Primary Schools** (usually head teachers)
- Local Councils (buying for local playgrounds)

The clients/users in bold are what I'll be mainly focusing on due to the requirements/wording of the contextual challenge, however, that doesn't mean the final product won't appeal to the others.

As can be seen in the brainstorming phases of the product, I know usually children in primary schools are aged 4 – 11, however, after initial user research I have categorized the users into three user groups: ages 4-5 (reception – year 1), 6-8 (years 2 – 4) and 9 – 11 (years 4 – 6). Those user groups were decided upon by how similar the interests between the children of those ages where. Grouping the users in this way will allow me to defiantly meet user requirements with a prototype/product. The categorization has to be done due to rapid changes in appropriate themes and interests during child development. The following interactive products illustrate this point (Product on the left aimed at 4-year-olds and the other aimed at 8-year-olds:

User needs and wants:

Here is a list of the applicable information towards the contextual challenge in different user groups:

Ages 4 - 5:

- Like to come up with dramatic make-believe scenarios in which they act out with one another and play different roles.
- Enjoy stepping into roles of power (so interested in):
  - Parenting
  - Doctors
  - Policemen
  - Lions (animals in general)
  - Superheroes
- (Due to cognitive skills increasing) they desire objects with realistic detail but not concerned about them mirroring reality.
- Fine motor skills are starting to increase so enjoy toys that require physical skills however they are relatively risk-averse.

Ages 6 - 8:

- Themes such as superheroes or friendship very popular.
- Start using logic to solve problems.
- High interest in physical outdoors play.
- Want to develop on specific skills such as physical games and games that require greater hand dexterity.
- Greater endurance, stronger and more willing to take risks as in rough and tumble or risk-taking games.
- They pay higher attention to detail.

Ages 9 - 11:

- At this age, some basic games become predictable and boring.
- They prefer products that incorporate advanced motor skills and logical thinking.
- Although not toys they enjoy activities such as:
  - Robotics / automation
  - Advanced science projects
  - Computing

From this point on I am going to focus on designing a product for children aged 6 -8 because in my opinion it allows for more diverse designs. Summary of user needs and wants:

Form: Any figures should be accurately drawn, (Client is adamant on) no sharp edges.
Function: The product should require some form of logic and physical play. The user likes using their hands to interact with products. The product should incorporate a safe amount of risk to properly engage the user.

Investigating existing products:

The following pages show a variety of existing interactive products that have been evaluated against a set a criteria (e.g. form, function, etc).
This evaluating will help me to solve the contextual challenge and perhaps give an understanding of what features the client/users want in a new product.
After the evaluations of the products I will be asking the client specific questions that will allow my to gain a deeper insight into the needs of the user (in this case client rather than the users themselves)

3D Maze Magic Cube:

Function:
The purpose of this product is to entertain and educate its user as it is an interactive toy. The user has to navigate a small ball around cube maze and get it to the other side. It allows the user to practice their brain memory skills (as it's marketed as a challenging puzzle) and improve hand skills/mobility. It tests the user and also improves on their patience, perseverance and hand-eye coordination. Other the six sides of the maze there are wholes to which if the user isn't careful the ball may fall through the go back to the start.

Form:
It has an outer completely transparent cube which has rounded and smooth edges. Inside there is a dark blue smaller cube but with a maze design on all 6 sides. All the lines on the edges have rounded ends and a smooth finish all around.

Cost:
On amazon it is priced at £3.79. This price is generally low for an interactive toy and may reflect on its ease to manufacture therefore cost will be low.

Materials:
This product is made from **ABS** and the small bead is made from **steel.**

Safety:
All the sides and corners of the exterior cube are rounded and smoothed which will reduce the chance of them doing any damage to the client as they aren't sharp. Another safety feature is that the ball is enclosed within the toy meaning that it can't come out; this means it is not a choking hazard.

Environmental:
Since the product is made from ABS (which is a thermoplastic) it can be easily recycled. This is great for the environment as new ABS plastic doesn't have to be made or manufactured for new products reducing CO_2 emissions which would otherwise be created. However, one disadvantage for the environment is that ABS (like most plastics) is not biodegradable so it will persist in the environment which may harm animals. Also, the steel bead which is used in the product is easily recyclable but it is not biodegradable.

Client:
The client for this product will be the following buying for children (however some children may buy it for themselves):
Parents
Nursery, Primary and Secondary schools
Kids Clubs

Performance Requirements:
The encloser means that the ball won't escape the product, so it won't go missing. Its use of materials means that it should be durable enough for an indoor environment.

User requirements:
Through logical thinking, it prompts the user to develop key neural skills. It also has rounded edges meaning the product can be easily handled without discomfort.

Giant Noughts and Crosses:

Function:
This product is a large-scale version of the classic game noughts and crosses otherwise known as tic tac toe. The function of the product is to entertain and occupy up to two children at once whilst still enriching their strategy skills. This product is designed to fit onto a jungle gym however it can be attached to fences or made to be free-standing.

Form:
The interactive middle part of the product is made up of 9 yellow cylinders arranged in a 3 x 3 formation. Each third of the cylinders has either a red cross, blue noughts or playful green monkey which match its 6 green attachment points, 3 at each end. The attachment points are half-spheres but with a flat top, the part that faces you, and flat top and bottom.

Cost:
On most online retailers it is listed for £65.99. This price tells us it is a premium product however it's still a very reasonable price for schools and possibly parents.

Materials:
The majority of this product is made up of "UV-stabilized" HDPE however it also includes an inner steel frame, steel screws and stickers made of vinyl.

Safety:
The first safety feature of this product is that it is designed to be attached to a fence are other stable objects making it self-stable, provided that it's mounted correctly. It being stable means it will not fall onto anyone, causing them harm. Secondly, the product's edges are smooth and not sharp, reducing the chance of it wounding a person or causing any other harm.

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Users:
This product is designed for anyone 3 – 10 years old however the most interest towards the product will be from the ages 3 – 6 as 7 – 10 years old's may be to mature. The product isn't specifically designed for any child with a physical disability; however, the large symbols may allow the partially sited to be able to use the product easily.

Environmental:
The majority of the product is made of HDPE, which is a nonbiodegradable so it's important at the end of the product's life that it is recycled. If the HDPE isn't recycled it will persist in the environment for centuries which is especially bad due to the large amounts used. since it doesn't require any electricity or emit any greenhouse gasses or pollutants it won't cause any additional harm to the environment.

Clients:
Children aren't the clients for this product as it is too expensive for them to buy themselves but an adult buying the product for children are the clients. These include parents, but especially local councils and primary schools.

Performance Requirements:
This product, being designed for an outdoors environment, has, on the whole, an appropriately robust construction (due to the HDPE and its UV resistance). However, the stickers may be worn down or lose adhesion due to harsh weather and rough use. This may mean that they have to be replaced, adding further cost and complications to the product.

User Requirements:
As mentioned in the form section, this product develops strategic skills and due to its multiplayer capabilities, it prompts a health sense competitiveness.

Giant Noughts and Crosses:

Cost:
The listed price for this product on its main website is £189.99. This price will reflect on its size as larger products cost more to transport and ship to a customer/store however this is done in a flat-pack like way but it still does weigh 12kg (when shipped). The price may also be this high due to the number of materials it uses however this isn't a large factor.

Function/ User requirements:
The function of this product is to entertain children by making them compete against each over by being the first to complete a series of 4 coloured cylinders. One player must achieve this before the grid fills up and all 42 playing counters/pieces have been used. At the bottom of the product, there is a sliding rectangular piece with handles at each end, when this is pulled out any pieces in the grid will fall out of the bottom and the grid will be blank and reset.

Clients:
The clients for this product will be headteachers or people in authoritative positions in primary schools. It's high price and size means it is unlikely to be bought by parents. Also, since this product has external playing pieces it is unlikely to be bought by local councils for parks as the pieces are probably going to be lost.

Materials:
This product is made up of "thick, heavy-duty plastic". Since plastic is being used it won't rust, less prone to corrosion and possibly lighter than a wood alternative.

Form:
The main piece of this product is located in the middle and is a dark blue grid of 7 x 6 circles. At the side of the grid, there are two large stands, one at each end, which are dark green with a glossy finish. The top of the blue gird has a large notch cut out of the top in which there is a sticker saying "Connect4" and there are three-cylinder playing pieces stickers at both ends. The slide at the bottom matches the same dark blue of the grid.

User:
This product is recommended for 8 years + because you need to be tall enough to reach the top to insert the playing pieces. A particular target audience however if it were to have one it would be from ages 8 – 11. However, there are many adult variations with less vibrant, more mature colours.

Performance Requirements:
The board should be easily cleared (this is achieved through the bottom platform that can be easily pulled out). This product is suitably durable for its environment; however, the product may still topple over in windy conditions due to its large surface area.

Safety:
Due to its weight, when fully assembled with all pieces, being around 10kg it is unlikely to be blown over by weather however due to its large surface area it may be caught by strong winds and subsequently be blown over onto someone or something, the legs at both sides have been designed to prevent this with there upside-down semi-circle design. Another safety feature of this product is that it has smoothed edges rather then them being sharp. This safety feature has been implemented as its target audience is more likely to impale or generally injure themselves if sharp edges had been used. It's use of rounded smoothed edges reduce the chances of injury happening.

Environmental:
Due to its size and weight, more fuel will be required to transport it. This leads to more CO_2 emissions and since CO_2 is a greenhouse gas it leads to global warming and subsequently climate change.

Pogo ball (does go by other names):

Function/User Requirements:
The object of this toy is to stand on the outer rim (where footprint marks are shown) and once on, be able to balance to stop the rim from touching the ground and then squeeze their feet against the inflatable ball and bounce. This challenges children, and therefore, entertaining them. The Saturn skipper can be either played with by one person or a group of children which then can coordinate themselves on multiple Saturn skippers to balance themselves more easily. When the product is used it's a good form of exercise, improves core strength, balance and coordination. Also, if a group of children are using them it can improve co-operation skills.

Form:
A "pinkish" red ball runs through the centre of the product and is intercepted halfway by a smooth grey disk which has a satin finish. On the up-right side of the disk, there are many outdent lines in the shape of feet and stars. The foot shape outdent has many curved and diagonal lines inside of it. Where the disk touches the ball there is a thin circular rim. The product resembles Saturn giving it its name "Saturn Skipper" however this product does go under other names.

Cost:
From playground toy suppliers this product is sold in packs of 6 for £64.95 due to delivery purposes. These means one would cost £10.82 however you would have to consider delivery prices. Return to this.

Safety:
One risk of this product is that someone may fall off it causing that person harm to themselves or someone else but this is product tries to prevent this as the grey rim people stand on has a textured surface which adds grip to it, therefore, reducing the chance of someone slipping/falling off it when in use. Also, the top of the rim is smoothed which may prevent scratches especially if stood on with bare feet.

Users:
The product is listed as being suitable for people aged from 3 - 11 years old. It's not very inclusive towards children with a physical disability either due to its function or the product's risky nature.

Materials:
The inflatable ball in the middle of the product is likely to be made from vulcanized rubber. The grey rim is made from HDPE.

Environmental:
During it the products lifetime it does not require any energy, therefore, will not cause harm to the environment. The plastic the rim is made from can be recycled therefore reducing emissions as new plastic doesn't have to be processed. This reduces the total amount of energy needed to make the plastic by approximately 76 per cent. However, if the product isn't recycled the plastic will persist in the environment which may cause harm to animals. In most cases, recycling facilities won't accept the rubber the inflatable ball is made from and they must be taken to specialised recycling plants. This leads to less being recycled and since rubber isn't biodegradable it will, like the plastic, persist in the environment and may cause harm to animals.

Clients:
Headteachers and people in charge of kid's clubs will be the main clients for this product (especially as it is sold in packs of 6). However, it will not be suitable for local councils buying for playgrounds as the product is likely to go missing.

Performance Requirements:
The lip in the rubber capsule will prevent the disk in which a user stands on from coming out. This product will require monthly maintenance as it can deflate and no longer be usable without reinflation.

Client Views on existing products: (Client description on market section)

Is this product suitable?	This is defiantly orientated at the 6 -8-year-old market however it doesn't seem to be robust enough for the playground environment where there are concrete and other hard surfaces. But in the classroom setting, this product would be of great interest and they would be bought in larger quantities and competitions could be held based on how quick the children can solve the puzzles. Also, the children may argue over it as it's not stationary.
Is it interactive and fun?	The idea of the maze is very interactive, and children would look forward to playing with it as soon as they saw it. If the maze concept were made into a playground toy it would have to be robust enough, but it would make a very interactive and fun toy.
What do you think of the colours?	The product's colours don't make it not as eye-catching as it could be, the blue gives it a more serious air and makes it more business-like / professional but for the 6 – 8 age group the colours should be changed to either directly opposing colours (e.g. white and black) or primary and secondary colours that give a contrast.
Is the cost reasonable?	The cost, £3.79, is reasonable we, and other primary schools would be will to afford that.
What are your thoughts on safety of the product?	From what can be seen this product looks safe to be used by children. Especially since the ball is enclosed and therefore can't be thrown or chocked on. Also, the smoothed edges of the cube is a sensible precaution.

Pros	•Very interactive •Fits in with target audience •Reasonable cost
Cons	•Colors aren't effective •Not robust enough •Not stationary

Is this product suitable?	This is exactly what we are looking for our playgrounds, provided that it's robust enough. This game has always been popular with multiple age groups and this will reflect on their interest as there may be ques, in the middle of the playground, of children waiting to play with it. However, if in a playground environment it will have to be very robust.
Is it interactive and fun?	There is plenty of interaction and it will appeal to the children's competitive nature and you can have them compete against each over in groups (for example friends, boys vs girls, and groups of two) and this makes the product fun for the children.
What do you think of the colors?	The colours are good, and that sort of colour scheme should be brought into the new product.
Is the cost reasonable?	The price is reasonable and £66 is the sort of price we'd be looking to pay for this sort of thing.
What are your thoughts on safety of the product?	Most of the obvious precautions you have to take into account a child's toy have been implemented into this product. However, one concern is that children may get their fingers trapped between the rollers, the chances of this can be reduced if the gap between the rollers was smaller, so fingers can't get in, or make the gap between them large enough so fingers can't get stuck in between them in the first place.

Pros	•Reasonable cost •Very interactive •Teaches Co-operation •Colors used
Cons	•May easily break overtime

Is this product suitable?	This product, in my opinion, is orientated at an age range of people aged between 5 and 11. The pieces or counters are a concern as they are likely to end up on the floor around the game and on the playing field so this means they will have to be picked up by a member of staff. So, the fact the pieces are external is a huge drawback in the way that children may skid them across the playground floors creating a hazard, if it was used as intended they'd have fun with it however it may be misused by the unruly side of the populous. This game should, therefore, be shrunk down and played in a classroom setting.
Is it interactive and fun?	A child in primary school would very much enjoy this and find it interactive and fun, whilst working on their forward planning strategic skills and the ability to change strategy when it starts to fail which is great.
What do you think of the colours?	The colour scheme is good and will appeal to all children in primary schools.
Is the cost reasonable?	Because of the potential behavioural and intellectual gains this product has £190 is something the school would be willing to pay.
What are your thoughts on safety of the product?	The obvious safety concern with this product is the loose parts where its possible fingers could get caught as plastic counters come down as they are hard and not soft however this is partially prevented because the edges of the counter are smooth. Also, the pieces may be thrown around and the children may end up throwing them at each other.

Pros	• Larger range of target audience • Very educational for the children • Priced reasonably
Cons	• External pieces may be misused.

Is this product suitable?	This product is defiantly suited for the playground and it is not just for the strongest fittest child but it is also is for children that have or are devolving a good sense of balance. I think this product will be very good at training co-ordination and it would allow several of the children to compete with each over. Also, team forming instincts would be encouraged with this if multiple where used, therefore, making this product something you would want several of. It would also train core strength and balance.
Is it interactive and fun?	The risk of falling would very much excite a child and they will find that the interaction, to prevent themselves from falling, fun.
What do you think of the colors?	The colours are good and the patterns on the top will appeal to the children as they suggest action and fun. The rim is going to get dirty as children will be standing on it, this means it will have to be quite a subdued colour and it is. The ball part of it should be and is as bright therefore as eye-catching as possible so that it appeals to a child.
Is the cost reasonable?	The cost of £10.82 is very good value and that will encourage several to be bought.
What are your thoughts on safety of the product?	When a child stands on it you would want to make sure it deformed in such a way that the edge of the ring is quite close to the ground so that if a child did fall off they wouldn't have far to fall, this will reduce the chance or severity of injuries. The texture on the product also seems to be designed so that grips to shoes and this will reduce the chance of a child slipping on it which is a defiantly a positive.

Pros	• Very good price • Appeals to a wide range of children. • Trains and exercises
Cons	• risk of injury

Market research

In this section, I will be describing my client to explain why they were chosen. After that, I will be focusing research on the specific market research and the context the product will be used in.

My client:

By choosing a specific client I will be able to gather much-needed feedback to allow for good refinements and eventual a good product that meets all the needs of the client.
My Client's name is Jonathon Smith and he is the Headteacher of two primary schools located in Cambridgeshire. I selected this client because they perfectly suited the primary school aspect of the contextual challenge. After an initial interview, The problem my client has identified is that the "children, especially in the younger years, are coming in from playtime, whether from morning or lunch break, loud and agitated". He then goes onto say that to fix this problem "We need a toy that exercises children either physically or mentally, but preferably both, for are playground so that after the children's playtime they aren't agitated or excessively loud during lessons. This will improve their concentration and result in the pupils getting better grades". The client doesn't mind what year groups the prototype for the product is aimed at, as long as it's aimed at children between 4 and 11.

How big are the markets?

It's important to note that although the product will be designed around primary schools that does not limit the market to just them. Therefore, I will also be conducting some market research into other clients.

Primary Schools: 20,832
Kids Clubs: 20,000
Local playgrounds (which local councils buy for): 16,000

After conducting research into the size of the different markets it's clear that the overall market is defiantly large enough. This also goes to show how important it is that the product not only suitable for primary school playgrounds but also Local playgrounds and kids clubs.

What is the importance of playgrounds (public or primary) and interactive toys?

As an initial introduction into this question, I will be looking at the Governments report on "public parks", this is a particularly useful source of information as it is reliable and answers why playground environments are so important.
Firstly, A survey undertaken by Fields in Trust in November 2015 found that 69 per cent of respondents believed that the loss of parks could be detrimental to children's development due to the child's loss of interactivity with the toys- thus its evidently important that interactive toys are a key part of a child's development. This is also demonstrated as 90% of households with children under five visit or use their park at least once a month. Furthermore, "The rights of children to play and join in other recreational activities are enshrined in Article 31 of the United Nations Convention on the Rights of the Child (UNCRC)" meaning that the government also recognises the importance of a child's play.
Parks (and therefore toy) are also important for physical and mental health as shown by the fact that almost everyone who inquired in the "Fields in trust" survey, raised the contributions of parks to both physical and mental health.
In another study, the key things interactive toys develop (clients will want as many as possible) are Cognitive Skills, Social Skills, Language skills and motor skills.

What are the safety requirements of the Market?

Since the prototype is for a product that will be deployed in a playground environment, it's important that it successfully meets all the safety standards playgrounds are subject to.
A study done in 1998 (please note the statistics aren't significantly different to todays) shows that 1.2 to 1.5 million children had accidents resulting from leisure activates. However, fixed playground equipment was only responsible for 41,700 accidents, which is a very low percentage – signifying fixed playground equipment is much safer.
There have been several studies in identifying playground hazards, one of which regards fall injuries- showing that the number of injuries was greater for equipment over 1.5m. This, therefore, indicated that my product should be no taller than 1.5m. If the product could put the child in risk of a fall injury it mustn't be over concrete; suitable surfaces are sand, grass or rubber. One study done by "Sosin et al" identified what the best and worst surfaces were for such playground toys; he found that "The incidence of fall injury was found to differ with under-surface type: sand was lowest (7), grass, rubber mats and gravel had similar rates (12 to 16), and concrete was highest (44)."

Research in the context the product will be used:

By researching the context in which the product will be used I'll be able to make sure the product is suitable for its environment.
Within a primary school (and public playground) the environment is either:

Partially covered:

Fully exposed:

After speaking with my client, they said they would prefer if the product was suitable for fully exposed conditions. Designing for fully exposed conditions is better because it means that the product is apt for all environments, increasing the potential market (as the product's still suitable for those who don't have covered conditions.
Performance requirements for a fully exposed environment (compared):

- UV Resistance
- Temperature resistance
- The product must be waterproof (if there are electronics)
- Rust/corrosion resistance

In both cases, if the product involved electronics, it would be impractical to design a product that required external power so it would have to power itself.

Research into possible materials:

At this stage, it is difficult to conduct research into specific materials as I don't know what I am specifically designing. However, I can research materials that will withstand the outdoors (playground) environment the product will be situated in. I will also research materials commonly used within the market/outdoors environments and in my four similar products, showing why they're suitable. All the materials that are chosen, as well as their amounts, will have to be chosen with present and future environmental regulations.

Material requirements:

If the material being used where exposed it will have to be weatherproof meaning that it will have to be temperature, rot, high humidity and UV resistant as well as waterproof (if required). If the material on its own isn't suitable, it may be possible to treat it to make it comply with the requirements. If the material isn't exposed it will just have to be temperature resistant (i.e. won't easily deform with heat). Another vital requirement Is that it must be durable enough to survive slightly more than general levels of "wear and tear" as the product will be in constant use from children.

Materials in the four similar products:

- ABS
- HDPE
- Vinyl
- Stainless steel

Other components used in market/outdoors environments:

- Acrylic
- Mild steel
- Western red cedar
- Marine plywood

Stainless steel:

Stainless steel is often used for har-waring applications such as sinks and countertops due to its high durability and corrosion resistance.

Mild steel:

Mild Steel Is known for its strength and high durability. However, if left untreated, it can rust easily, therefore, paint will need to be applied.

ABS:

ABS is known for its impact resistance, toughness and (with minor modification) heat resistant. Furthermore, unlike most materials, its impact resistance does rapidly decrease at lower temperatures but on its own, it isn't perfectly suitable for an outdoors environment because ABS can be degraded/damaged by sunlight.

Western Red Cedar:

Western Red Cedar is commonly used outdoors as it is naturally rot and decay-resistant due to naturally occurring compounds in the wood. It also doesn't tend to warp if made wet. As it's moderately durable for use in a playground environment. Easy to work with, whether with hand or power tools and finish. It's relatively light meaning that it can be relatively easily transported.

Marine plywood:

Marine plywood is often used in environments similar to ones of outdoor playgrounds. This is shown through its use cases for things so as benches for outdoor areas of restaurants or in parks. Marine plywood is suited for this use case because it doesn't swell up or rot as much in exposed environments when compared to plywood as it often has more layers and is made with waterproof glue. Although the glue is waterproof, the wood, in general, is not as the glue just prevents delamination. Therefore, a waterproof finish must be used if water mustn't be absorbed into the product. Like Western Red Cedar, Marine Plywood is resistant to bending/warping.

Acrylic:

Acrylic is weather and UV resistant so suitable for outdoors applications in that regard. It can also come in many colour variants in both translucent or opaque (and transparent). However, acrylic is more susceptible to scratches when compared other plastics so must be used in areas of the product that are subject to stressful conditions (e.g. can be used in the interior of the product). It's important to consider the environmental factors of acrylic if used as it is a large concern.

HDPE:

HDPE (high-density polyethene) is the most common plastic used for playground equipment. It's commonly used in school and council playgrounds because of its relatively high strength-to-density, the fact it can be easily formed into a variety of shapes and that it can easily take on a variety of bold and vibrant colours. Another benefit of HDPE is that it's sustainable as that type of plastic is commonly recycled, this makes it better than most plastic in no negatively affecting the environment. As previously mentioned, HDPE can be easily shaped using conventional methods such as pressure and vacuum forming. HDPE's thermal conductivity (ability to cool down quickly) allows for quicker cycle times (you don't have to wait for the material to cool) which will reduce costs of labour.

Vinyl:

Vinyl is durable, strong, moisture-resistant and withstands corrosion and rust whilst still having a relatively low cost. Vinyl is stated as "consistently [scoring] better than other materials in many economic and environmental performance categories and 50% of vinyl production comes from renewable resources. It is, however, important to note that, however in terms of recycling, the demand for recycled vinyl far greater than the current supply (almost twice as much). Vinyl is commonly used for stickers so comes in self-adhesive variants. It's also sold in thin sheets which are then cut to the required shape (using a craft knife or scissors).

General Specification list:

A general overview of research findings:

- Fixed playground equipment is generally safer.
- If the product is greater than 1.5m tall it tends to cause more injuries.
- Bright Colours particularly appeal to children.
- Fixed playground toys tend to be safer.
- The product will be in a fully exposed environment.
- Good weather resistance materials are:
  - HDPE
  - Acrylic
  - Western Red Cedar
  - Stainless steel
- Children at the age of 6-8 are more willing to play with toys involving risk.
- 6 years old is when a child starts to develop more logical thinking skills

Problem:

“children, especially in the younger years, are coming in from playtime, whether from morning or lunch break, loud and agitated”.

Design Brief:

I am going to design a prototype for a product that is interactive through the required need of mental and physical exercise, targeted at the 6 – 8-year-old user group. The prototype for the product must also develop key skills which may be needed for later life.

Function:

- The product must be Interactive.
- The product must be easy to understand and be operated by a user between the ages of 6 – 8.
- The product must develop multiple essential skills.
- The product must exercise children physically and mentally.
- The product must be replayable.
- The product must be Inclusive as possible.

Form:

- It must incorporate themes and other things that appeal to the 6 – 8 user group.
- The edges of the product must be round/smooth.
- The product must be brightly coloured.

Performance requirements:

- The product must be suitably durable (and weatherproof).
- All pieces must be secured to the product.
- The product must have the ability to be secured.
- The product must exercise Children physically and mentally.
- Any weights/electrical information of the product must be displayed.

User requirements:

- All the product's measurements must fit in with the target users.
- The product must be enjoyable for the user to play with.
- The product must be as Inclusive as possible.

Cost:

- The product must be reasonably priced
- Where possible, affordable materials should be used.

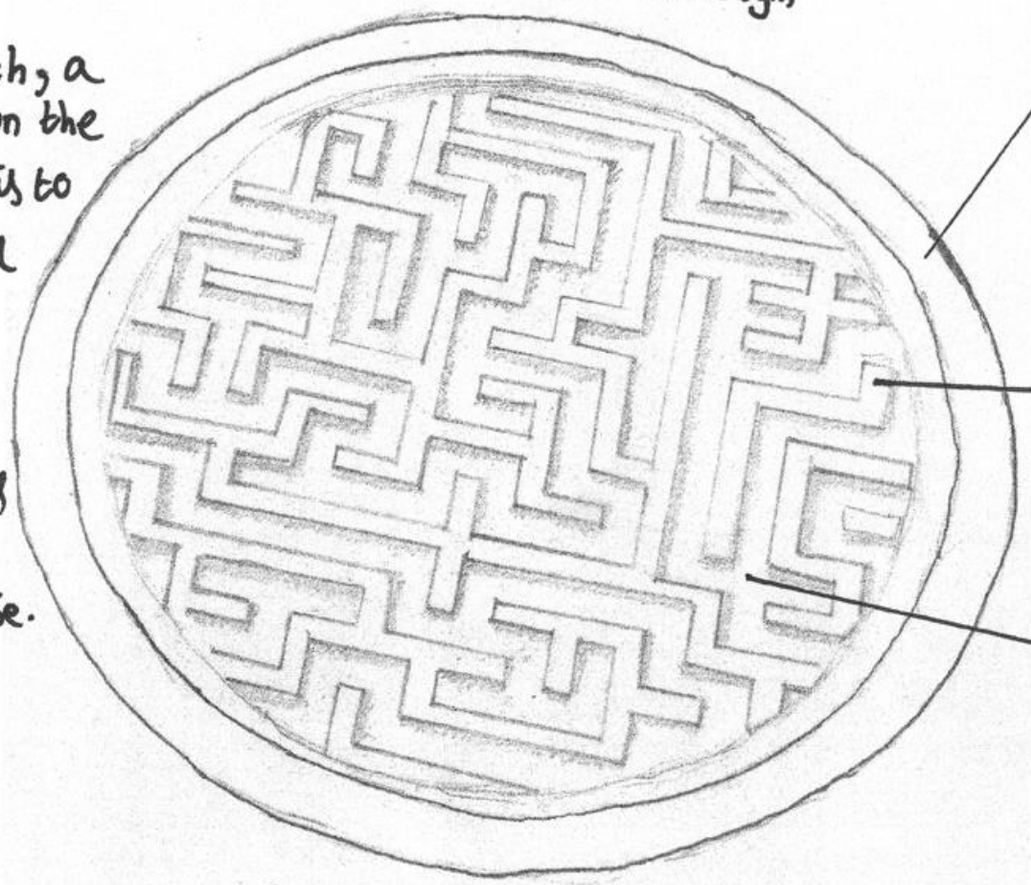
Materials and components:

- The product’s materials must be able to be easily separated
- The product must use as few materials and components used as possible.
- Where possible materials and components used in the product should be locally sourced.
- All materials/components must be recyclable.

Please note that some requirements (Such as “The product must be enjoyable for the user to play with”) will require further testing and therefore will be evaluated at a later stage. Also, the requirements “Any weights/electrical information of the product must be displayed”, “The product must be reasonably priced” and “All the product's measurements must fit in with the target users.” will be developed at a later stage when feasible numbers are possible to obtain.

note: The maze is for proof of concept and is not functional (in this design)

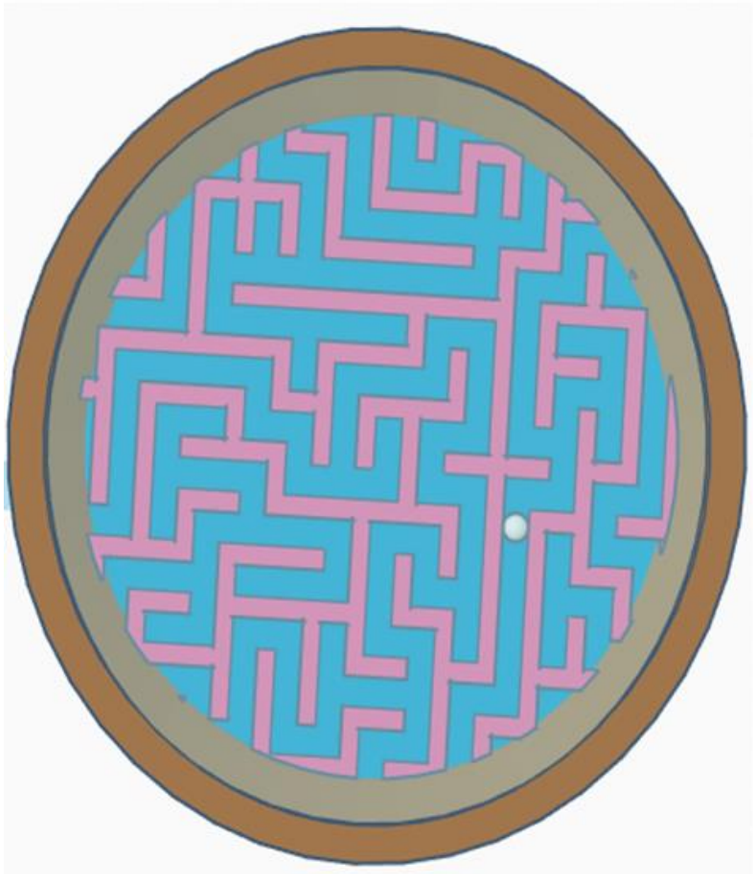
To use / play with, a child will stand on the toy and the aim is to maneuver a ball inside the maze from one place to one of four places marked that a child will choose.



Outer ball / bowl:
- Plastic — Vacuum formed — Acrylic, easy to vacuum form
- Wood — Lathe

Maze:
- Plastic — Laser cut in several layers — Acrylic — use tensol to glue plastic together
- Wood — Laser cut in several layers — use wood glue to form one thicker piece

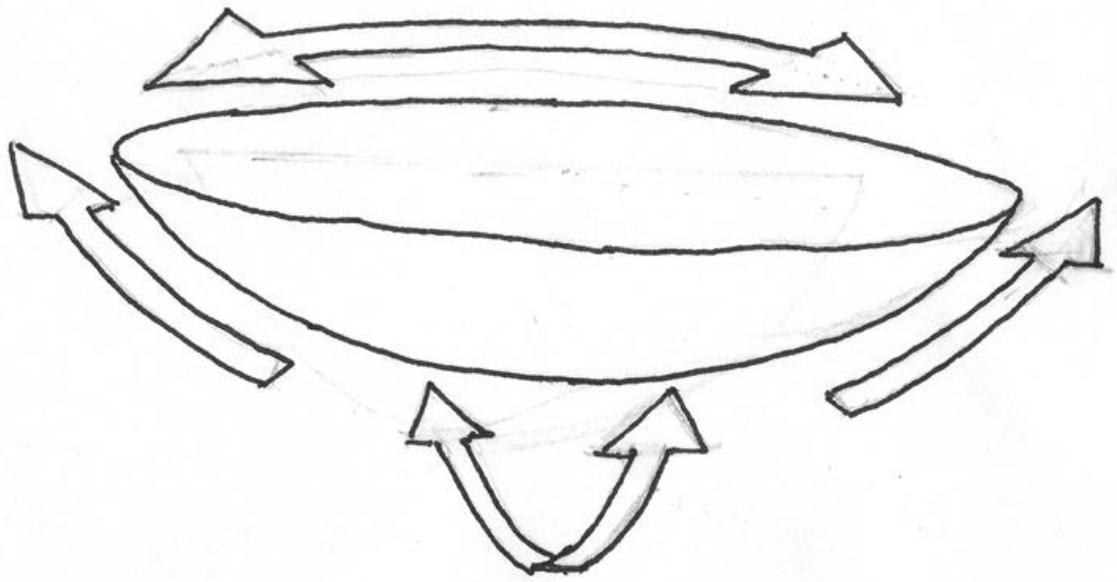
Transparent top: Plastic — Acrylic, easy to laser cut



Products colour's:

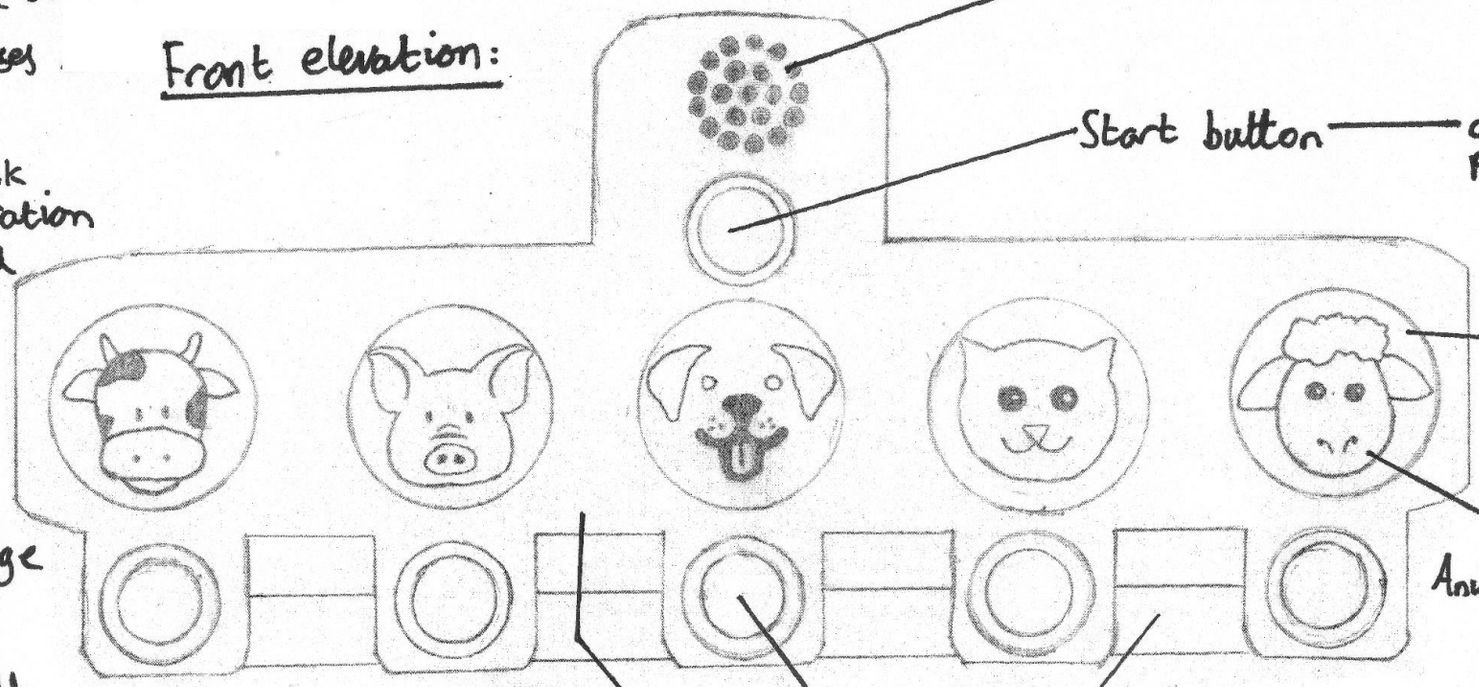
- Bright eye-catching colours that will appeal to the target audience.
- The ball's colour contrasts the backdrop of the maze making it easy to locate.
- The colour of the outer half sphere will depend on the material used which will be decided on in futher research.

Movement: omni directional



To play, a child will press the start button and then the speakers will play three animal sounds one after the other in random order. Whilst the animal noises are being played the corresponding animals disk will light up for the duration of its sound. If a child presses the buttons underneath the animals in the order they were played, the child will advance to the next stage in which there will be one more sound then the previous stage. If the child incorrectly presses a button out of order all the disks will flash orange and the game will reset back to stage one.

Front elevation:



Holes for speaker — Will be drilled or laser cut depending on material/thickness

Start button — classic arcade push button

Translucent disk (to let light through)

Acrylic, easy to laser cut and can come translucent.

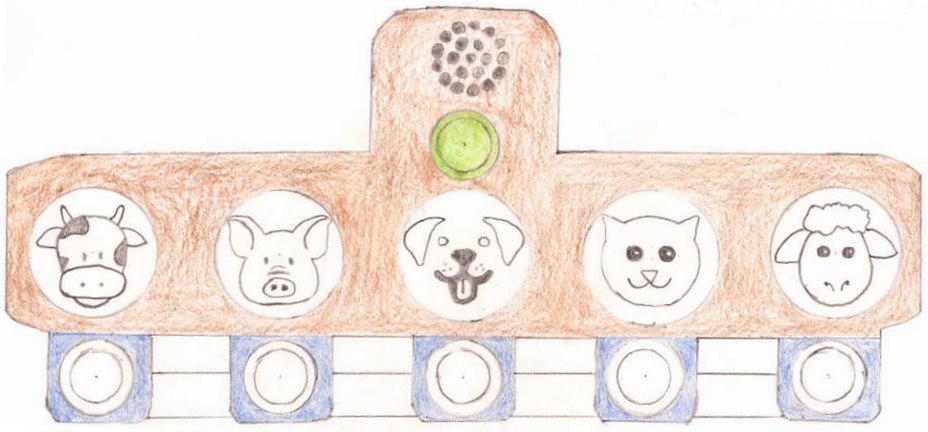
Animal faces — Cut from a sheet so it's a sticker

3D printed with PETG (Stronger than PLA as well as being more weather resistant and easier to print than ABS)

Support beam — Cedar as it is durable and weather resistant.

Push buttons — commonly found in arcade machines so will be bought

Main piece — cut from sheet then edges sanded down — Maple, durable and weather resistant



Colours:

- Green to signify a start button
- Bright colours (blue, white, green) so the product will appeal to children.

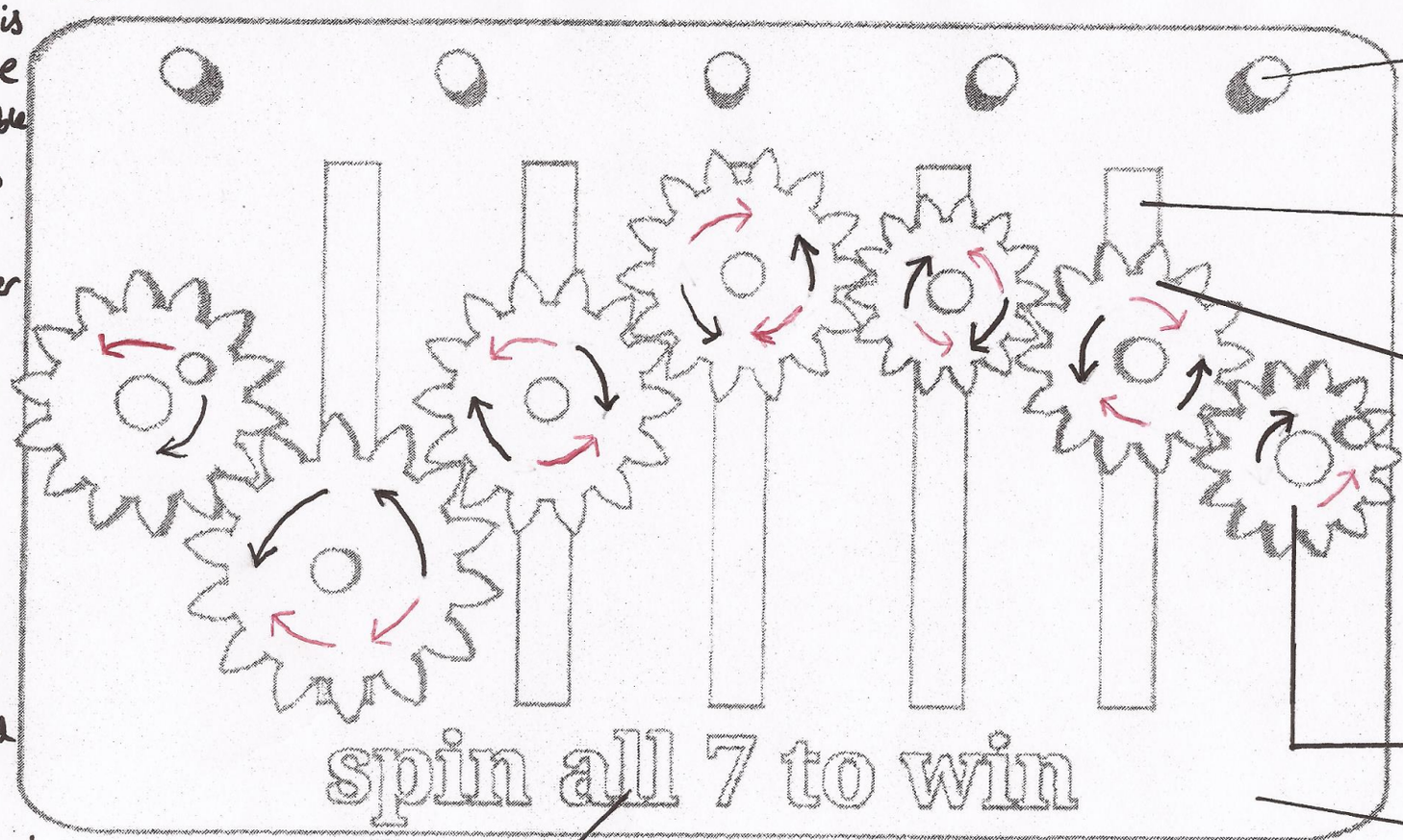
Front elevation: (When completed)

The object of this game is to place the five detachable gears on the pegs so that when a child spins either of the two end gears all seven gears spin.

Key:

Red arrows represent the motion of the gears when the first gear is turned anti-clockwise

Black arrows represent the motion of the gears when the first gear is turned clockwise.



pegs for storing gears

decorative columns — Western Red cedar — laser cut then glued on

detachable gears — Western Red cedar — durable / weather resistant.

Cut with a C.N.C router.

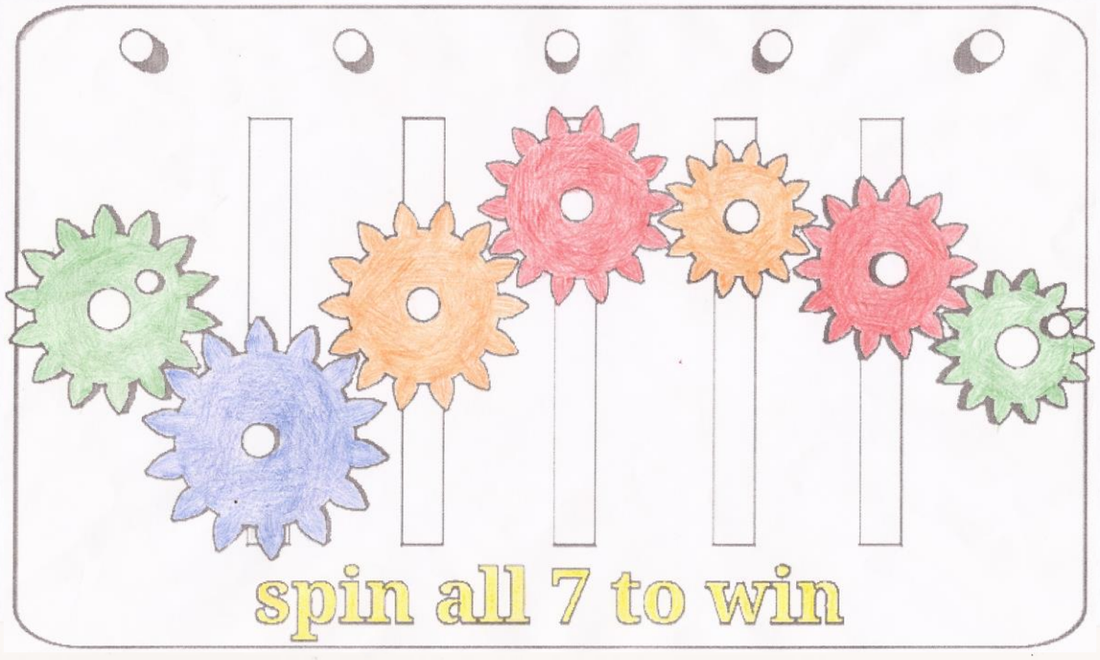
laser cut

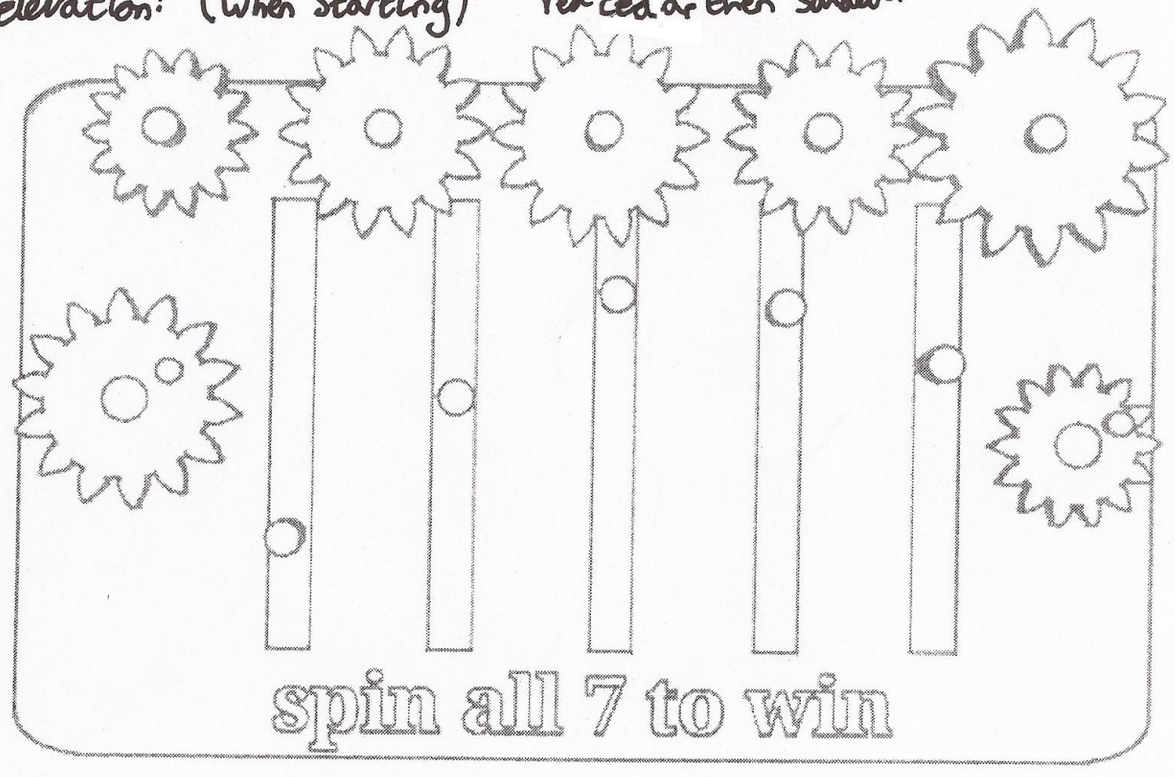
Permanent gears with small pegs so the can be spun by the user

Main piece cut from a sheet of Western red cedar then Sanded.

Simple instructions — laser engraved / painted with stencil

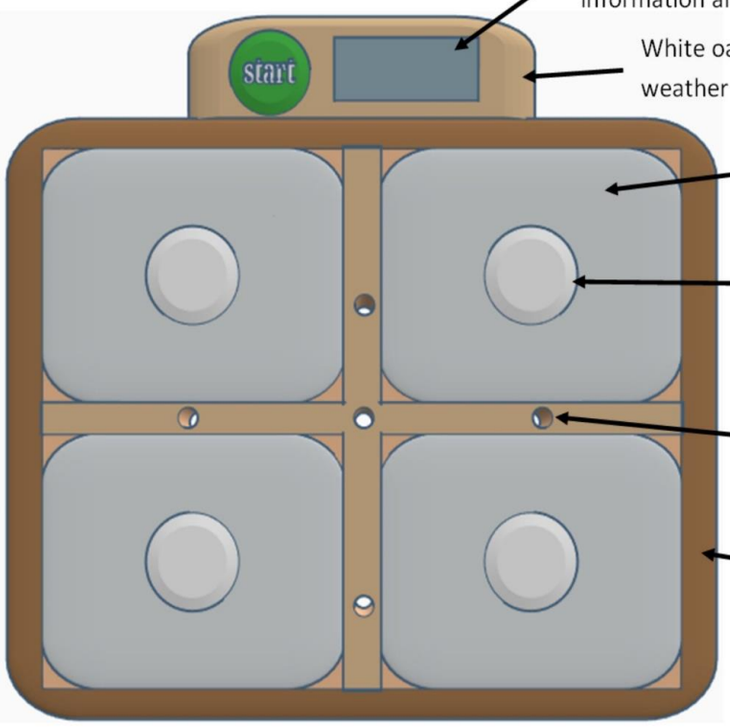
Front elevation: (When Starting)





Game Objective:

When the start button is pressed the LCD screen will display the name of one colours: yellow, red, blue, green and purple. The four panels will then proceed to turn, randomly, into one of the five colours. The user will then change the colour of the panels to the one the LCD screen by pressing the push buttons. Once all the colours of the panels match the colour name on the LCD the game will be reset and the child will gain a point. A game will last 90 seconds and the objective is to get as many points as possible.



LCD screen for displaying game information and statistics.

White oak, durable and weather resistant.

Translucent panel to allow light through. Laser cut from a thick acrylic sheet.

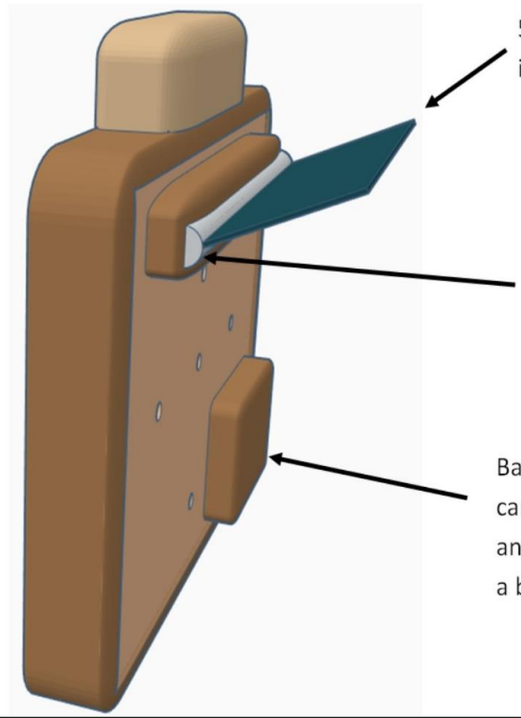
Standard 28mm push buttons commonly found in arcade control panels.

Mounting holes, drilled with a drill bit on drill pillar.

Exterior rectangle, stained cedar (rot and weather resistant), cut using a jig saw.

Product's colours:

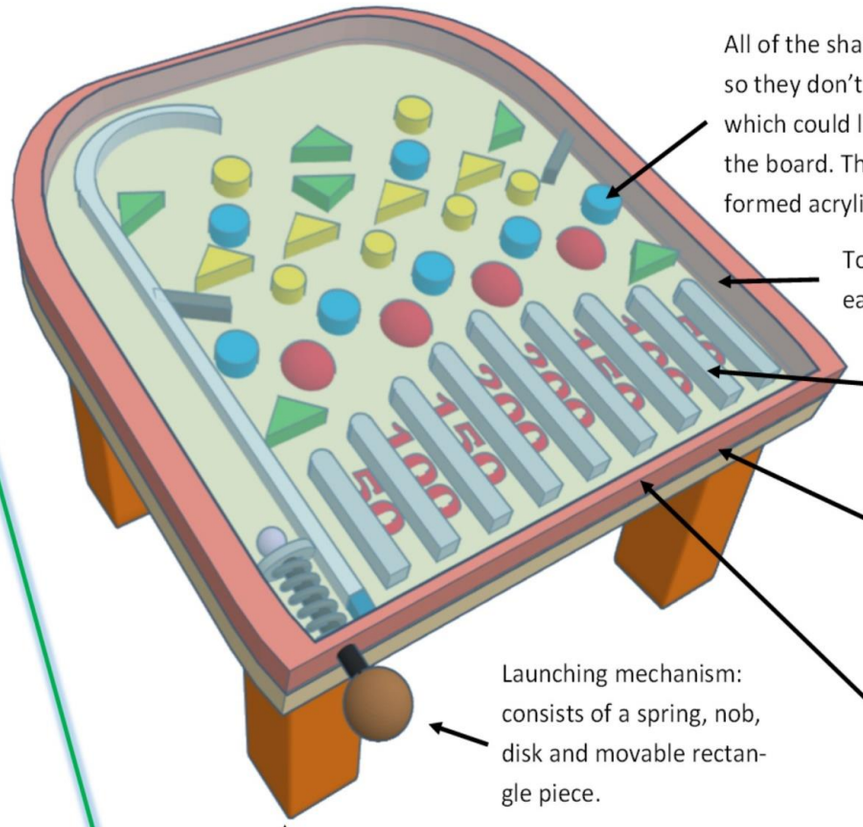
- There's green to signify that the button start's the game.
- Within the game there are bright colours such as yellow, red, blue, green and purple.
- In this design the rest of the product, the wooden sections, have not been painted. Adding colour to the frame will be something to develop.



5V solar panel for charging battery pack

Hinge to adjust position / angle of solar panel (this feature will be useful when it comes to mounting the product).

Battery pack encloser carved out with a CNC and then sanded using a belt sander



All of the shapes where selected/positioned so they don't have a flat horizontal edges which could lead to the ball getting stuck on the board. The shapes could be vacuum formed acrylic.

Top panel: Made of Perspex which can be easily cut with a laser cutter.

Pegs can be made from plywood or stuck together layers of acrylic due to its impact resistance.

This top piece could perhaps be made out of Marine plywood with a CNC router. Alternatively, It could be made from layers of acrylic, which have been cut from a laser cutter, And struck together.

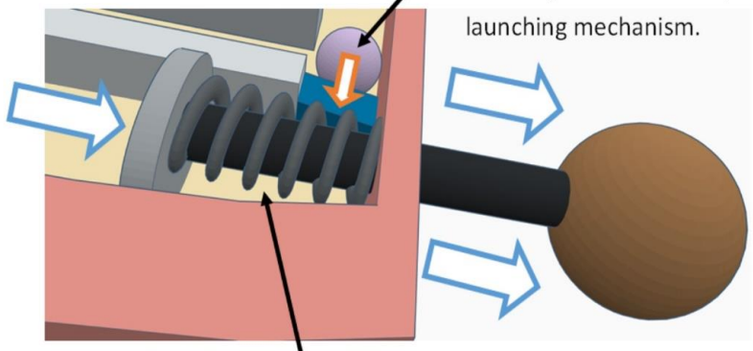
The bottom of the board is angled so that the ball will roll back to the launching mechanism.

Launching mechanism: consists of a spring, nob, disk and movable rectangle piece.

The 4 Legs can be made from wood or plastic. If wood perhaps cedar, if plastic probably HDPE.

Launching Mechanism:

When the rod is pulled back piece will lower, allowing the ball to be correctly mounted on top of the launching mechanism.

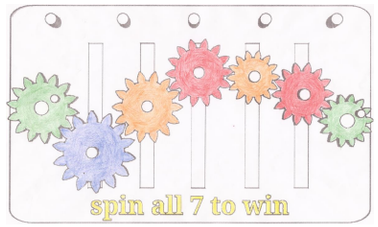
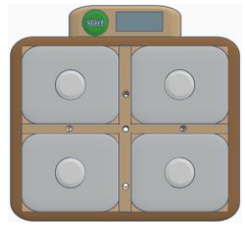


Spring will compress, which will supply sufficient force to the ball upon release.

Game Objective:

The idea of this game is to launch the ball in such a way so that it goes into the highest scoring gate. To do this, (when the ball is on top of the launching mechanism) a user will pull back the handle and then release. The ball will then fall down the board of shapes and then reach one of the gates, the number underneath the gate the ball falls in, will be the score. When using this product the user will find that a certain amount of pulling force (on the launch mechanism) will result in a better score.

Review of initial ideas:

Design Idea:	 Balance maze	 Animal memory game	 Spinning gears	 Light flash (game)	 Ball launch (game)
Function: The product must be interactive.	The interactivity with the ball and the maze (both through movement) makes this product interactive.	The use of the buttons, lights and the game makes this product very interactive.	The movability and rotating factor of the gears means that this product is interactive.	The changing of the light panels as a result of a button press makes this product relatively intractable.	Apart from the pulling of the lever, compared to the others, this product is relatively not interactive.
The product must be easy to understand and be operated by a user between the ages of 6 - 8.	This product shouldn't be too hard to operate/understand as it is similar to products the child would have probably already played with.	This product is for people for a lower age but as seen by the relatively long operation instructions, this product may be a bit more difficult to understand, however, the idea of having to repeat a pattern previously displayed shouldn't be too hard for the users to grasp because at that stage (as can be shown by research) "Start using logic to solve problems."	The concept of this game will be easily understandable (due to the simple instructions on the front of the product). I believe this game to also be appropriately challenging for the age group as they have greater problem-solving capabilities.	As it stands this product may be to complex for the user group to grasp, however some still may.	Although there is a game objective, which an adult can easily explain to the users, the child will have just as much fun coming up with a game themselves to play on the product. Therefore, this means the child doesn't need to understand/operate the game objective as seen in the annotations.
The product must develop multiple essential skills.	Through the requirement of balance and movement this product develops coordination and motor skills. Due to the maze, it will also improve the child's memory and logical thinking, if used correctly.	If the game is played correctly develops short term memory and echoic memory (memory involving sound), pattern recognition and solves the contextual challenge as it improves concentration.	The gears will prompt the development of mechanical skills. The product will also promote logical thinking and improve problem-solving skills. It can also teach a child a basic understanding of gears.	This product develops colour recognition and improves reaction times and develops a healthy sense of competition (because of its screen which can display high scores), useful in later life.	This product will only develop hand dexterity skills, compared to the other products in the market, this is not enough to meet this specification.
The product must exercise children physically and mentally.	This product exercises the user physically as the user constantly has to adjust the way they apply weight and balance on it. The logical thinking required for the maze also effectively provide mental exercise.	Due to the large form factor of the product, it will require constant movement for the pressing of different buttons and will exercise physically. The memorisation aspect of the game within the product will also prompt mental exercise.	This product only exercises physically, not mentally. This is because very little effort will be required to move the gears into place, however correctly doing so will require thinking.	This product induce mental exercise if used correctly however won't require much physical movement.	The force required to pull the launching mechanism back and the fact that a certain amount of force will probably lead to a better outcome means that the child will develop cognitive skills.

Green: Meet Red: Fail Black: N/A

Design Idea:	Balance maze	Animal memory game	Spinning gears	Light flash (game)	Ball launch (game)
The product must be replayable (in terms of playability):	Due to there only being one maze this product isn't adequately replayable as correct path through the maze may be memorized, meaning it no longer promotes logical thinking.	Due to there only being one maze this product isn't adequately replayable as the correct path through the maze may be memorized, meaning it no longer promotes logical thinking.	The gears can probably only be laid out in one way, so the game isn't particularly replayable.	The randomness of colours in the game, make it replayable.	Changing the amount of force used to pull back the launching mechanism will change the outcome, therefore meaning the game can be replayed.
The product must be as Inclusive as possible.	The products requirement for balance and movement means users with a mobility hindering disability may not be able to use it; this also serve dyspraxia. Also, children with certain conditions (such as autism) may put themselves at harm when attempting to use the product.	Due to the flashing lights, the product can still be used by someone who is partially sighted. Also, the product can be used by a blind user if they memorise what buttons correlate with each animal noise. The product doesn't require much mobility so can be used by users with various disabilities.	Can be used by a variety of users with different levels of ableness. However, when users with conditions such as serve autism use the product they should be supervised (usually this is the case) because of the gears.	The need to see the colours mean that users with particular types of colour blindness won't be able to use the product. Colour blindness being relatively common means that this product doesn't meet this requirement.	Due to the product being immobile there are only two factors the user must have, mobility of hands and medium eyesight. Therefore, compared to other products on the market, this product is quite inclusive.
<u>Form:</u> The edges of the product must be round/smooth.	Due to its round design this product doesn't have any sharp corners, also the edges of the product will be smooth.	There are several corners in this product that have not been rounded.	There are sharp edges/points to the gears, this may lead to injury.	All corners are rounded, and all edges have been beveled.	As it stands, there are sharp edges and corners which could potentially cause harm.
The product must be brightly coloured.	The inner bowl and maze are brightly coloured; it will say so as it isn't subject to the same amount of street as the outer bowl.	The majority of the product isn't brightly coloured except for the support beam and start button. Since the majority of the colouring is bland it fails this requirement.	The use of many first and secondary colours on the gears and text do give the product a brightly coloured appearance. **The colour of the main piece has not yet been defined but it will be coloured to meet the requirement.**	With exception to the start button, when off the product has not bright colours and has been left unpainted. It does have more vibrant colours when in use such as yellow, red, blue, green, purple but that'll not be the effect when off.	Like the gear initial design, this product's use of first and secondary colours means it meets this requirement.
<u>Performance requirements:</u> The product must be suitably durable:	The top piece and maze are made from Acrylic which is a weather-resistant durable plastic so it will withstand the stressful environment. However, it probably won't be suitable for the outer bowl therefore a wood or different material will be better suited.	The support beam adds structural strength to the product and prevents the button tabs from being hit off. Cedar and maple, the two main types of wood used, are durable and weather resistant.	The majority of the product is made from western red cedar making it durable and rot-resistant. One minor concern may be the paint coating wearing off on the gears of the teeth but as a whole, the product is quite durable.	The use of white oak makes the top section very durable and weather resistant. The thickness of the acrylic panels makes them durable. The outer compartment will be made from cedar which is weather resistant.	Non-rotting materials are used for the legs so their structural strength will not be compromised. The rest of the materials that will be used, such as acrylic, will be durable enough to last for a considerable time.

Green: Meet Red: Fail Black: N/A

Design Idea:	Balance maze	Animal memory game	Spinning gears	Light flash (game)	Ball launch (game)
All pieces must be secured to the product:	Due to the ball being completely enclosed the chances of it being separated from the product are minimal. No pieces can be removed from the product by the user and it will remain as one piece.	All pieces including the animal disks and button are safely secured to the product and would require significant force to remove. Therefore, the product's pieces are all secured.	The gears can be removed from the product therefore not all pieces are secured to the product and there is a possibility they may go missing or be misused.	This product has no external pieces; however, it does have a hinge which the child may be able to rotate, but the child should still not be able to detach the solar panel.	There are no mobile pieces on this product which aren't covered with a top panel. This top panel means that a user won't be able to reach inside and remove the ball, which is what the client wants.
The product must have the ability to be secured:	Its operation is based on movement; therefore, it will be impractical to secure the product. After speaking to the client, they are aware and happy about this product not to have to be secured to anything.	Since it's a design a mounting system has not been developed, however, in reality, it will either be attached to a fence or it'll have its own mount (meaning it will be secured to the ground).	The product doesn't show any form of securing it, however in practice it will probably be attached to an outdoor play area.	Mounting holes allow the product to be secured to outdoor play areas or fences.	The legs of the product don't yet have a mechanism of securing them to the ground, one will have to be developed.
<u>Cost:</u> Where possible, affordable materials should be used:	If the outer a type of cedar, it would be relatively inexpensive whilst still being somewhat durable. However, glass-reinforced plastic will be far more durable but at the same time more expensive (this will be a decision the client will make). The Perspex and acrylic being used is relatively cheap yet is suited for its environment.	Both marine plywood and cedar are inexpensive; the same goes for acrylic PETG and the vinyl sheets. However, the electronics and buttons needed will drive the cost up, but it still meets this requirement as they are necessary for the function of the product.	The materials used make the durability of this product high whilst keeping the cost at a reasonable price (there are no, more expensive, materials used where they're not needed).	White oak is relatively expensive and a cheaper material can be used that will have adequate durability.	Materials such as HDPE and Perspex are highly durable yet relatively inexpensive so they're the ideal material to use. Furthermore, Marine plywood is a good value material to use.
<u>Materials and components:</u> The product must use as few materials and components used as possible:	Within this product, there are at most 4 materials used (not including forms as glue) this uses relatively fewer materials and components when similar toys in the market.	This product incorporates relatively more materials/components. This consists of cedar, maple, ABS (for the buttons), LEDs, acrylic and a speaker.	Apart from the paint (and possible mounting solutions) the entirety of the product is made with western red cedar or marine plywood.	This product requires an LCD screen, 5 arcade push buttons and a solar panel. It also requires stainless steel (for the hinge), thick acrylic and cedar.	Except for the launching mechanism (which will use very small amounts of the material) the entirety of the product is made up of HDPE, acrylic (including Perspex) and cedar or marine plywood.

Green: Meet Red: Fail Black: N/A

Design Idea:	Balance maze	Animal memory game	Spinning gears	Light flash (game)	Ball launch (game)
The products materials must be able to be easily separated:	The four main pieces of the products can easily be separated as they're only attached with glue.	Even though this product incorporates a high number of different components/materials they can be quite easily separated.	The gears can be separated with ease and the pegs unclipped both of which can be ground down for use in MDF. Once those have been taken off there is the main panel piece made from one material.	The hinge on which the solar panel is swivelled may be difficult to separate from the product.	The shapes on the main panel will probably be glued on, due to the number of shapes and glue being used, these will difficult to separate.
Where possible, materials and components used in the product should be locally sourced:	Perspex (if it were to be for the disk) is manufactured in Lancashire (in the UK) so can be easily locally sourced. However, the cedar used for the outer bowl will have to be imported so marine plywood would be used if wood is a suitable material for the bowl.	The raspberry pi, that'll control the product, is manufactured in South Wales, which is relatively close compared to materials and components used in other products in the market. Unlike western red cedar, marine plywood can be locally sourced so that's what the main piece will have to be constructed to meet this requirement. Finally, both acrylic and PETG can be manufactured and sourced in the UK.	The gears can be made from ABS, PETG, acrylic or marine plywood, all of which can be manufactured and sourced locally (please note that although cedar was mentioned in the evaluation it will have to be imported). The main panel will also be made from locally sourced marine plywood.	The Perspex used for the top panel is manufactured in Lancashire. The rest of the materials used can also be sourced in the UK.	Although there are suppliers of springs (for the launching mechanism) in the UK, it's difficult to know where they'll be manufactured at this stage.
All materials/components must be recyclable:	The cedar used will be easily recycled however, although possible, Perspex and acrylic is hard to recycle but still possible.	Both cedar and marine plywood can be easily recycled as well as the PETG (and, although harder to recycle, acrylic) used for the animal faces. ABS also being a thermoplastic means it can be easily recycled. Finally, once the lifespan of the battery is over, the majority of the cells will still be functional and be reusable.	All or the majority of the product can be made from marine plywood which means it can be easily recycled. The other possible materials that were proposed in the design are also easily recycled (with the one exception of acrylic, but that's still recyclable.	Upon research, I've found that the RGB LEDs and LCD screens can be easily recycled. Also, all the wood used will be easily recycled. However, if a raspberry pi where to be used as the computer, that will be difficult to recycle.	All components of the launching mechanism, HDPE and marine plywood can be easily recycled. Although more difficult, the Perspex/acrylic can also be recycled.

Green: Meet Red: Fail Black: N/A

Development of design into chosen design (part 1): (Balance Maze)

In part 1 of this section, I will be developing two of the initial designs by making prototypes/models and also refining and developing them so they meet all the aforementioned specifications as well as refinements provided by feedback from my client.
After interviewing my client they have decided that they want me to further develop the 1st product ("Balance maze") and 2nd product ("Animal memory game").

Firstly, the maze ball product has to be developed to meet the following general requirements:

- The product must be replayable (in terms of playability)
- The product must be as Inclusive as possible.

Also, some of the general requirements that need further testing or further research should be meet after initial (part one of) development. Such requirements are:

- The product must be enjoyable for the user to play with.
- All the product's measurements must fit in with the target users.

I first 3D modelled, and 3D printed out what can be seen in the initial design drawing. After the first model, I printed out an improved more functional version.

This model was 3d printed from the initial design (meaning that the maze is still not functional) and was made in order to get a physical view of what the product at that stage would look like.
From this, I've learnt that in my opinion and the clients that the **maze pieces should be made thicker** and a **section should be cut out of the bowl** in order to house the transparent top in which a user will stand.
The Client agrees with my observations as well as things that need to be developed.

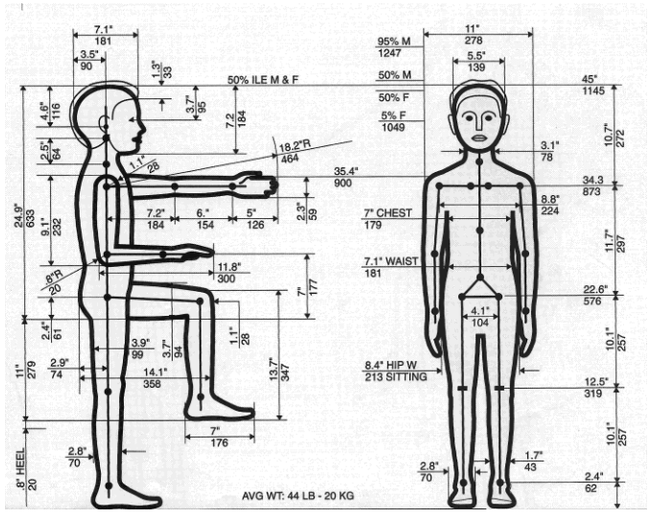
Like the previous one, this model was almost fully 3d printed however, the required changes have been made such as making the maze pieces thicker, so giving more depth to the product. Also, an acrylic laser cut disk has been inserted into the section that has been cut out of the rim. In this model, I also experimented with the colours based on previous client views.

After showing the product to the client said they said that they "like the contrast of the red and white on the maze pieces" However they then go onto say that "A paler shade of blue should be used as the ball is quite hard to see especially for a child that may be only partially sited". After looking at this the client wants more colours to be used for the maze pieces. The functional prototype was then given to four people within the products recommend age range (6 – 11). With knowing that the maze had not been made functional they said they had fun operating the prototype with their hands and would look forward to a version they could use with their feet. This, therefore, shows the product meets the requirement of it being fun for users to play with.
However, one problem that arose during testing of the functional prototype was that hands (representing feet in this case) had to be constantly moved in order to see the ball. So both I and the client agree that this problem will have to be solved.
I will now develop and refine the product's design so that it meets the remaining general requirements and the client preferences. These preferences and extra things I need to develop are:

- Make appropriate footprint cut-outs of the maze.
- Use a paler blue for the inner bowl.
- User a proportionally larger ball.
- Make the product safer to operate.

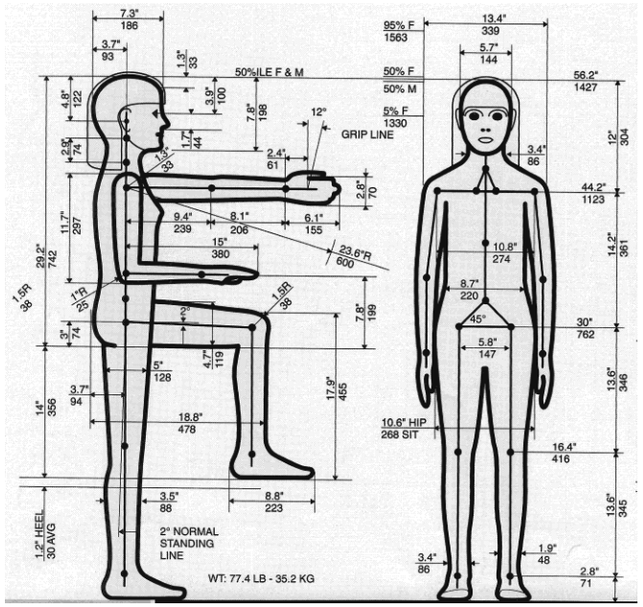
Anthropometric data:

By researching the anthropometric data I will be able to meet the requirement: "All the product's measurements must fit in with the target users."
Since this product is being designed for children, I will be making the dimensions to the 50th percentile rather than 90th percentile. Since this product fits in with the age groups within a primary school: 6 – 8 and 9 -11 years old I will be using the anthropometric data from those years of both genders. I will be using the data from 6-year olds as minimum measurements and 11-year olds data as maximum measurements.



Age 6 (averages):
Relevant Anthropometric Data:

Weight (kg)	20
Foot length (mm)	176
Foot width (mm)	70
Shoulder width (mm)	278



Age 11 (averages):
Relevant Anthropometric Data:

Weight (kg)	35.2
Foot length (mm)	223
Foot width (mm)	86
Shoulder width (mm)	339

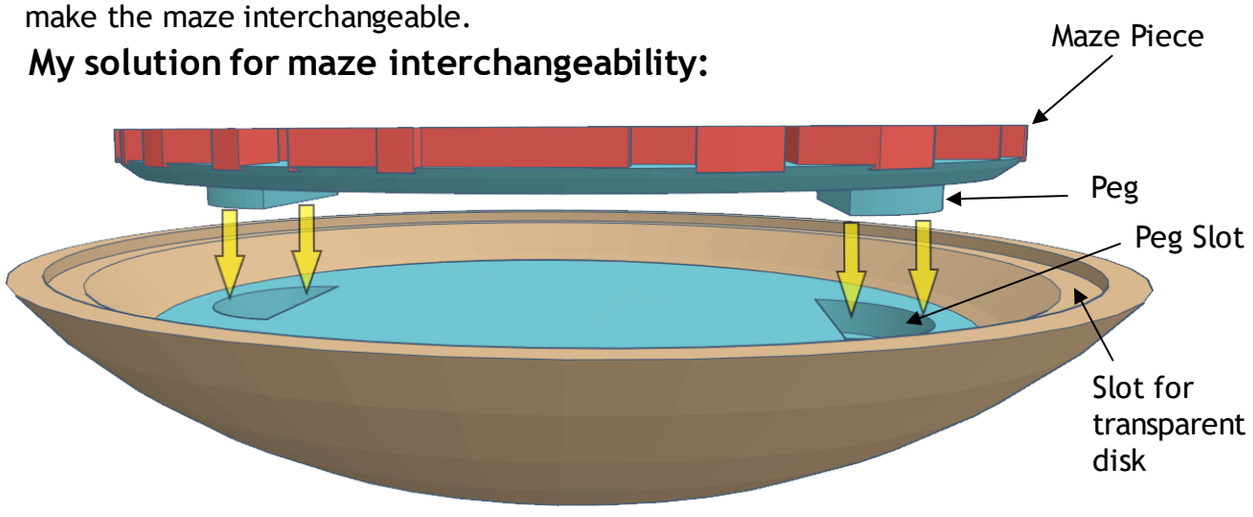
What does this anthropometric mean for the product?:

The product must at least be able to take 35.2kg, however, to be safe it should take 10kg on top of that so the product should be able to take a weight of 45.2kg without breaking. The diameter of the clear disk will be slightly smaller than the shoulder width of an 11-year old, so 300 mm (300mm is greater than the foot length which is good). The outer bowl diameter will give half a foot's width of clearance so it will be 300 + (86 ÷ 2) which is 343mm.

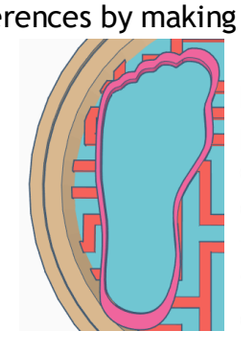
Developing the maze:

So this product meets the replayability specification point I will be developing a way to make the maze interchangeable.

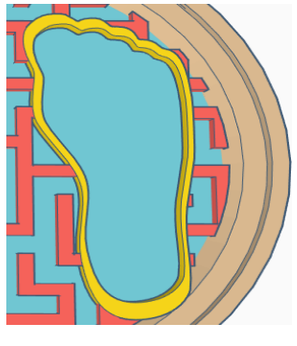
My solution for maze interchangeability:



To explain this solution, there will be a maze piece which consists of the maze, a disk and two pegs. These two pegs will slot into their corresponding slots. If this design moves onto further development (part two) I will develop a locking mechanism to prevent the maze piece from falling out when upside down. With this solution, I have met the replayability specification point. As can be seen from the photo I have also met one of the client's preferences by making the inner-bowl a paler blue.



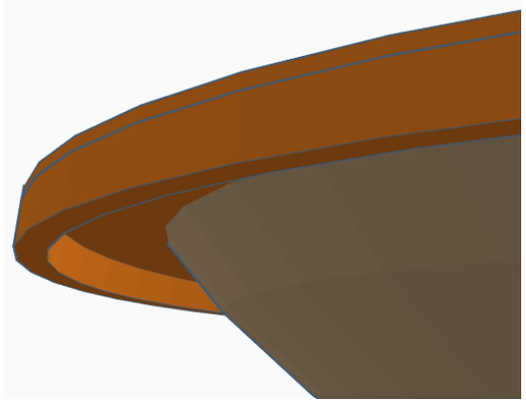
In the pictures to the right and left I have fixed the issue we had during playtesting by incorporating feet exclusion zones. In this part of development, I won't be designing a fully functioning maze, however, if this product moves onto further development I will be.



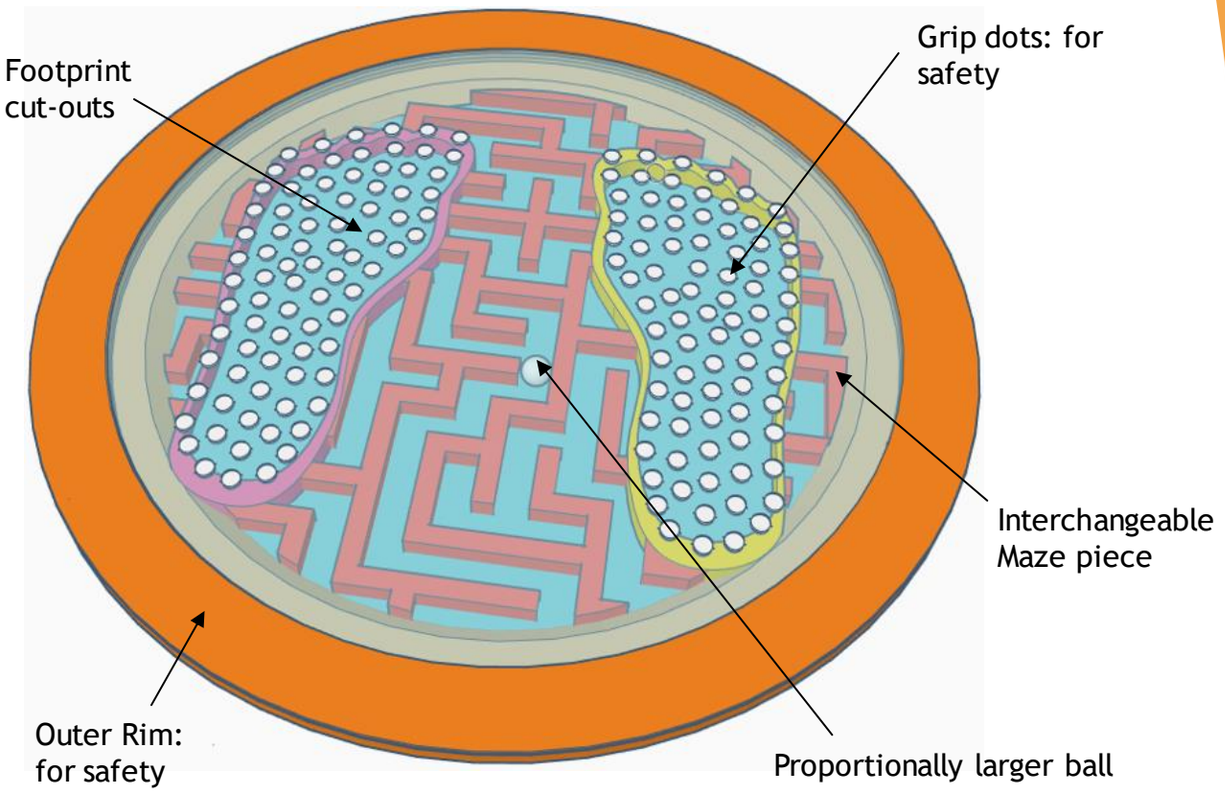
Developing safety:

By making the product safer I am not only ensuring the product meets the points raised in the client feedback but also making the product more inclusive (for people with motorial disabilities who are more likely to put themselves at risk of injury).
To make the product safer to operate, I will add a rim to the outer bowl so when the edge of the outer bowl hits the ground it won't flip over. I will also be adding textures circular stickers over where a user will stand. These stickers will provide grip so the user doesn't slip off the transparent disks. Such stickers will be arranged in the shape of feet so the user knows what position they should stand on the product.

The picture to the right shows the development of the rim and what it will look like if this product where to be made.



Below is the design of the "Balance Maze" with all the initial improvements and refinements made (please note the maze has not yet been made functional). I will show this and the client along with the other product and they will decide which one should be developed into a final design.



Development of design into chosen design (part 1): (Animal Memory Game)

For the initial development of this product, I will be making the initial refinements so that the design for the product meets all the initial specifications and improvements/features the client has asked for in the interview. I will also be refining the product so that it meets the specifications that required some more development. After the refinements have been made, I will be making a functional prototype of the electronics. Please note that after talking to my client they are happy for me to proceed with developing a playground toy for children aged 4-6 rather than 6 – 8 (this will slightly change the wording for one of the specifications).
The initial specifications that this product failed, which will need to be met, are:

- The product must be easy to understand and be operated by a user between the ages of 4 - 6.
- The edges of the product must be round/smooth.
- The product must be brightly coloured-This will be done in further development if chosen.
- The product must have the ability to be secured.
- The product must use as few materials and components used as possible.

The initial requirements that will require the initial development stage are:

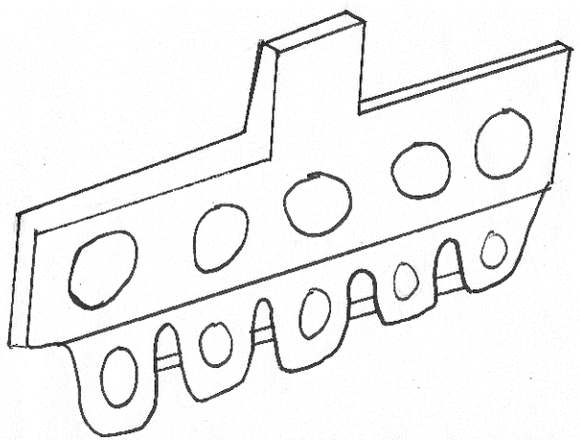
- The product must be enjoyable for the user to play with.
- All the product's measurements must fit in with the target users.

In the interview with the client, they said that:

- A way of mounting the product using a stand is required. (This stand must be able to bolt into concrete). Also, the product must be able to rotate on its stand and lock into position.

Developing the form:

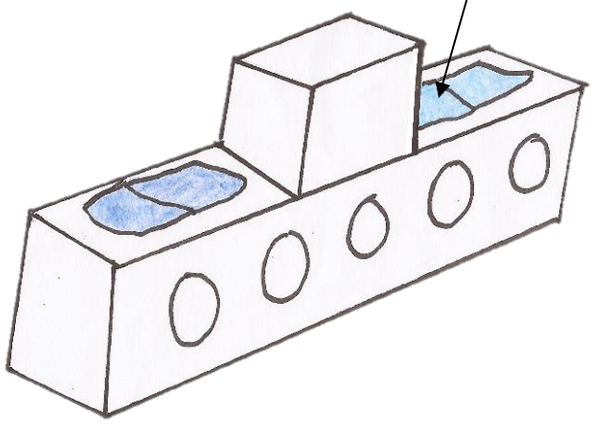
Since it's being used in a playground environment all the sharp corners which can be currently seen on the product must be replaced with round ones for safety reasons and so that it meets the initial requirement. "The edges of the product must be round/smooth" for safety reasons. I will also demonstrate the thickness of the product.

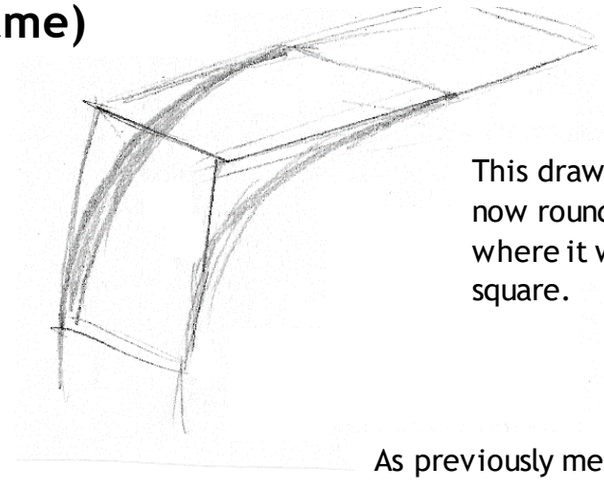


This first drawing is a 3D version of the initial design. However, for development purposes, I have started out with square, and not round edges.

In this development drawing the product has been made thicker, as to allow for internal electronics, and solar panels have been displayed where they are likely to be in the final design. Also, the arcade buttons and support beam have been removed and the acrylic disks have been replaced with LED push buttons in which the animal faces will be on top. This will **reduce the number of materials needed**.

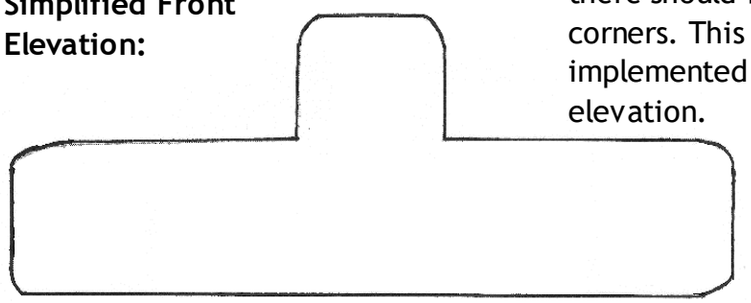
Solar Panels (shown for the relative thickness of the product)





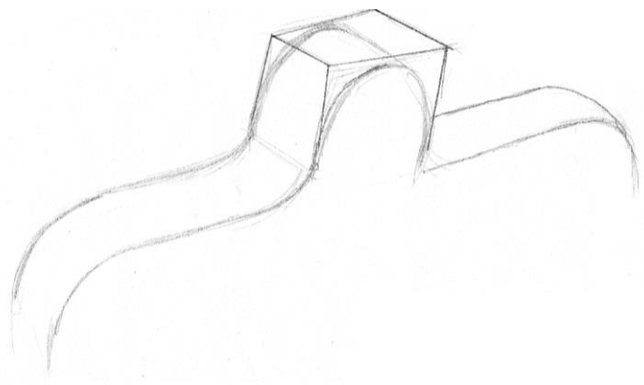
This drawing shows the now rounded corner where it was previously square.

Simplified Front Elevation:

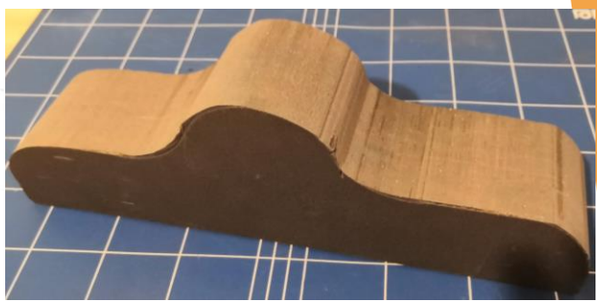


As previously mentioned, for safety, there should be no sharp edges or corners. This precaution has been implemented in this simplified front elevation.

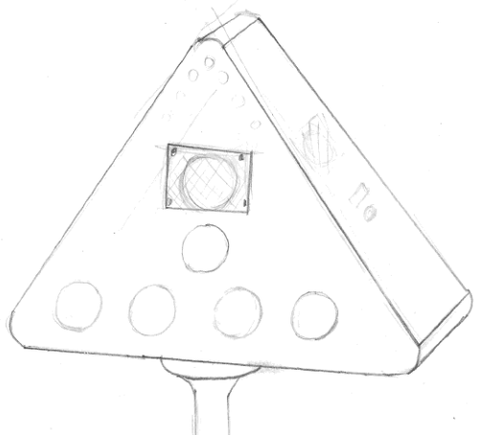
In this development drawing, I rounded the two sides of the panel and the top section.



This is the model I made to demonstrate the curves of the product.



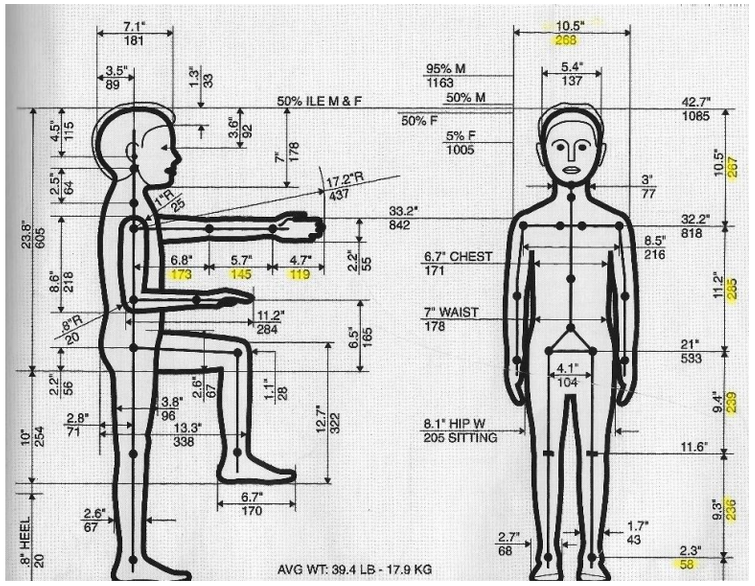
After developing this form for the product I showed sketches to the client for alternate designs that still meet the round edges/corners requirement. This was done in order to avoid **design fixation**. The sketches can be seen below:



After looking at these two sketches, and the one above, both the client and I agree that the form that was previously developed (the one above) should be continued with.

Anthropometric data:

By researching the anthropometric data I will be able to meet the requirement: "All the product's measurements must fit in with the target users."
As this product will be used by children aged 4 – 6 I will be using the measurements from the average anthropometric data of children aged 5.
Please move onto the next page, that's where I do research into the relevant anthropometric data for this product.



Age 5 (averages):
Relevant Anthropometric Data:

Height of shoulder:
58 + 236 + 239 + 285 = 818mm

Wingspan:
173 + 145 + 119 = 437 X 2 = 874 + 268 = 1142mm

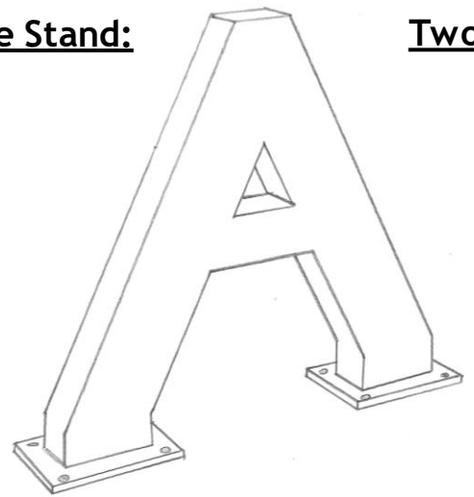
How this applies to my design:

The height of the buttons need to be positioned (around) 82cm from the ground.
The furthest the buttons can be placed apart from each over should be no more than 1142 mm

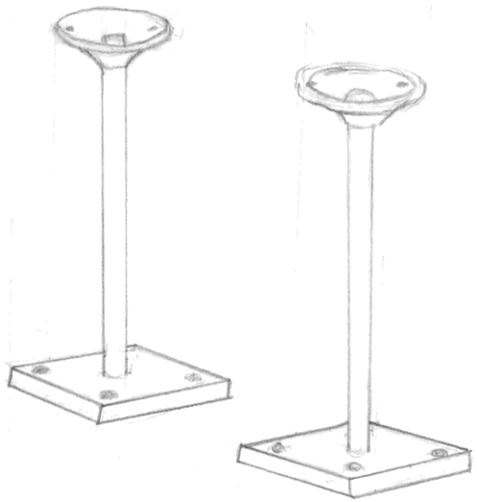
Developing a Stand:

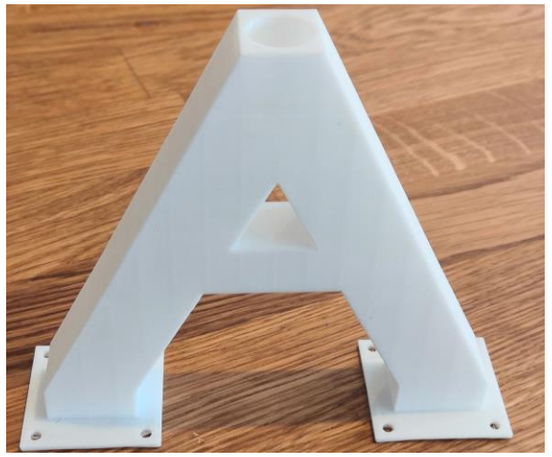
Since the client requires this product to have its own way of being mounted, I will be developing a stand for the product to be mounted and secured to. The client and I agree it would be good if the mounting system allowed the product to be rotated so the product can be rotated away from direct sunlight and so it's easier to find a place for the stand to be secured to the ground. It's important that there is also a locking mechanism, stopping the product from being able to spin.
To develop the stand I will first do sketches of what the stand could look like. I will then ask the client to chosse the best/most appropriate sketch for the stand. The final stage of development of the stand in this part (initial development), will be to develop a mechanism to allow the product to rotate and then be able to lock into a fixed position.

A-Frame Stand:



Two Pole Stand:



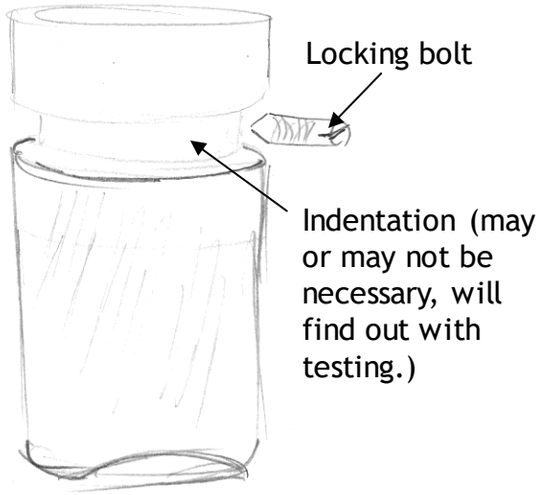


After showing those sketches to the client, they said that they preferred the A-frame stand but they would like to see a model/prototype before it was further developed. Such model/prototype can be seen to the left. After seeing the prototype they were happy for me to continue development of the A-frame stand.

Swivel and lock mechanic:

As seen at the top of the A-frame prototype I made, there is a hole. In the real thing, in that hole, I intend for there to be a pipe inserted into it. This pipe will be connected to a steel plate which in turn will be connected to the product itself. This steel plate will be able to freely rotate.

Locking mechanism sketch:



As can be seen by the locking mechanism sketch, a "locking bolt" will stop the pipe, and therefore the main piece, from being able to rotate. The bolt will be inserted into a nut on the back of the product and will be tightened down once the main piece is in position. This bolt will be tight enough to stop anyone without a spanner (aka children) from being able to loosen it.

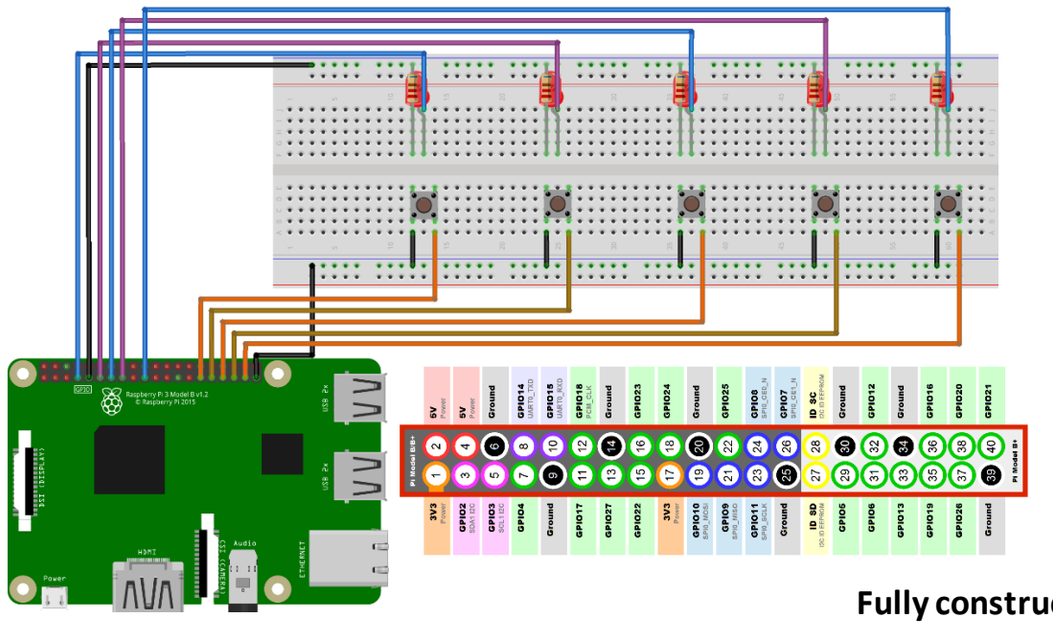
Developing Electronics Prototype:

In this part of development, I will be producing a functional electronics prototype that will have the game as described in the annotations of the initial designs. Making this prototype will allow testing to be done on the users and allow the client to provide feedback. Such feedback will provide improvements which will be made if this product moves onto further development.

What electronics will be used for Prototyping/development:

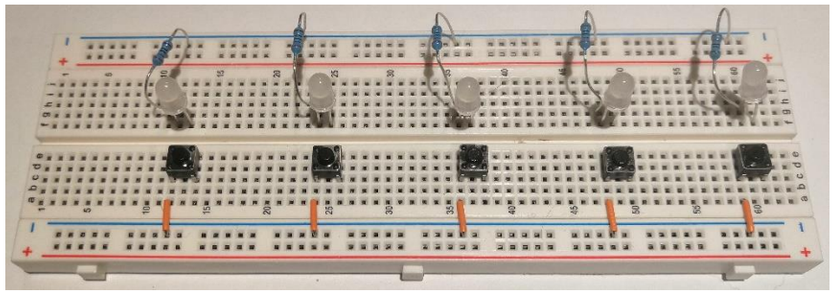
- The prototype of the electronics will be done with the Pi Model 3 + as it has the adequate amount of outputs needed to run the game.
- A breadboard will be used for the electronics because changes can be easily made (without soldering or de-soldering).
- In place of the large LED buttons I plan to use in the final product, I will be using 6mm square momentary pushbutton switches and LEDs along with 220 Ω to protect the Raspberry Pi.

Prototype Raspberry Pi Wiring Diagram:

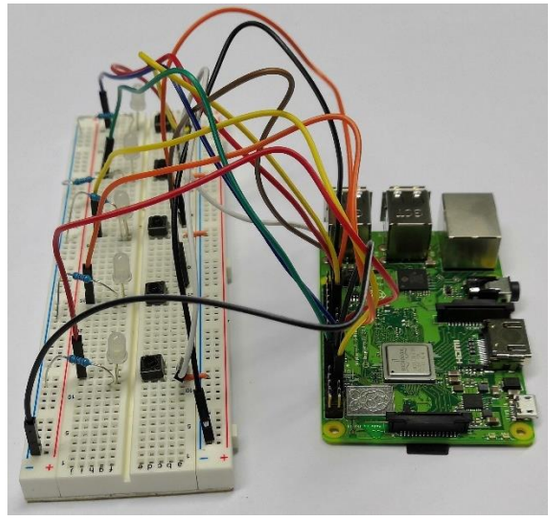


Using the GPIO (General Purpose Input/Output) pin layout for the Raspberry Pi model 3 I have made this diagram to help and use when making the prototype electronics for this product.

Bread Board with components:



Fully constructed initial prototype for electronics:



Game mechanics and coding:

Just before I start coding the game I will be presenting two similar but different game mechanics and then bearing in mind his views, I will be making a decision on the best one to choose. The two-game different mechanics are:

1. Upon completing the first level, where three randomly chosen animals are shown as a sequence, on the next level there will be a sequence of four animals which are different from the first three-part sequence. This pattern of having a new sequence generated but with one more animal continues upon every stage advanced until the game is lost and then it's reset back to a sequence of three animals.
2. Upon completing the first level, where three randomly chosen animals are shown as a sequence, a new animal is added to the animal sequence. So, every time a user completes a level one animal is added to the sequence.

The client did not have a preference to either one so I will be choosing which game mechanic based on research findings. As can be seen from other games children play (such as the "I went to the supermarket and bought" … game) and nursery songs such as "Old Macdonald had a farm", iteration is a key part of a child's educational development. Therefore, I will be going with the second game mechanic as it incorporates more iteration than the first.

The following are the code objectives:

- Generate the required number of events (the order animal noises and flashing lights)
- Display those events to the user.
- Allow time for user inputs and match them against the computer's generated events.
- **If they match,** proceed to the next round (add one event to the sequence).
- **If they don't match,** finish the game and let the user know through the speakers what their final score was.

Coding on the Raspberry pi:

As I have most experience coding with python I will be using that programming language in both the prototype and then the iterations that may be made to get to the code for the final product.

After researching what Python library to use in order to get inputs and outputs from the Raspberry Pi's pins, I have found that the most popular and best one to use is GPIO. There are two main versions of GPIO for the Raspberry Pi: standard GPIO and gpiozero. I will be using gpiozero as it has a simpler interface when compared to GPIO, therefore, it'll be easier to understand and find/reduce the chances of bugs in the code.

The code:

Please note that within the code I introduced a Quick tutorial sound, that will make the product easier to operate by 4 - 6-year-olds (this was one of the improvements that had to be made).

```
import random
import time
from gpiozero import Button, LED
import pygame

pygame.init()

cowSound = pygame.mixer.Sound("cow.wav")
pigSound = pygame.mixer.Sound("pig.wav")
dogSound = pygame.mixer.Sound("dog.wav")
catSound = pygame.mixer.Sound("cat.wav")
sheepSound = pygame.mixer.Sound("sheep.wav")
memGameTutorial = pygame.mixer.Sound("memGameTutorial.wav")
score = 2
rounds = 1
#Animal Order: cow pig dog cat sheep
sequence = []
userSequence = []
sequenceNumber = rounds + 2

led1 = LED(4)
led2 = LED(17)
led3 = LED(27)
led4 = LED(22)
led5 = LED(10)
button1 = Button(5)
button2 = Button(6)
button3 = Button(19)
button4 = Button(13)
button5 = Button(26)

memGameTutorial.play()

def level(score, rounds, sequence, userSequence, sequenceNumber):
```

```
    i = len(sequence)
    while i < sequenceNumber:
        animal = random.randint(1,5)
        sequence.append(animal)
        i = i + 1
    display(score, rounds, sequence, userSequence, sequenceNumber)

def display(score, rounds, sequence, userSequence, sequenceNumber):
    c = 0 #(counter)
    i = 0
    while i < sequenceNumber:
        if sequence[c] == 1:
            led1.on()
            cowSound.play()
            time.sleep(1.5) #amount of time led is on
            led1.off()
        elif sequence[c] == 2:
            led2.on()
            pigSound.play()
            time.sleep(1.5)
            led2.off()
        elif sequence[c] == 3:
            led3.on()
            dogSound.play()
            time.sleep(1.5)
            led3.off()
        elif sequence[c] == 4:
            led4.on()
            catSound.play()
            time.sleep(1.5)
            led4.off()
        elif sequence[c] == 5:
            led5.on()
            sheepSound.play()
            time.sleep(1.5)
            led5.off()
        time.sleep(0.5)
        c = c + 1
        i = i + 1
    print(sequence)
    UI(rounds, sequenceNumber, userSequence)

def UI(rounds, sequenceNumber, userSequence):
    i = 0
    while i < sequenceNumber:
        a = True
        while a == True:
            if button1.is_pressed: #(If the Cow button is pressed)
                uInput = 1
                led1.on()
                cowSound.play()
                time.sleep(1.5)
                led1.off()
                userSequence.append(uInput)
                i = i + 1
                a = False
            if button2.is_pressed: #(If the Pig button is pressed)
                uInput = 2
                led2.on()
                pigSound.play()
                time.sleep(1.5)
                led2.off()
                userSequence.append(uInput)
                i = i + 1
                a = False
            if button3.is_pressed: #(If the Dog button is pressed)
                uInput = 3
                led3.on()
                dogSound.play()
                time.sleep(1.5)
                led3.off()
                userSequence.append(uInput)
                i = i + 1
                a = False
            if button4.is_pressed: #(If the Cat button is pressed)
                uInput = 4
                led4.on()
                catSound.play()
                time.sleep(1.5)
                led4.off()
                userSequence.append(uInput)
                i = i + 1
                a = False
            if button5.is_pressed: #(If the Sheep button is pressed)
                uInput = 5
                led5.on()
                sheepSound.play()
                time.sleep(1.5)
                led5.off()
                userSequence.append(uInput)
                i = i + 1
                a = False
    if sequence == userSequence:
        rounds = rounds + 1
        sequenceNumber = sequenceNumber + 1
        print("correct") #move onto next round
        userSequence = []
        level(score, rounds, sequence, userSequence, sequenceNumber)
    elif sequence != userSequence:
        print("Game over")
        print("Score: ", rounds - 1)
    else:
        print("Error with ending game")

level(score, rounds, sequence, userSequence, sequenceNumber)
```

So the code will run upon start-up, I imported and set up a piece of software called crontab on the raspberry pi. After configurating crontab to launch the code, the game automatically runs when the raspberry pi receives power and the raspberry pi bypasses login procedures as well as the desktop.

I ran this code on the raspberry pi (please refer to the **"Fully constructed initial prototype for electronics:"** captioned photo on the previous page) and let the target users as well as the client play with it. One improvement the Client wanted, after using the prototype, is that there should be another game mode. Such game mode should exercise the child more physically; I proposed that the new game mode should be one where a button lights up and then the user has to press the button as quickly as possible, this would improve the users' reaction times and physically exercise them. The client was happy with the concept for the new game mode.

Development of design into chosen design (part 2):

After developing the two initial designs further, I asked the client which one they would like to proceed into further development. Both the Client and I agree that the Animal Memory Game should be further developed into a final product because it's a better solution to the problem and contextual challenge compared to the Balance Maze product.

Please note that calculations to determine material quantities and technical details of materials will be done in the cutting list section.

In this section I will be implementing any final improvement/refinements that either I think should be made (based on research) or from client feedback. I will also be conducting research into key aspects of the product.

Further development of electronics and code:

Improvements to be made to the electronic/code:

- Add a start and select button - to make the game functional.
- Use RGB buttons, instead of just white.
- Add a seven-segment display – makes the product more inclusive (deaf people can know there score).
- Introduce a new game mode - to make the product more engaging.
- Incorporate RGB LEDs instead of just white LEDs - to make the product more engaging.
- Add more sounds - to make the product more engaging.
- Add a high score system – to develop a healthy sense of competitiveness.
- Make it so the Raspberry Pi runs the game file upon start-up.

Firstly, I will replace the regular LEDs for RGB LEDs and add a seven-segment display. The seven-segment display can either be done with cheaper individual seven-segment display modules and shift registers, the wiring diagram of which can be seen below, or with a slightly more expensive 4x 7-segment module can be used on its own. I decided to go with the 4 x 7-segment display module because, as can be seen from the photos, it needs less wiring and allows for the needed start and select button.

Diagram w/ shift registers:

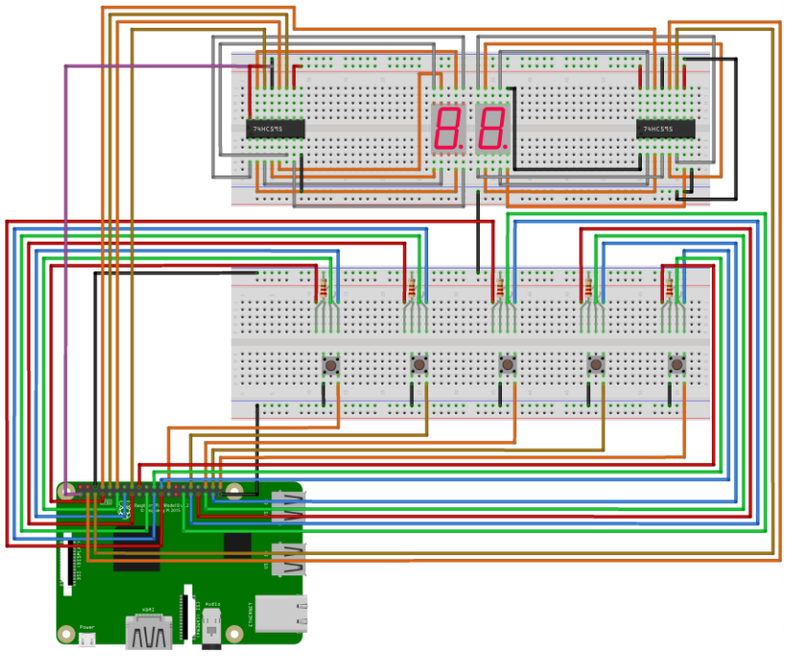
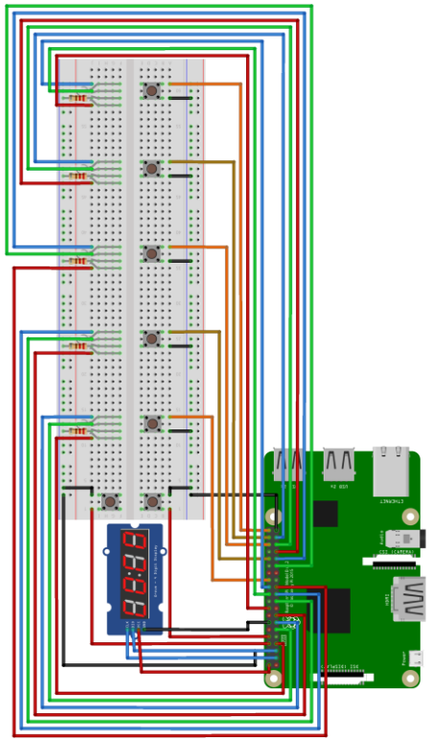
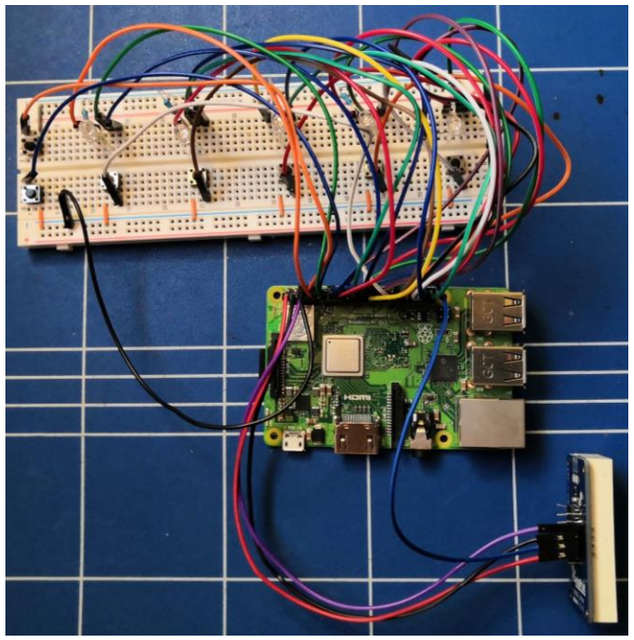


Diagram w/ 4x 7-segment module:





Once the prototype (with the 4x7-segment module) was constructed, I coded the second game mode into the game's python file, this game mode was called "speed game". After conducting research into the 4x 7-segment display module I'm using (the "Adafruit 0.56" 4-Digit 7-Segment Display"), I realised I had to install the "Adafruit_LEDBackpack" library and enable i2C on the raspberry pi. In both cases the raspberry pi terminal was used, to install the required library I used the command "sudo pip3 install Adafruit_LEDBackpack" and to enable i2c I used the command "raspi-config" and then navigated through the menu to the i2c enabling section.

In order to incorporate RGB LEDs I followed online tutorials I learnt that the format led_identifier = RGBLED(red=red_pin, green=green_pin, blue=blue_pin).

For adding more sounds, I recorded the same person that did the memory game tutorial sound, saying the list of sounds that would be incorporated into the game. I then saved the audio files as WAV files and then placed the files under the same directory as the game file that's being run.

To do the high score system, I made text files that would store the high scores for the individual games. The number in these files could be accessed when needed. I also made a number output system that would stitch sounds for numbers together and then output them. For example, 87 would be "eighty" and "7" or 124 would be "one hundred", "and", "20" and "4".

In order to make the game more appealing, I added some Light animations.

The following is the code that will be used in the final product:

```
#Final version
import random #used for generating random orders of sequences.
import time #used throughout for timing purposes
from gpiozero import Button, RGBLED #mainly used for user input/output
import pygame #used for sound effects
import threading #used for timer
from Adafruit_LED_Backpack import SevenSegment #used for seven segment display
#Animal Order List: cow pig dog cat sheep
#colour list and order: red green blue yellow purple
colours = ["red = 1", "green = 1", "blue= 1", "color = (0.75, 0.75, 0)", "color = (0.5, 0, 1)"]
led1 = RGBLED(red=4, green=17, blue=27)
led2 = RGBLED(red=22, green=10, blue=9)
led3 = RGBLED(red=11, green=21, blue=20)
led4 = RGBLED(red=16, green=12, blue=7)
led5 = RGBLED(red=8, green=25, blue=24)
button1 = Button(5)
button2 = Button(6)
button3 = Button(19)
button4 = Button(13)
```

```
button5 = Button(26)
buttonSelect = Button(14)
buttonStart = Button(15)
pygame.init()
cowSound = pygame.mixer.Sound("cow.wav")
pigSound = pygame.mixer.Sound("pig.wav")
dogSound = pygame.mixer.Sound("dog.wav")
catSound = pygame.mixer.Sound("cat.wav")
sheepSound = pygame.mixer.Sound("sheep.wav")
memory_gameSound = pygame.mixer.Sound("memory_game.wav")
speed_gameSound = pygame.mixer.Sound("speed_game.wav")
amazingSound = pygame.mixer.Sound("amazing.wav")
blntSound = pygame.mixer.Sound("better_luck_next_time.wav")
lbSound = pygame.mixer.Sound("lets_begin.wav")
lsiycbtSound = pygame.mixer.Sound("lets_see_if_you_can_beat_that.wav")
nhsSound = pygame.mixer.Sound("new_high_score.wav")
nice_trySound = pygame.mixer.Sound("nice_try.wav")
perfectSound = pygame.mixer.Sound("perfect.wav")
phenomenalSound = pygame.mixer.Sound("phenomenal.wav")
roaSound = pygame.mixer.Sound("round_of_applause.wav")
thats_correctSound = pygame.mixer.Sound("that's_correct.wav")
twgSound = pygame.mixer.Sound("that_was_great.wav")
well_doneSound = pygame.mixer.Sound("well_done.wav")
ysiSound = pygame.mixer.Sound("your_score_is.wav")
lsiycbtSound = pygame.mixer.Sound("lets_see_if_you_can_beat_that.wav")
nhsSound = pygame.mixer.Sound("new_high_score.wav")
thsiSound = pygame.mixer.Sound("the_high_score_is.wav")
speed_game_introSound = pygame.mixer.Sound("speed_game_intro.wav")
memory_game_introSound = pygame.mixer.Sound("memory_game_intro.wav")
display = SevenSegment.SevenSegment()
display.begin()

def sevenSegCleanUp():
    display.clear()
    display.write_display()

def sevenSegScore(score):
    display.clear()
    display.print_float(score, decimal_digits=0)
    display.write_display()

def numberOutput(score):
    runningScore = score
    hundreds = runningScore // 100
    runningScore = runningScore - 100 * hundreds
    tens = runningScore // 10
    runningScore = runningScore - 10 * tens
    ones = runningScore // 1
    runningScore = runningScore - 1 * ones
    hundreds = hundreds * 100
    tens = tens * 10
    if score > 0:
        if hundreds != 0:
            str(hundreds)
            hundredSound = pygame.mixer.Sound("{}.wav".format(hundreds))
            hundredSound.play()
            time.sleep(1.2)
            andSound = pygame.mixer.Sound("and.wav")
            andSound.play()
            time.sleep(0.5)
        t = 1
        if tens != 0:
            str(tens)
            if tens == 10:
                tensSound = pygame.mixer.Sound("1{}.wav".format(ones))#for teens
                t = 0
            else:
                tensSound = pygame.mixer.Sound("{}.wav".format(tens))
            tensSound.play()
            time.sleep(0.8)

        if t == 1:
            if ones != 0:
                str(ones)
                onesSound = pygame.mixer.Sound("{}.wav".format(ones))
                onesSound.play()
                time.sleep(1)
    else:
        zeroSound = pygame.mixer.Sound("0.wav")
        zeroSound.play()
        time.sleep(1.2)

def scoreOutput(score, speedGame):
    well_doneSound.play()
    time.sleep(1.25)
    ysiSound.play()
    time.sleep(1.25)
    numberOutput(score)
    if speedGame == True:
        if score < 20:
            blntSound.play()
            time.sleep(1)
        elif score <= 20:
            twgSound.play()
        elif score <= 40:
            amazingSound.play()
        else:
            phenomenalSound.play()
    elif speedGame == False:
        if score <= 2:
            blntSound.play()
            time.sleep(1)
        elif score < 2:
            twgSound.play()
        elif score < 5:
            amazingSound.play()
        else:
            phenomenalSound.play()
    time.sleep(1)

def highScoreOutput(speedGame):
    if speedGame == True:
        speedGameHigh = open("speedGameHigh.txt","r") #File needs to be created when in use
        score = int(speedGameHigh.readline())
        speedGameHigh.close()
        thsiSound.play()
        time.sleep(1.25)
        numberOutput(score)
        for i in range(3):
            display.clear()
            display.write_display()
            time.sleep(0.5)
```

```
        display.print_float(score, decimal_digits=0)
        display.write_display()
        time.sleep(0.5)
    else:
        memGameHigh = open("memGameHigh.txt","r")
        score = int(memGameHigh.readline())
        memGameHigh.close()
        thsiSound.play()
        time.sleep(1.25)
        numberOutput(score)
        for i in range(3):
            display.clear()
            display.write_display()
            time.sleep(0.5)
            display.print_float(score, decimal_digits=0)
            display.write_display()
            time.sleep(0.5)
    lsiycbtSound.play()
    time.sleep(2.5)

def highScoreCheck(score, speedGame):
    if speedGame == True:
        speedGameHigh = open("speedGameHigh.txt","r")
        highScore = int(speedGameHigh.readline())
        speedGameHigh.close()
        if score > highScore:
            speedGameHigh = open("speedGameHigh.txt","w")
            speedGameHigh.write(str(score))
            nhsSound.play()
            time.sleep(1)
            speedGameHigh.close()
    elif speedGame == False:
        memGameHigh = open("memGameHigh.txt","r")
        highScore = int(memGameHigh.readline())
        memGameHigh.close()
        if score > highScore:
            memGameHigh = open("memGameHigh.txt","w")
            memGameHigh.write(str(score))
            nhsSound.play()
            time.sleep(0.7)
            roapSound.play()
            time.sleep(0.7)
            memGameHigh.close()

def allOn():
    led1.red = 1
    led2.green = 1
    led3.blue = 1
    led4.color = (0.75, 0.75, 0)
    led5.color = (0.5, 0, 1)

def allOff():
    led1.off()
    led2.off()
    led3.off()
    led4.off()
    led5.off()

def LEDSwipe():
    led1.red = 1
    time.sleep(0.1)
    led1.off()
    led2.green = 1
    time.sleep(0.1)
    led2.off()
    led3.blue = 1
    time.sleep(0.1)
    led3.off()
    led4.color = (0.75, 0.75, 0)
    time.sleep(0.1)
    led4.off()
    led5.color = (0.5, 0, 1)
    time.sleep(0.1)
    led5.off()
    led4.color = (0.75, 0.75, 0)
    time.sleep(0.1)
    led4.off()
    led3.blue = 1
    time.sleep(0.1)
    led3.off()
    led2.green = 1
    time.sleep(0.1)
    led2.off()
    led1.red = 1
    time.sleep(0.1)
    led1.off()

def allFlash(n):
    x = 0
    while x < n:
        allOn()
        time.sleep(0.4)
        allOff()
        time.sleep(0.4)
        x = x + 1
def startEndAnimation():
    LEDSwipe()
    allFlash(2)

def menu():
    sevenSegCleanUp()
    colours = [0, 1, 2, 3, 4]
    colourAssignment = []

    def memGame():
        memory_game_introSound.play()
        time.sleep(2)
        while 0 < len(colours):
            d = random.randint(0, (len(colours) - 1) )
            colourAssignment.append(colours[d])
            del colours[d]
        i = 0
        while i <= 4:
            if colourAssignment[i] == 0:
                colourAssignment[i] = "red = 1"
            elif colourAssignment[i] == 1:
                colourAssignment[i] = "green = 1"
            elif colourAssignment[i] == 2:
                colourAssignment[i] = "blue = 1"
            elif colourAssignment[i] == 3:
                colourAssignment[i] = "color = (0.75, 0.75, 0)"
            elif colourAssignment[i] == 4:
                colourAssignment[i] = "color = (0.5, 0, 1)"
            i = i + 1
        led1On = "led1." + colourAssignment[0]
        led2On = "led2." + colourAssignment[1]
        led3On = "led3." + colourAssignment[2]
        led4On = "led4." + colourAssignment[3]
        led5On = "led5." + colourAssignment[4]
        highScoreOutput(False)
        lbSound.play()
        startEndAnimation()
        sevenSegScore(0)
        rounds = 1
        sequence = []
        userSequence = []
        sequenceNumber = rounds + 2

        def level(rounds, sequence, userSequence, sequenceNumber):
            i = len(sequence)
            while i < sequenceNumber:
                animal = random.randint(1,5)
                sequence.append(animal)
                i = i + 1
            display(rounds, sequence, userSequence, sequenceNumber)

        def display(rounds, sequence, userSequence, sequenceNumber):
            c = 0 #(counter)
            i = 0
            while i < sequenceNumber:
                if sequence[c] == 1:
                    exec(led1On)
                    cowSound.play()
                    time.sleep(1.5) #amount of time led is on
                    led1.off()  # off
                elif sequence[c] == 2:
                    exec(led2On)
                    pigSound.play()
                    time.sleep(1.5)
                    led2.off()
                elif sequence[c] == 3:
                    exec(led3On)
                    dogSound.play()
                    time.sleep(1.5)
                    led3.off()
                elif sequence[c] == 4:
                    exec(led4On)
                    catSound.play()
                    time.sleep(1.5)
                    led4.off()
                elif sequence[c] == 5:
                    exec(led5On)
                    sheepSound.play()
                    time.sleep(1.5)
                    led5.off()
                time.sleep(0.5)
                c = c + 1
                i = i + 1
            UI(rounds, sequenceNumber, userSequence)

        def UI(rounds, sequenceNumber, userSequence):
            i = 0
            while i < sequenceNumber:
```

```
a = True
while a == True:
    if buttonSelect.is_pressed:
        highScoreCheck(rounds - 1, False)
        scoreOutput(rounds - 1, False)
        menu()
    if button1.is_pressed: #(If the Cow button is pressed)
        uInput = 1
        exec(led1On)
        cowSound.play()
        time.sleep(1.5)
        led1.off()
        userSequence.append(uInput)
        i = i + 1
        a = False
    elif button2.is_pressed: #(If the Pig button is pressed)
         uInput = 2
         exec(led2On)
         pigSound.play()
         time.sleep(1.5)
         led2.off()
         userSequence.append(uInput)
         i = i + 1
         a = False
    elif button3.is_pressed: #(If the Dog button is pressed)
         uInput = 3
         exec(led3On)
         dogSound.play()
         time.sleep(1.5)
         led3.off()
         userSequence.append(uInput)
         i = i + 1
         a = False
    elif button4.is_pressed: #(If the Cat button is pressed)
         uInput = 4
         exec(led4On)
         catSound.play()
         time.sleep(1.5)
         led4.off()
         userSequence.append(uInput)
         i = i + 1
         a = False
    elif button5.is_pressed: #(If the Sheep button is pressed)
         uInput = 5
         exec(led5On)
         sheepSound.play()
         time.sleep(1.5)
         led5.off()
         userSequence.append(uInput)
         i = i + 1
         a = False
if sequence == userSequence:
    score = rounds
    sevenSegScore(score)
    thats_correctSound.play()
    allFlash(2)
    rounds = rounds + 1
    sequenceNumber = sequenceNumber + 1
    userSequence = []
    level(rounds, sequence, userSequence, sequenceNumber)
elif sequence != userSequence:
        score = rounds - 1
        highScoreCheck(score, False)
        scoreOutput(score, False)
        menu()
    level(rounds, sequence, userSequence, sequenceNumber)

def speedGame():
    speed_game_introSound.play()
    time.sleep(3)
    while 0 < len(colours):
        d = random.randint(0, (len(colours) - 1) )
        colourAssignment.append(colours[d])
        del colours[d]
    i = 0
    while i <= 4:
        if colourAssignment[i] == 0:
            colourAssignment[i] = "red = 1"
        elif colourAssignment[i] == 1:
            colourAssignment[i] = "green = 1"
        elif colourAssignment[i] == 2:
            colourAssignment[i] = "blue = 1"
        elif colourAssignment[i] == 3:
            colourAssignment[i] = "color = (0.75, 0.75, 0)"
        elif colourAssignment[i] == 4:
            colourAssignment[i] = "color = (0.5, 0, 1)"
        i = i + 1
    led1On = "led1." + colourAssignment[0]
    led2On = "led2." + colourAssignment[1]
    led3On = "led3." + colourAssignment[2]
    led4On = "led4." + colourAssignment[3]
    led5On = "led5." + colourAssignment[4]
    highScoreOutput(True)
    lbSound.play()
    startEndAnimation()
    sevenSegScore(0)

    def timeUp():
        f= open("speedGameStatus.txt","w")
        f.write("over")
        f.close()
        timer.cancel()

    def speedGameStart(score):
        time.sleep(0.1)
        animal2 = random.randint(1,5)
        time.sleep(0.1)
        if animal2 == 1:
            exec(led1On)
            cowSound.play()
        elif animal2 == 2:
            exec(led2On)
            pigSound.play()
        elif animal2 == 3:
            exec(led3On)
            dogSound.play()
        elif animal2 == 4:
            exec(led4On)
            catSound.play()
        elif animal2 == 5:
            exec(led5On)
            sheepSound.play()
```

```
def gameScoreDisplay(score):
    score = score + 1
    sevenSegScore(score)
    #play score announcement
    speedGameStart(score)

def carryOn(score):
    gameScoreDisplay(score)
def sequence(animal2, score):
    time.sleep(0.1)
    a = True
    while a == True:
        if buttonSelect.is_pressed:
            timeUp()
        else:
            f = open('speedGameStatus.txt', 'r') #Move this all under sequence instead
            if f.readline() == "over":
                f.close()
                allFlash(3)
                highScoreCheck(score, True)
                scoreOutput(score, True)
                menu()
            else:
                if button1.is_pressed: #(If the Cow button is pressed)
                    if animal2 == 1:
                        led1.off()
                        animal2 = 0
                        carryOn(score)
                    else:
                        sequence(animal2, score)
                elif button2.is_pressed: #(If the Cow button is pressed)
                    if animal2 == 2:
                        led2.off()
                        animal2 = 0
                        carryOn(score)
                    else:
                        sequence(animal2, score)
                elif button3.is_pressed: #(If the Cow button is pressed)
                    if animal2 == 3:
                        led3.off()
                        animal2 = 0
                        carryOn(score)
                    else:
                        sequence(animal2, score)
                elif button4.is_pressed: #(If the Cow button is pressed)
                    if animal2 == 4:
                        led4.off()
                        animal2 = 0
                        carryOn(score)
                    else:
                        sequence(animal2, score)
                elif button5.is_pressed: #(If the Cow button is pressed)
                    if animal2 == 5:
                        led5.off()
                        animal2 = 0
                        carryOn(score)
                    else:
                        sequence(animal2, score)
    sequence(animal2, score)

timer = threading.Timer(60, timeUp)
```

```
    timer.start()
    f= open("speedGameStatus.txt","w+")
    f.write("going")
    f.close()
    speedGameStart(0)

def select(gameMode):
    b = True
    while b == True:
        if buttonSelect.is_pressed:
            gameMode = gameMode + 1
            if gameMode % 2 == 0:
                memory_gameSound.play()
            else:
                speed_gameSound.play()
            time.sleep(0.5)
            select(gameMode)
        if buttonStart.is_pressed:
            b = False
            if gameMode % 2 == 0:
                b = False
                memGame()
            else:
                b = False
                speedGame()
select(0)
startEndAnimation()
menu()
```

Lines = 536

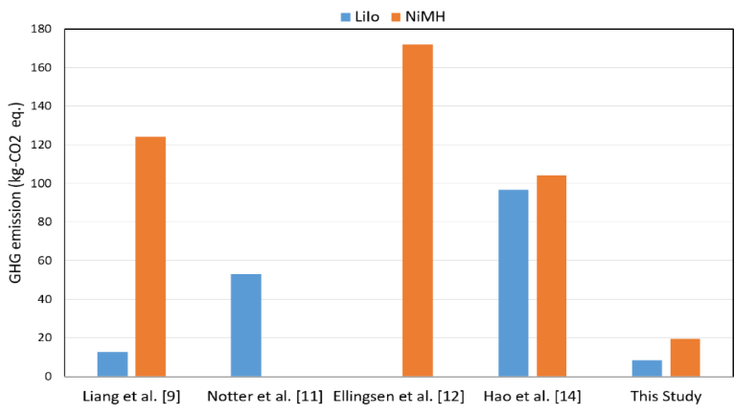
Research into batteries:

Due to the environment this product will be situated in, the battery will have to be able to comply with these requirements:

- Use and storage temperature from -20°C – 40°C (These are suitable minimum and maximum temperature for the UK climate)
- Rechargeable
- Be no thicker than 10mm (as to fit into the product so no outdent needed

After looking into the batteries that fit the criteria a battery such as an alkaline battery won't be suitable as it is non-rechargeable. Also, Li-Po batteries won't be suitable due to their temperature requirements. However, Li-ion and NiMH batteries meet the requirements. Therefore, I will continue to research these two battery types and then find the most suitable battery.

Comparing environmental effects:

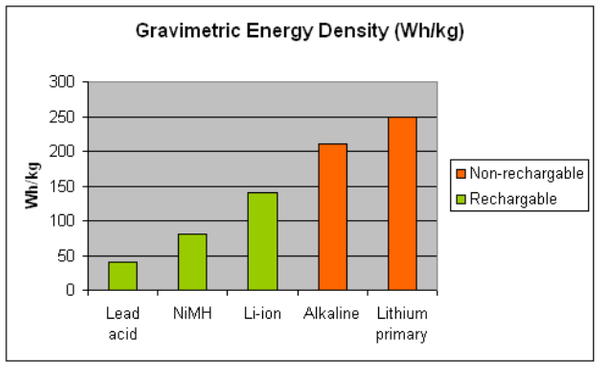


In this graph, we can see that all the studies show that Lithium-Ion batteries have less GHG emissions during production.

Also, from a comparative L.C.A of comparing the two batterie types, published in February 2019, it is shown that "there is a significant environmental impact caused by nickel-metal hydride batteries in comparison with lithium-ion batteries." This is primarily because of the toxic chemicals in NiMH batteries. Source: https://www.mdpi.com/2313-0105/5/1/22/htm

Comparing energy densities:

As stated by many sources, Lithium-ion cells have "one of the highest energy densities of any battery technology", with their energy density being from 100-265 Wh/kg. This, therefore, means more energy can be stored in the battery weighing less than the equivalent in other battery technologies. This means that fewer batteries or lighter battery variants of Li-ion could be used when compared to NiMH, which will save on weight.



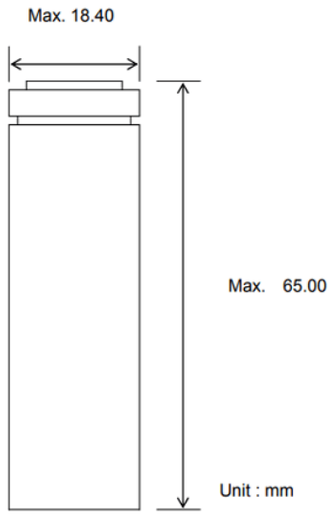
This shows that out of the rechargeable batteries Li-ion has the best energy density by a substantial margin meaning that from an energy density standpoint it should be chosen.

Choosing battery type and format:

After researching the two most suitable battery types I am choosing to go with Li-ion as it has a higher energy density when compared to NiMH batteries and they are relatively more environmentally friendly as they don't use the toxic chemicals found in NiMH batteries as well as having a lower carbon footprint.

The most common Li-ion cell used today is the 18650 cell, due to its price and availability as a result of its mass production. The 18650 cell also complies with all the requirements as a result of the product's environment. Also, 18650 cells can be found in device batteries such as dead or just discarded laptop batteries. The 18650 cells can be extracted and then tested to see if they're working and if deemed to be functional, used for the product. Using Recycled batteries means that the batteries won't go to landfill, potentially causing harm to animals, and fewer batteries need to be produced leading to less CO^2 emissions. Therefore, I will be going for the 18650 mainly because of they're more common and therefore easier to obtain.

Using the 18650 cell in the product:



Due to the relatively small dimensions of the 18650 cell, which can be seen in the diagram, it allows them to be arranged in a variety of formations, which will be helpful.

To connect the batteries, I will be spot welding them together using a spot welder. This is a much safer and more durable way of connecting the batteries when compared to soldering.

The raspberry pi I'm using draws 2000mA and after doing power calculations ((1 ÷ 3) X 1000) the current draw of the electronics is 2333.3 mA (2000 + 333.3). An adequate amount off time for the product to be able to run of the battery alone is 10 hours, therefore, I will need to wire 12 18650 cells, with a capacity of 2000 mAh, together in parallel. This means the battery will have a capacity of 24000 mAh giving me a run time of 10.3 hours (24000 ÷2333.3).

To connect the batteries, I will be spot welding them together using a spot welder. This is a much safer, easier and more durable way of connecting the cells when compared to soldering.

Selecting the remaining electronics:

For the solar panels, I have chosen to use 6X 250mAh 2V solar panels. I chose to use 6 smaller ones connected together, rather than two big ones, because of the requirement of them being separate because if one breaks, the broken solar panel is cheaper and easier to replace. I will connect two lots of three of the solar panels in series and put them on either side of the product. Then connect the two lots of solar panels together in parallel, this will give 6V and 500 mA when it's sunny. I will connect the solar panel outputs to a "DC-DC 0.9V-5V Step Up Power Supply Module" - this will give a constant 5-volt USB output. Please note it'll be rare that the solar panel exceeds an output of 6V and even if it does, upon testing, feeding the step-up power supply module 6V was found to be safe.

After researching several options the one I found to work best at powering the Pi was the "18650 Battery Shield V3 ESP32" (I'll be referring to it as the battery board). This will take the voltage from a 18650 cell and give a USB output that supplies enough voltage and current to power the raspberry pi. It also gives out multiple 3V supplies, one of which will be used to power the speaker. The solar panel power module will connect to the micro-USB input on the battery board; the USB output on the battery board will then connect to the micro-USB input on the Raspberry Pi.

As previously mentioned, I will need to select the speaker along with its PCB. The speaker must take a 3.5mm audio jack input and a 3V power input. I chose the "Kitronik Mono Amplifier Kit Version 3.0" as it meets all the for mentioned requirements and is reasonably priced at £2.09.

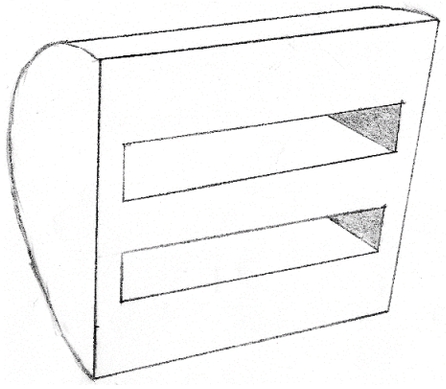
Developing curves:

In order to successfully meet the round corners requirement, I will need to develop a way of forming the curves. I will be developing the three following ways of forming curves and then choosing the best one to proceed with, in the final product:

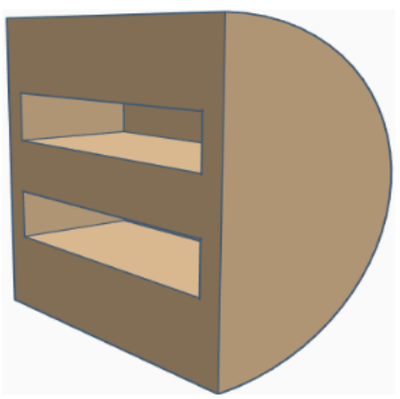
- A Lap joint
- A Living hinge
- Trapezium pieces

Lap joint prototyping:

A lap joint is made by reducing the thickness of each member (object) as to where they can fit together. For the first prototype of this joint, I will be designing a piece that will act as the curved piece for the product. I will be doing initial sketches then designing it in 3D CAD software. Finally, I'll 3D print a working prototype.

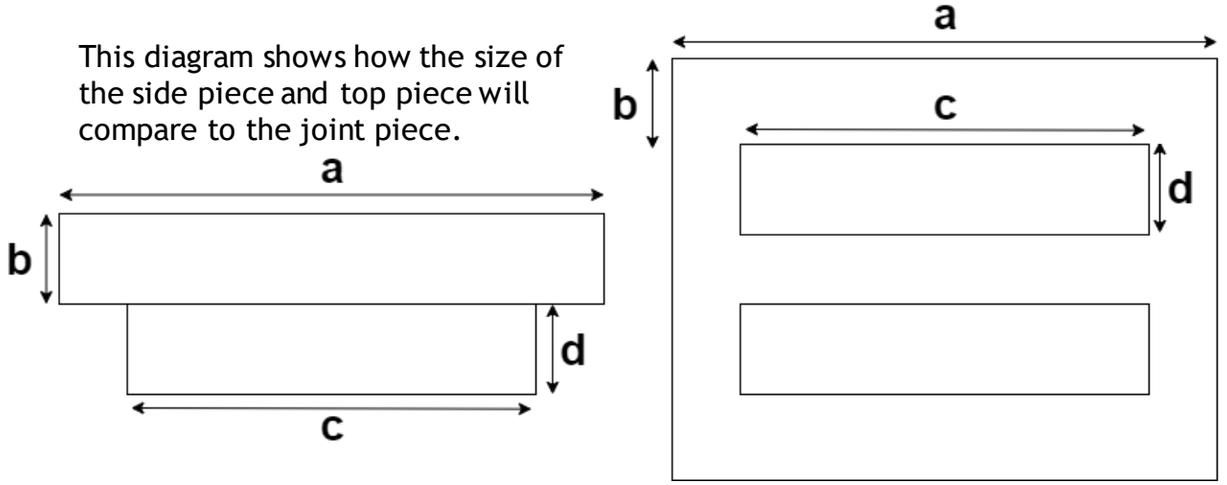


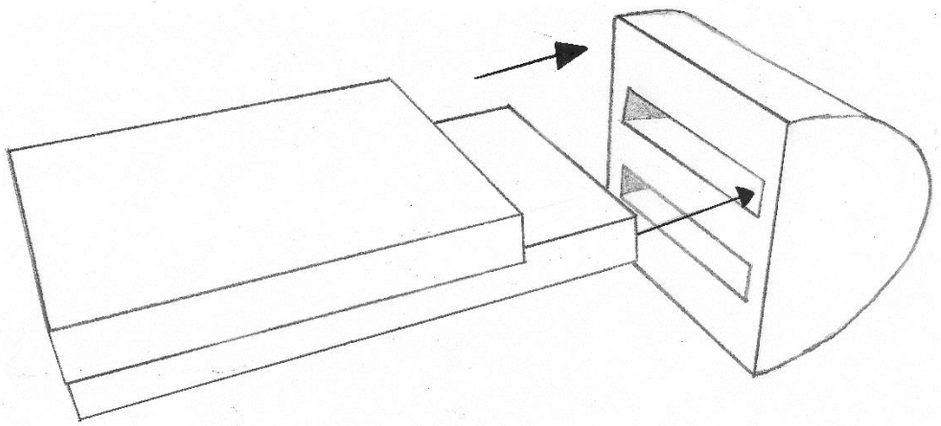
Initial sketch of rounded piece



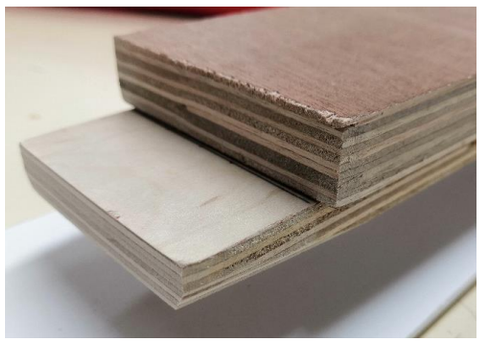
CAD for prototype of Side Joint

This diagram shows how the size of the side piece and top piece will compare to the joint piece.

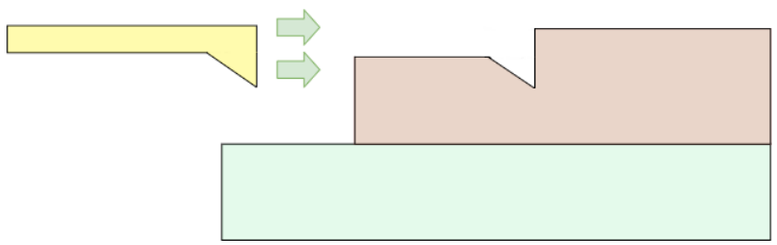


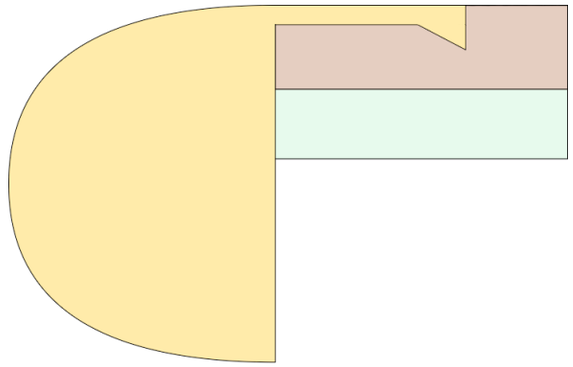


This drawing shows how the peg piece will be inserted into the top slot and top piece will sit flush with the top of the joint piece.

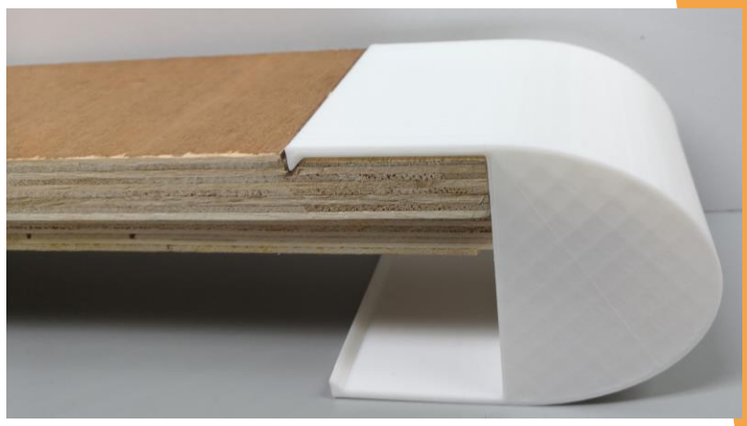


After looking at this joint prototype both the client and I agree that a development of the joint piece should be made to stop any water from being able to get inside the product.





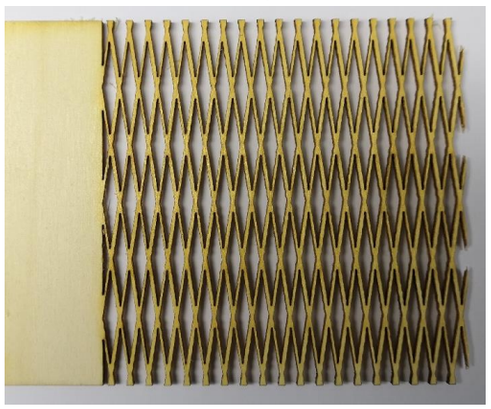
These sketches and diagrams show a piece that I have modified from the previous design to add sections in which would prevent water from entering the interior.

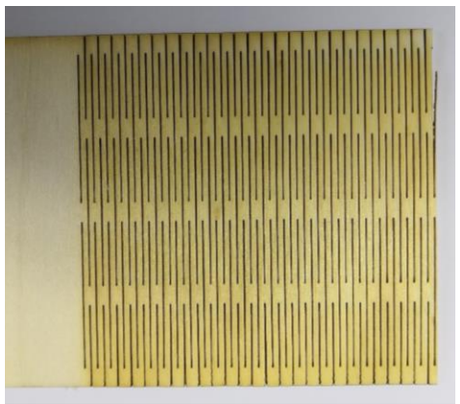


<u>Living hinge prototyping:</u>

A living hinge is a flexible piece of wood that connects two rigid pieces. Therefore, it is perfectly suited to be used for the curved form of my product.

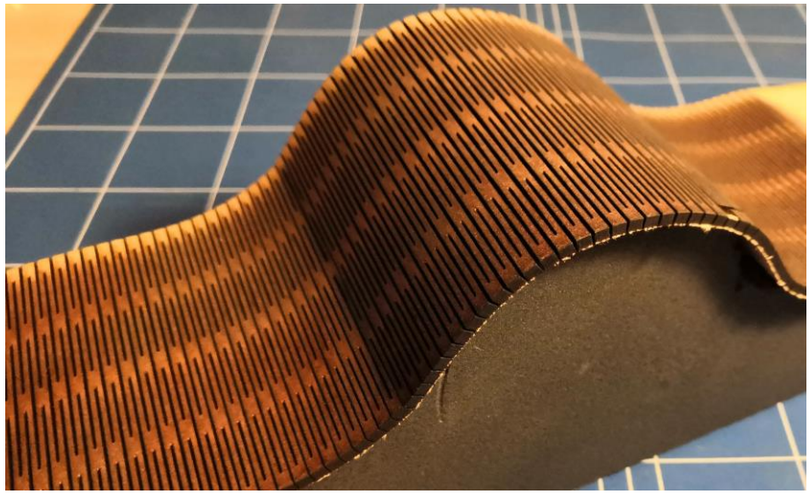
I will be designing and laser cutting different types of living hinges and then selecting the best one for my use case.





After laser cutting and testing all these living hinges I will be proceeding to develop the straight lines living hinge as it offers the best curve whilst retaining most of the wood's strength.

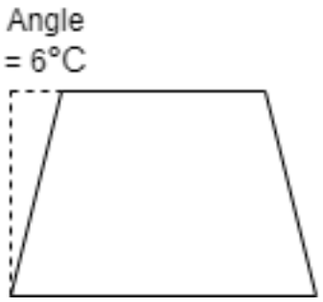
I used the previous model made to demonstrate the form to test the living hinge.



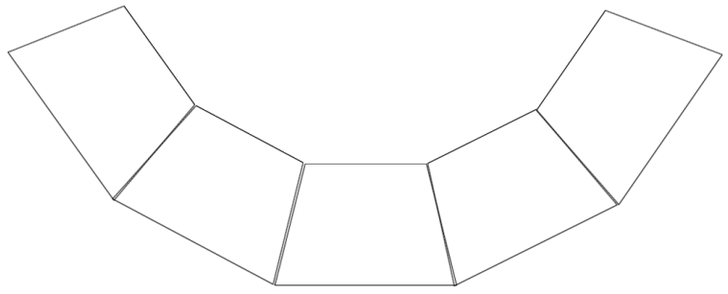
As can be seen from photo, the living hinge does form a nice curve however if it where to be used in the product A thinner piece of wood will have to be used and it will need to be made waterproof.

Trapezium pieces development:

Making a curve this way will require multiple trapezium prism pieces to be cut. This can be easily done using a table saw with the blade set to an angle.



By cutting identical trapeziums like this (left photo) I will be able to glue them together and form a curve as seen on the right.



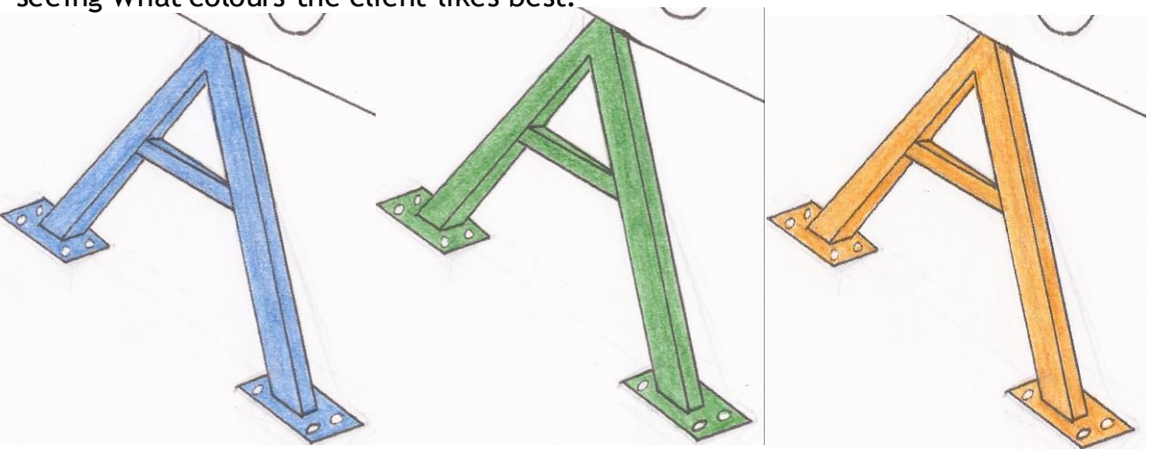
Once the trapezium prism pieces have been stuck together the exterior face will have to be sanded smooth.

Conclusion on what method to use:

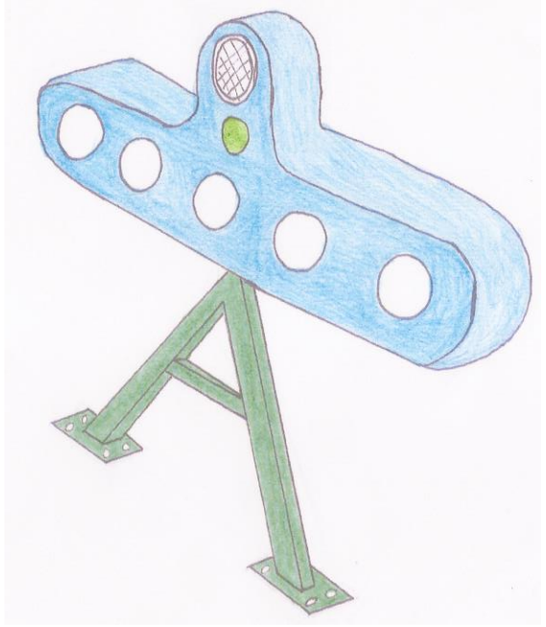
After weighing up the pros and cons of each way of forming a curve I have decided to proceed with the trapezium pieces technique as using that means the curves can be waterproof and don't use other materials like plastic.

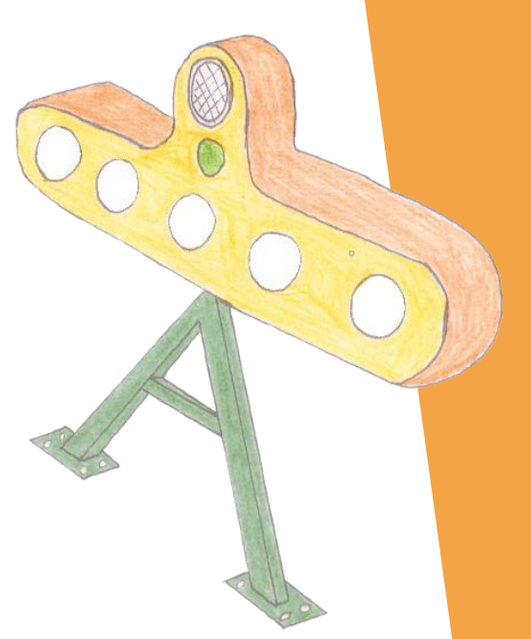
Developing colours:

As seen from the findings from the market research, bright first and secondary colours appeal most to children. As the product stands no colours have been given to it so that's what will be developed to meet the "brightly coloured" requirement. To see what colours work best, I will **roughly** sketch out the product so far and then apply different colours, first to the mount and then to the main piece, seeing what colours the client likes best.



The client preferred the green colour the most. The colour of the mount does need to be as bright because it's not the main piece.



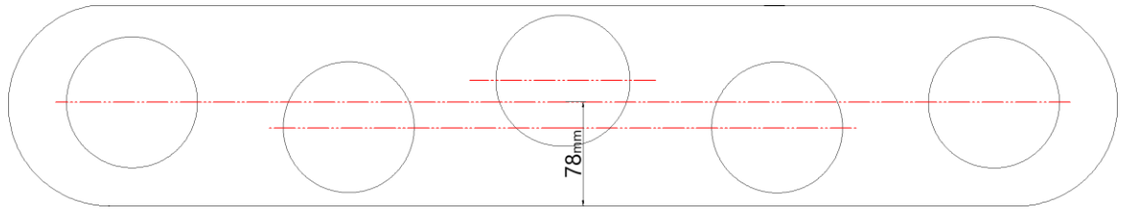


After looking at these two proposed colouring schemes the client has asked for the majority of the main piece to be painted blue. However, they do like the contrasting effects of the yellow and orange so I will incorporate those colours into the button's rims and disks.

Deciding button placements:

Up to now, all the buttons have been placed linearly, however, to make the product develop better at developing hand-eye coordination the buttons should be positioned at different heights.

As shown from research into the anthropometric data, the buttons should be around 818mm (which is the height of the shoulder) from the ground. Because the buttons will be placed at differing alternate heights, their middles can't all be placed at 818mm from the ground. So, it's important to ensure that all buttons overlap the line 818mm from the ground. This is clear in the diagram below showing where the buttons will be located on the product.



So the buttons get as close as possible to being 818mm from the ground, I've arranged them so that the two buttons at the far ends of either side are equidistant from the centre line of the one above and the two below. I've then made the two buttons at either side 78mm mm from the main piece, this will mean that the stand will have to be 740 mm (78+740 =818).

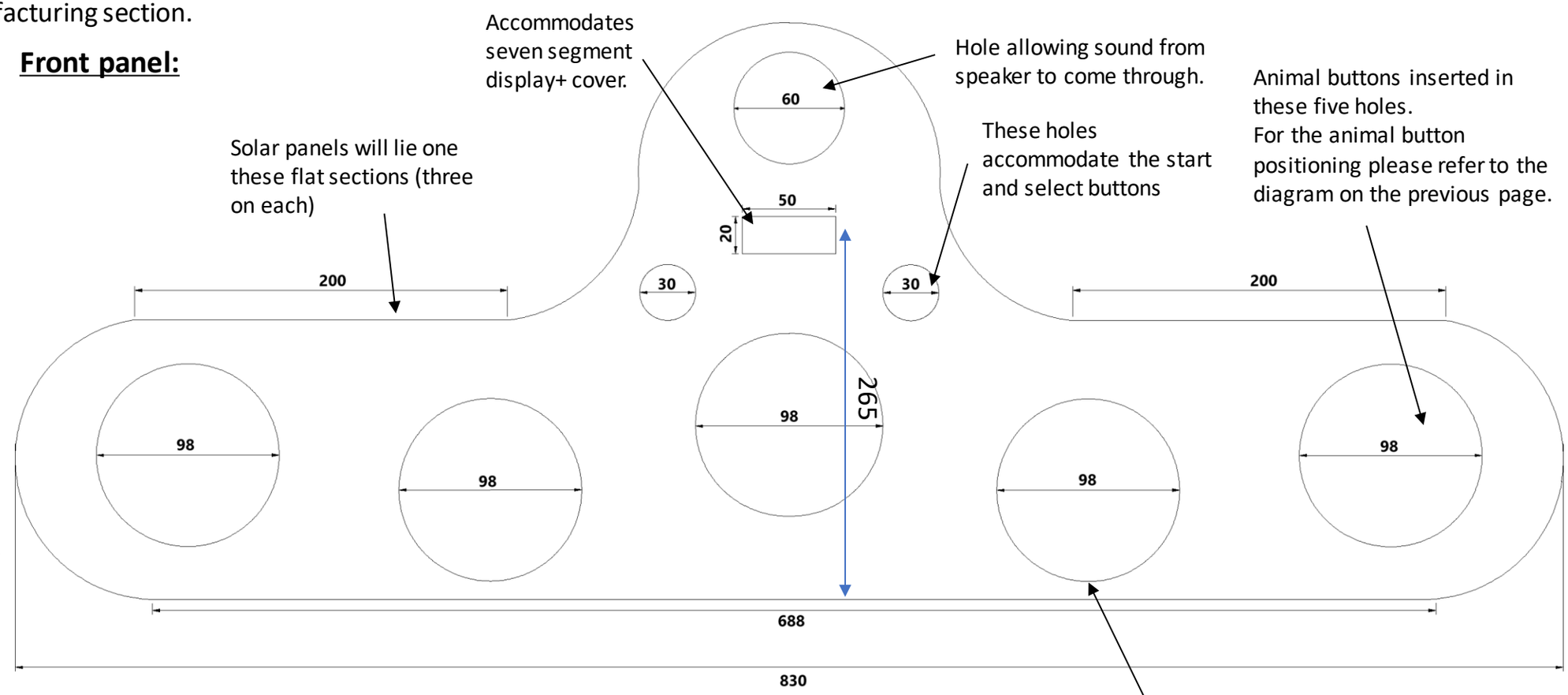
Final design section:

All sizes are in mm.

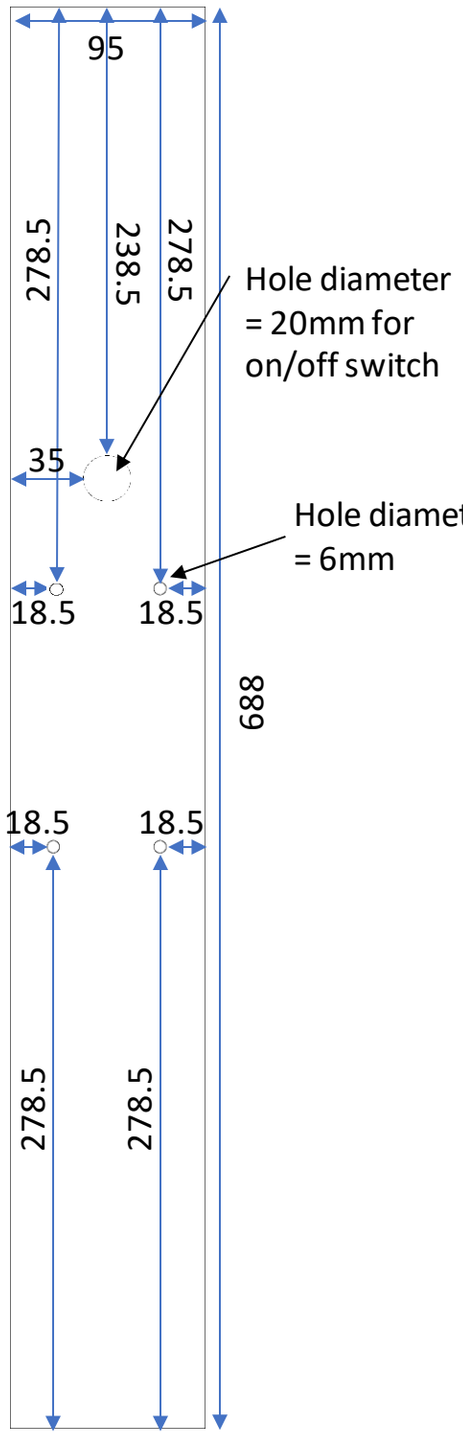
The front panel (12 mm thick) will connect to the back panel (12 mm thick) via pieces of wood which are 95 mm wide. This means that the whole product will be 119 mm thick.

For the materials used please refer to the first page of the manufacturing section.

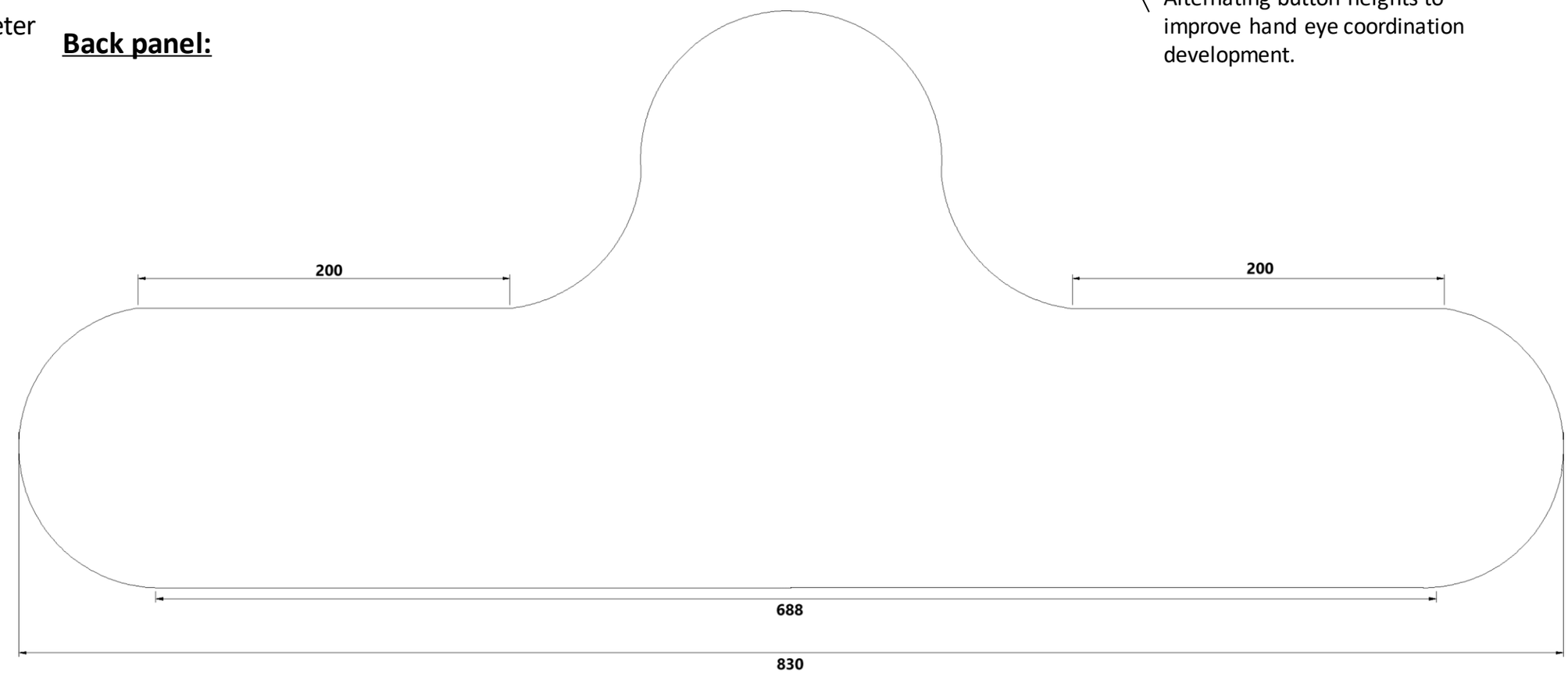
Front panel:



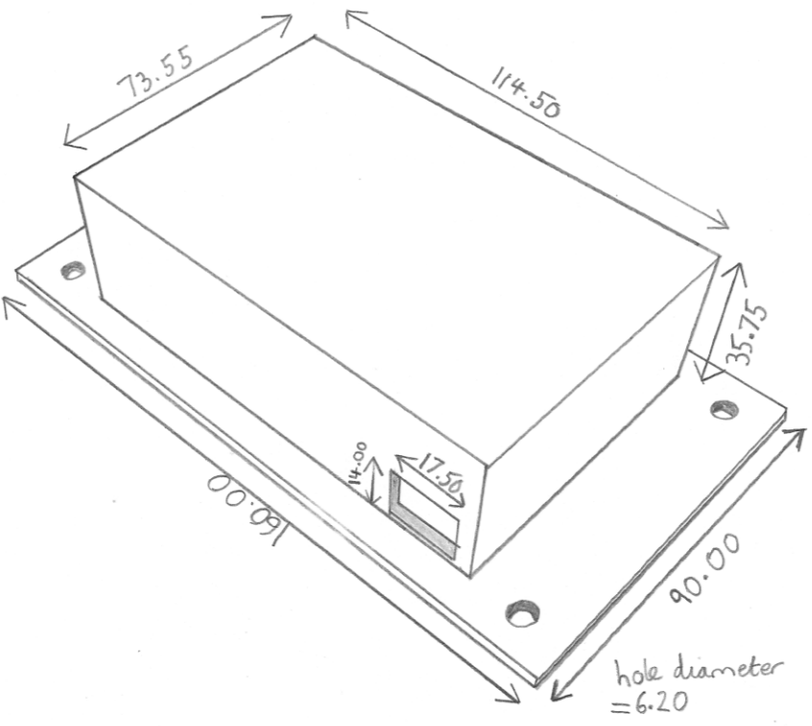
Bottom of main piece:



Back panel:

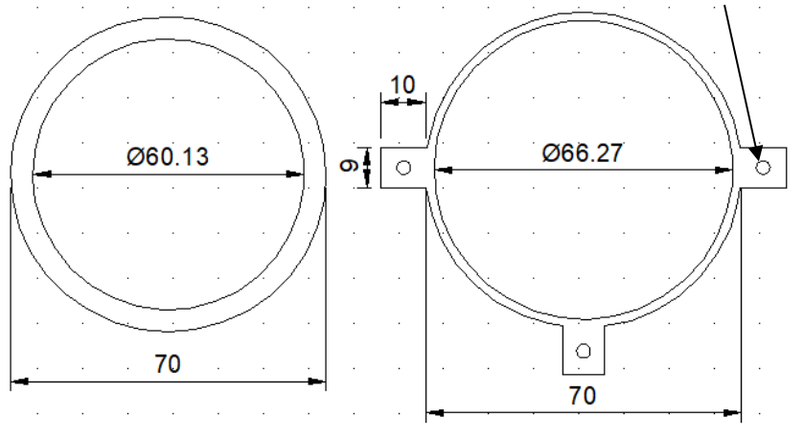


Battery holder/encloser:

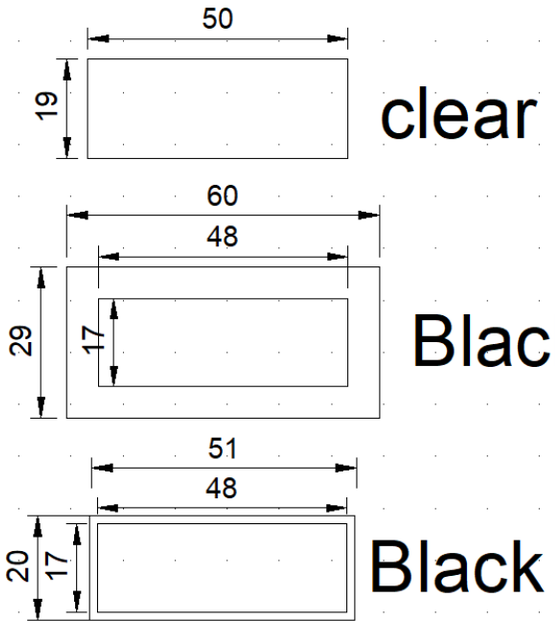


Speaker socket:

Hole diameter = 3mm

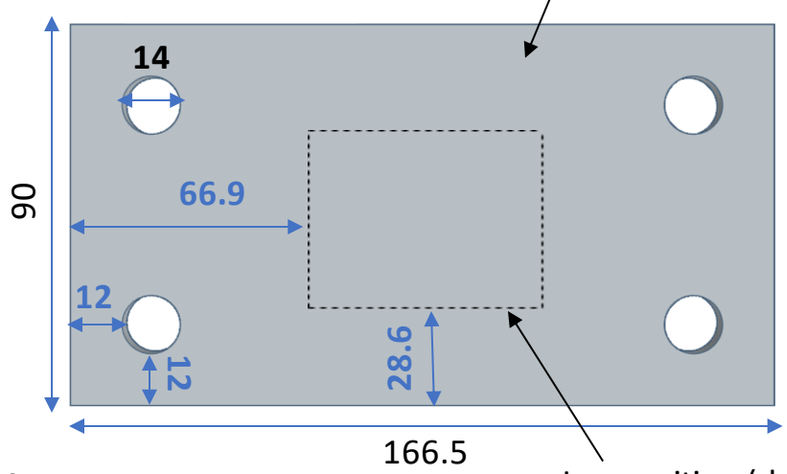


7-Segment display cover:



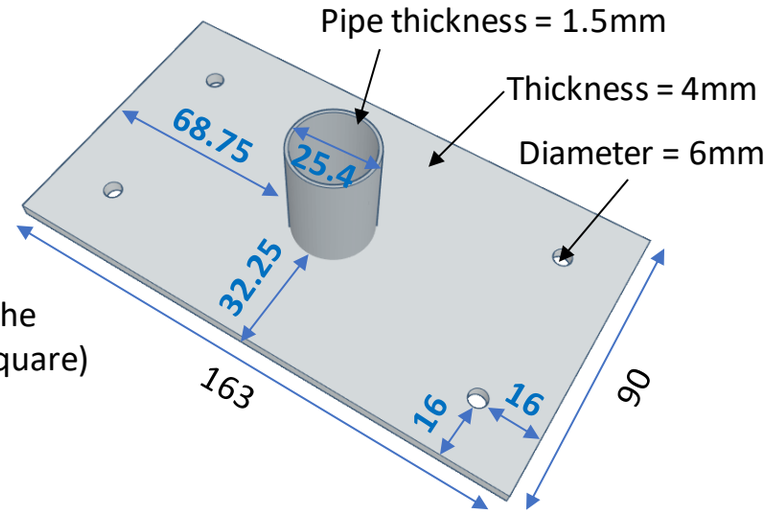
Base plate:

Thickness = 4mm



Leg position (due to the angle, it won't be a square)

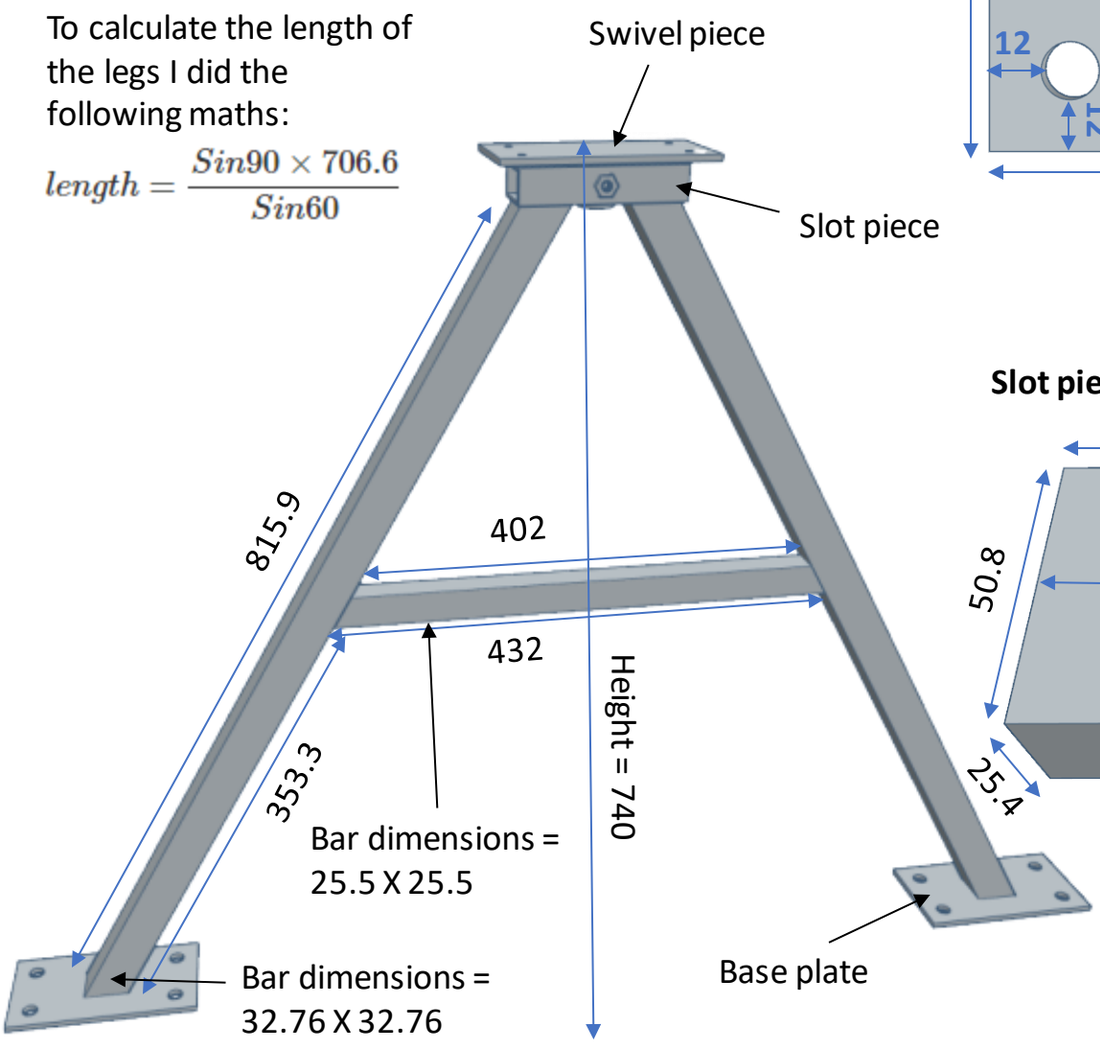
Swivel piece:



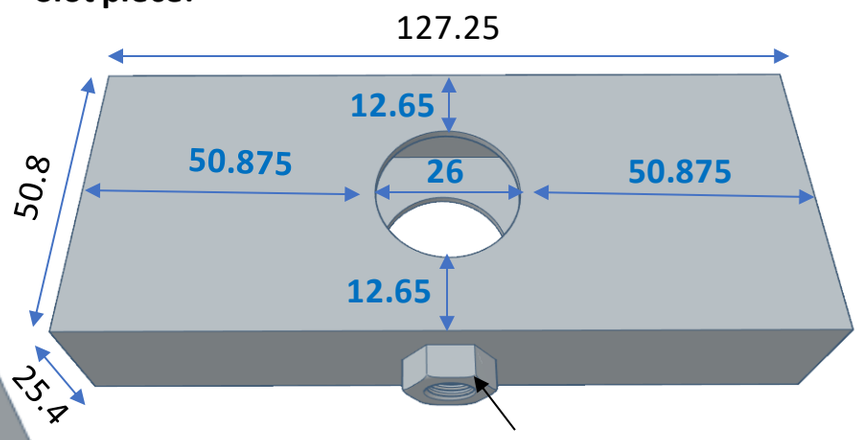
A frame stand (back view):

To calculate the length of the legs I did the following maths:

$$length = \frac{Sin90 \times 706.6}{Sin60}$$

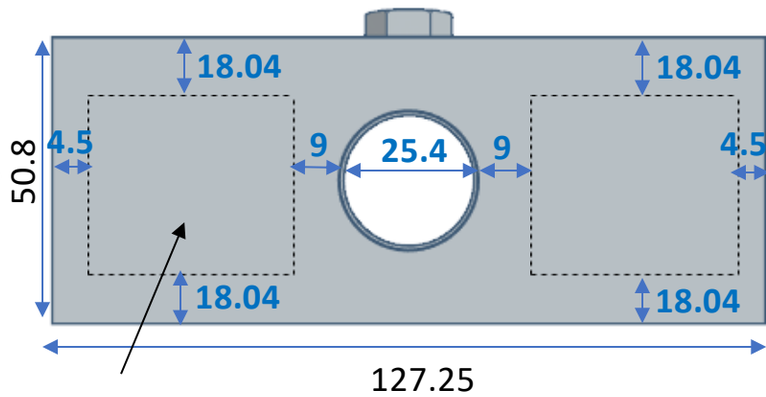


Slot piece:



M8 nut (positioned in centre of side face) with 8mm hole cut out.

Bottom elevation:

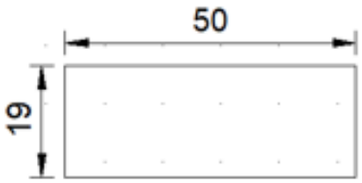


Leg positions (due to the angle, it won't be a square)

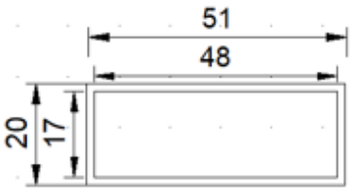
Cutting list (and quantities needed + cost calculations):

Wood:

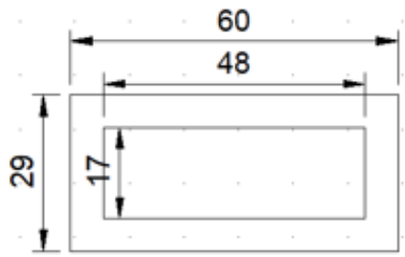
Length	Width	Thickness	Material	Quantity	Cost
860	700	12	marine plywood	1	£12
700	95	12	marine plywood	1	£2
210	95	12	marine plywood	2	£2
140	14	12	marine plywood	70	£7



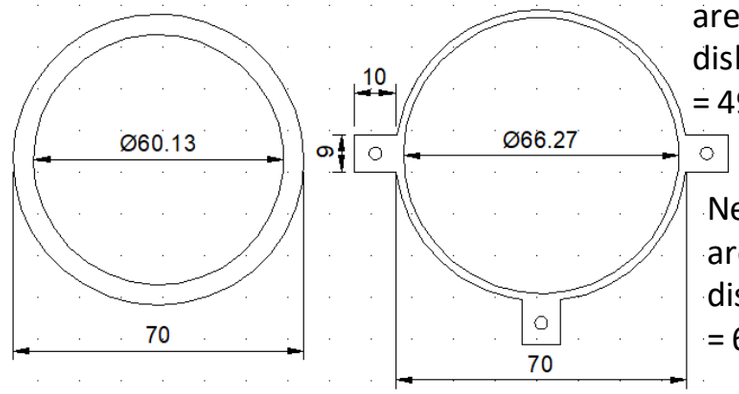
Needed cut area: 50 x 19 = 950mm²



Needed cut area: 51 x 20 = 1020mm²



Needed cut area: 60 x 29 = 1740mm²



Needed cut area (inner disk): 70 x 70 = 4900mm²

Needed cut area (outer disk): 80 x 80 = 6400mm²

Material	Calculated Price
Clear acrylic	£0.12
Black acrylic	£0.23
(any colour) acrylic	£0.97

Component	Quantity	Cost
Raspberry Pi 3 model b+	1	£24.40
100mm LED arcade buttons	5	£20
RGB LEDs	5	£0.72
30mm arcade push buttons	2	£0.96
Adafruit 0.56" 4-Digit 7-Segment Display	1	£5.50
Speaker + PCB	1	£2.09
2v 0.5W solar module(panel)	6	£18.60
DC-DC 0.9V-5V Step Up Power Supply Module	1	£1.87
18650 Battery Shield V3 ESP32	1	£2.20
Speaker cover	1	£1.48
Recycled 18650 cells	12	£6.00
On/off switch	1	£1.00

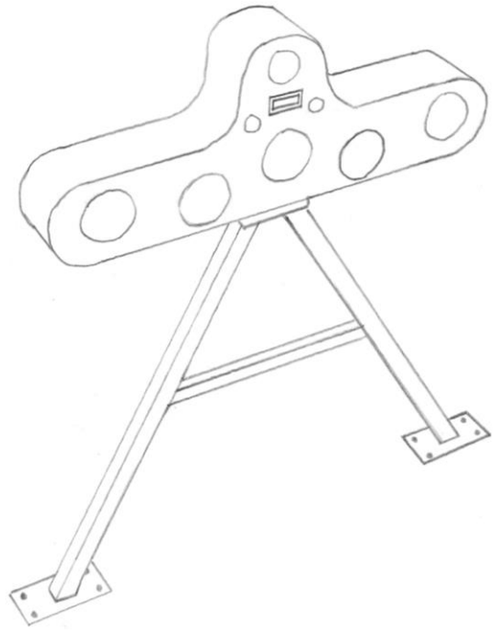
Metal:

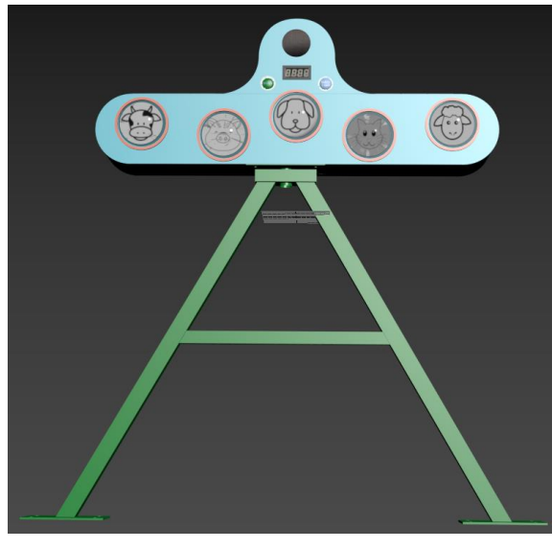
Length	Width	Depth	Thickness	Material	Quantity	Cost
1676.4	32.76	32.76	1.75	Mild steel	1	All metal was sourced from a recycling centre, free of charge, therefore, the cost for this section is 0.
496	90	n/a	4	Mild steel	1	
500	25.4	25.4	2	Mild Steel	1	
150	50.8	25.4	2	Mild Steel	1	
25.4 (Diameter)	25.4 (Diameter)	45	1.5	Stainless steel	1	

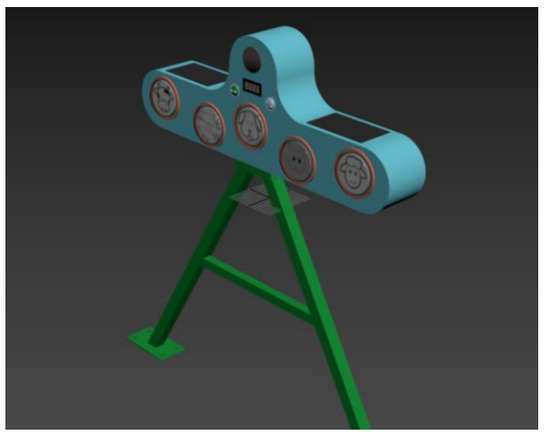
Total Cost: **£109.14**

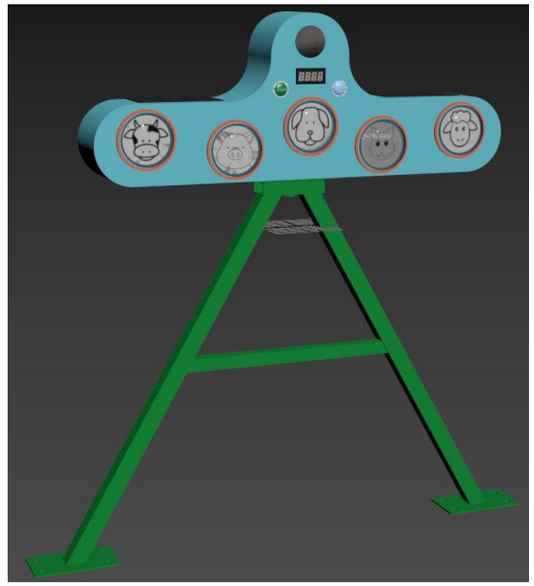
Please note I am using a Raspberry Pi 3 model b+ due to it being easier to develop on. If this product where to be manufactured a much cheaper board like a Raspberry Pi zero or something custom made, both would cost around £14 rather than £24.40 – meaning the total cost would be **£98.74**. Furthermore, the cost of raw materials would significantly drop if a suitable number were to be manufactured through batch production. Taking the cost of materials, components and labour into account the product will be suitably priced at £210.

View of Final design/CAD Model:









Review of chosen design:

Below are general specifications that the "Animal Memory Game" failed to meet (in red) and the refinements that have been made to the design in order to successfully meet them (in blue). I've therefore ensured that the final design meets all the initial specifications.

1. The product must be easy to understand and be operated by a user between the ages of 4 - 6 – The design now shows clear start and select buttons. Also, quick spoken tutorials were made and implemented to quickly teach the user how to play the game modes. The further developed electronic prototype was tested on three children, two aged 4 and one aged 5, and they all understood how to operate and play the games on the product.

2. The edges of the product must be round/smooth – Where the product previously had sharp edges or corners, curves have been introduced through the development of a mechanism of forming the curves was developed. Also, The legs and slot piece of the stand have got bevelled sides, meaning they're not sharp.

3. The product must be brightly coloured – Through Client feedback, I've decided that the entirety of the stand will be painted green and the main piece will be painted light blue with the buttons having contrasting colours of yellow and orange.

4. The product must have the ability to be secured – A stand has been developed for the product to be secured to. To secure it to the ground, the base plates of the stand have holes which can accommodate concrete bolts

5. The product must have as few materials and components used as possible. – All of the main piece (excluding the electronics) is made up of just one material, Marine plywood and the stand is just made up of two, mild steel and stainless steel. Also, structures such as the disks and supports beam, which were in the initial design and made up of different material, have been removed to reduce the number of individual materials used within the product. All the other components are necessary for the function of the product.

Below is the list of the feedback given by the client after either seeing a prototype or general improvements to make (in red) and the refinements/changes that have been made to the design/code to successfully incorporate them (in blue).

1. Introduce a new game mode to the product that exercises children physically – A game mode which requires the user to hit the buttons that have lit up as fast as possible was introduced. The speed aspect of the game meant it would require considerably more movement then the memory game mode.

2. Make the product suitable for children who can't hear – A seven-segment display was added which would display the score live. Such addition means that a deaf user can interact with the product (know their score).

3. The lights of the products buttons should incorporate colour – The regular white LEDs were replaced with RGB LEDs and the code was edited. Within the memory game mode, I assign each animal a random colour, so if the child wanted to, they could remember which colours appeared in what order.

4. The product must have a stand that is able to rotate and lock into position – I achieved this by designing an A-frame stand that has a swivel piece. The swivel piece would connect to the main piece and will be able to rotate freely. To lock the main piece into position a bolt would be tightened down on it. The only way of loosening this bolt would be to use a spanner. This means a child can't loosen it.

Final Specifications:

As well as meeting all the general specifications (as laid out before development) the product must meet all the following final specifications. These final specifications were made after an interview with the client on what specifically the prototype for the product must have. Measurable final specifications are in green, the rest of the specifications are in purple and the justifications for them are in blue.

Function:

- The game must fully function – as to meet the contextual challenge and problem.
- The game/product must be able to be switched on and off with a switch – as to make the product easier to use. Being able to easily turn the product off and back on again will conserve battery life.
- The product must be able to rotate on its stand. – Requested by the client to make the product more versatile.
- The product must be able to lock into the stand, stopping it from being able to rotate. – This will stop children from being able to freely rotate the product. It will also prevent people from stealing the main piece.
- The product must be able to charge and run without external power – This is because the environment it's in means it can't be plugged in.

Form:

- **The product's two outer buttons must have their centre points 818mm from the ground.** – This is based on anthropometric data research, 818mm is the height at which a 5-year-old can easily press a button.
- **The product must be 83 cm long** – as per the client request and the anthropometric data showing that the wind span of a five-year-old is 1142mm so it shouldn't be longer than that.
- **The stand must be 74cm tall** – as to make the product's height suitable for the target user age group.
- The animal faces must be large and recognizable – to make the product inclusive for the people with impaired vision.
- **The flat edges on the main piece must be 20cm in length** – as to accommodate the required solar panels.
- All holes cut must be correctly sized for the component they hold. – This is so all the electronics correctly fit onto the product and water doesn't leak through.
- **The 7-segment display's centre must 1005 mm from the ground** – This is so it matches up with the users eyeline, making it easy to see.
- There must be no sharp points on the product (especially where there are welds). – For safety reasons, to prevent the users hurting themselves.

Performance requirements:

- The product must be waterproof – this is mainly for safety and functional reasons as the electronics may break when exposed to water.
- The stickers must be suitably durable – This is so the instructions on what to do stay clear throughout the lifespan of the product.
- The stand must be strong enough to reliably hold the main piece. –A failure to do so would mean that the product either isn't functional or safe to use.
- Everything must stay secured to the product. – This is so children won't be able to remove any buttons or anything on the front panel.
- The product must not be able to rust – as to preserve the product athletics and structural integrity.
- The stand must be able to be suitably secured to the ground – as to make the product safe and prevent it from being stolen.

User requirements:

- The speaker must be suitably loud for a playground environment – So the user can hear the animal noises, it's also important that the speaker not be so loud as to damage hearing.
- The LEDs must be suitably bright. – This is so the user is able to see the lights flash and respond accordingly, the LEDs should be bright enough so that the light emitted through the button is able to be seen in a sunny environment.

Materials/components:

- **Any weights/electrical information of the product must be displayed** – To make the product safe to setup/repair/operate.
- The product must be reasonably priced – so primary schools will be able to buy the product.

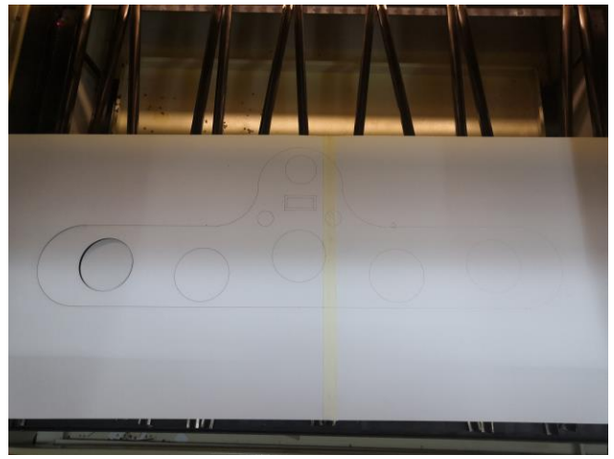
Manufacture: Selection of materials:

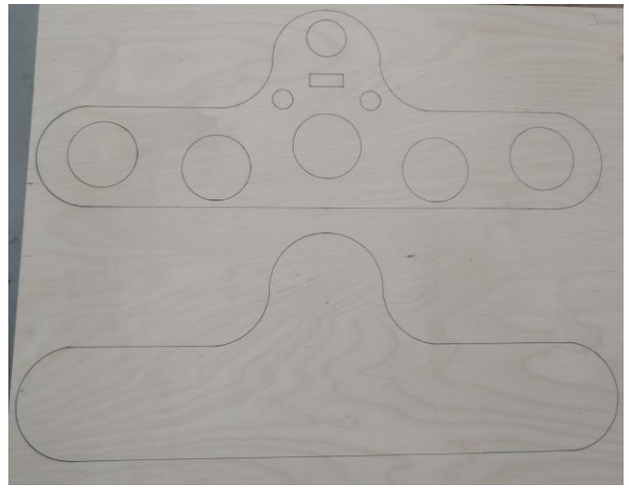
Part(s):	Material(s):	Material properties and why the material was chosen.
Main piece	Marine Plywood	Marine plywood was chosen because it can be locally sourced and is made with a waterproof glue, so the layers won't separate in an exposed outdoor environment. Although the glue is waterproof, it's important to note that marine plywood by itself isn't, however, it will be coated with paint which will make it both waterproof and rot-resistant. Marine plywood was also chosen over materials such as western red cedar because after its been treated, it has the same properties but is cheaper.
Stand (Excluding the pipe of the swivel pieces)	Mild steel	Mild steel has a relatively high impact strength whilst still being easy to form and relatively cheap. Its high impact strength is particularly useful because the stand's structural integrity won't be comprised upon any impact. In an exposed outdoors environment, bare mild steel will rust so a protective paint coating will be applied to prevent that from happening.
The Pipe of the swivel piece.	Stainless steel	Unlike mild steel, stainless steel will not corrode or rust. Stainless steel will be used for this particular piece of the stand because the layer of paint will probably scrape off due to its rotating motion. Because it's made of stainless steel, the exposed sections won't rust, prohibiting it being able to rotate.
Seven segment display cover and speaker mount.	Acrylic	Due to acrylic's weather and UV resistant properties it's excellent for the outdoors exposed and non-exposed environment it will be situated in. I specifically chose acrylic for the seven-segment display cover because acrylic can come in variants which offer excellent optical clarity and transparency. Another reason I chose acrylic for both these parts is that it comes in relatively inexpensive sheets and can be easily laser cut. One disadvantage of using acrylic is the harmful chemicals it's made up from however this should negatively impact the LCA to much as it is being used In very small amounts and acrylic is 100% recyclable.
RGB LED Holders and battery holder.	PETG	PETG is the optimal material for this part, as it is 3D printed, because PETG has most of the advantages of ABS, such as its durability and high impact strength, whilst being relatively easy to print with. Both these parts need to be suitably durable so PETG is the correct choice (as opposed to PLA). In the prototype, PETG will be used for the battery encloser because of the for mentioned reasons and that it's not electrically conductive. Environmentally speaking, PETG is 100% recyclable, however, it's not biodegradable.
Start and Select stickers.	Vinyl and clear enamel	Vinyl is moisture resistant, durable and able to withstand corrosion making it the ideal choice for stickers. Vinyl being for that very purpose means it comes in printable self-adhesive sheets which make it easy to manufacture the stickers. A protective coat of clear enamel will be used to make the stickers weatherproof.
Battery	18650 cells	To summarise points made in research, 18650 cells have relatively a high energy density, can withstand the UK's outside temperatures and can come from recycled sources (which reduces cost and is better for the environment). Their form factor also means that they can be easily spot welded to form a battery.

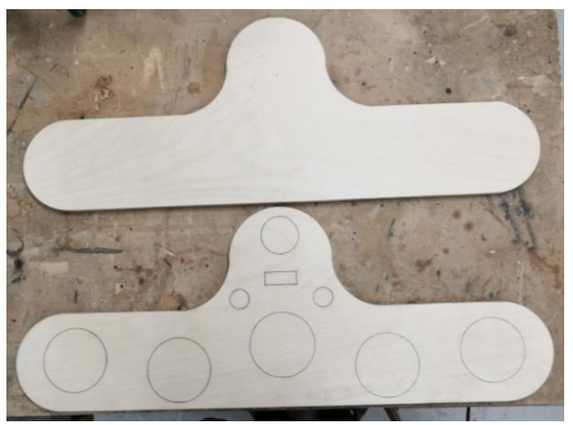
Components:	Material(s):	Material properties and why the component was chosen.
100mm dome arcade buttons	PVC and ABS	The clear dome is made of PVC so is durable and suitable for being outside. Apart from the spring, the rest of the button is made up of ABS which is resistant to strong impacts and also UV resistant. The main reason for choosing these buttons is that they can be easily disassembled and then reassembled; this will be particularly useful when it comes to engraving the animal face on the inside of the domes.
Start and select buttons.	ABS	As stated above, the ABS buttons were chosen in this case because they can withstand strong impacts (being pressed hard) and are suitable for an exposed outdoor environment.
Raspberry pi model 3B+	n/a	Since at this stage I'm producing a prototype a raspberry pi model 3B+ was chosen because it's easier to develop on and install within the product. It can also withstand the outdoors temperatures in the UK without the need of it having its own ventallation system (i.e. a fan). If this product were to be sold commercially something like a raspberry pi zero would be used instead because of its low cost.
Kitronik Mono Amplifier Kit Version 3.0 + speaker cover and grill with fabric	The speaker cover and grill is made of stainless steel.	The speaker cover and grill won't be painted or treated so it's important that they're made from stainless steel so that they don't rust. The speaker kit was chosen due to its suitable power (volume) and low cost. Because of the way the speaker will be mounted within the product, it doesn't matter if small amounts of water enter through the grill however the fabric that will be used on the grill should prevent that from happening.

Manufacturing: (Maine Piece)

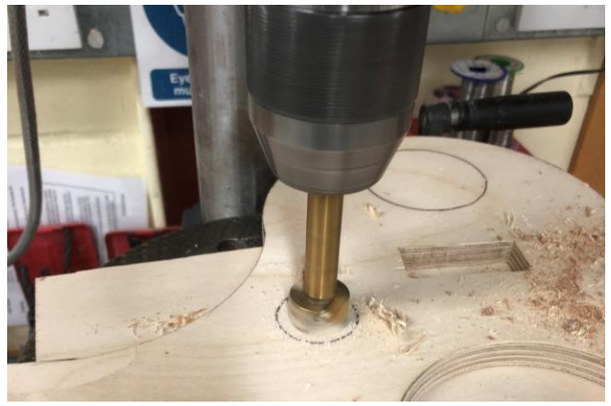
Step	Process	Tools and Machines used	Safe working practices
1	Draw out the front and back plates of the main piece of the product in 2D design, then laser engrave these onto the sheet of marine plywood. The groves created by the engraver are then to be easily traced over. The panels where plotted this way to ensure a high level of accuracy. The markings represent the lines which must be exactly cut out.	Computer-aided design software ("2D Design") and Computer-aided manufacturing software (for the laser cutter). Laser Cutter (set to engrave) A Pencil	Ensure that all the settings are correct on the laser cutter to engrave into marine plywood. Making sure that all the laser cutters safety equipment is functional and fully in use (e.g. the extractor fan is turned on and the protective lid is fully closed. Not leaving the Laser unattended.
2	Cut out the straight edges of the back and front panels of the main piece. Also, cut out the gap between the front and back piece (making them separate) as well as the side bit of the sheet (this piece of wood will be utilised later)	Bandsaw, miter gauge (Used for the straight edge).	Safety glasses were worn and a push stick rod was used before fingers got too close to the saw.
3	"Roughly" cut around the curved edges of the product (in straight lines) while making sure to not cut inside the curve. Once surrounding areas of the curve are down to a suitable level they are to be sanded down, so they're round.	A Bandsaw. For sanding, either a bobbin sander (for the inner curves) or a belt sander (for the exterior curves)	All the sanding tools used have an extraction system (whether inbuilt or exterior) to prevent dust for being inhaled. Also, Safety spectacles where worn.
4	On the front panel, mark the centre of the circles, repeat this for all of them. Then accurately cut out the five of the larger holes with a precisely set adjustable hole cutter to 98mm (49mm radius) (making sure it's cutting from the centre of the circles and with the same diameter). After they're cut adjust the hole cutter to have a diameter of 60mm and then cut out the speaker hole (located at the top of the front panel) the same way.	Pair of compasses, pillar drill, adjustable hole cutter and safety spectacles.	The pillar drill should be correctly set up with the chuck gripping on the shaft of the adjustable hole cutter securely and centrally aligned. The chuck guard should be in its down position. G-clamps should be used to secure the product when holes are being drilled. Also, safety spectacles must be worn.

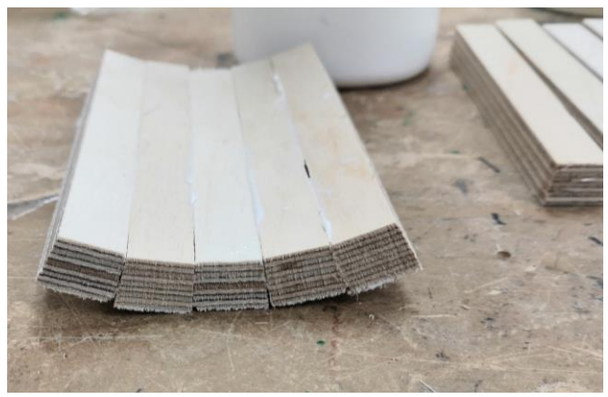




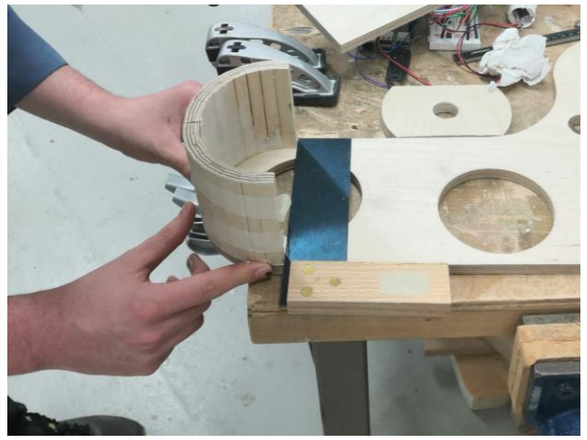


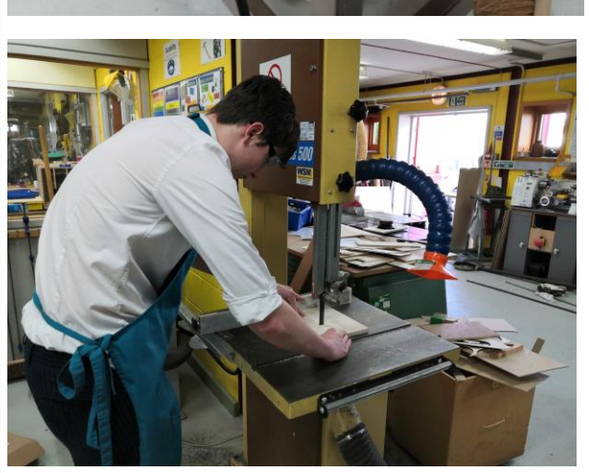
Step	Process	Tools and Machines used	Safe working practices
5	Cut the two smaller button holes using a 30 mm flat wood bit. Then drill 4 small (5mm was the size I used) holes in the corners of the rectangle zone, making sure not to drill outside of the zone. Then insert the blade of a coping saw into one of the holes, reattach, and then cut out the rectangle region. Once cut, I straightened the edges with a chisel and sanded it down with sandpaper.	Pillar drill, G-clamps, 30mm flat wood bit, 5mm drill bit, coping saw, chisel, 60 grit sandpaper and safety spectacles.	When using the pillar drill, all bits must be correctly fitted to the chuck and the chuck guard should be in the down position when drilling. You should also use the coping saw slowly as to prevent fingers slipping and being cut. When chiselling ensure that you are chiselling away from your body. Safety spectacles must also be worn.
6	Cut 70 pieces of 12mm thick marine plywood that measure 14mm (at the bottom face) by 95mm, this must be done on a table saw with the angle of the saw set to 6º. These pieces are trapezium prisms.	Ruler, pencil, table saw (with cut angle set to 6º), a push rod and safety spectacles.	Safety spectacles were worn when using the table saw and a push rod should be used before the saw gets close to hands.
7	Side Curves: With the cut marine plywood pieces, evenly spread one of them with PVA glue on one of its angled faces. Then apply and evenly spread PVA glue on another piece's angled face. After that, align and press the two sides with glue applied together so that they begin to form a curve. Repeat this process so that 17 pieces of wood are stuck together, this will form one of the side curves (it's important that corresponding sides are stuck together so a continuous curve occurs). Make sure the tops of the pieces are flush with each over and level and wipe away any excess glue with a cloth. Finally, apply masking tape to the perimeter of the curve whilst it dries so it retains its shape. I repeated this process twice to form the two side curves.	PVA glue, masking tape and a cloth.	In these three processes, the same exact safety procedures were followed. Hands must be washed to remove any PVA glue that might have stuck to them.
8	Top concave curves: Repeat the same glueing procedure as in the previous process however only do it with 9 of the cut pieces of Marine plywood. As before, making sure the top of the pieces are level and to apply masking tape so the piece retains its curve whilst drying. Repeat this process twice to end up two curved pieces.	PVA glue, masking tape and a cloth.	
9	Top convex curve: to make the top curve piece, glue 18 of the cut marine plywood pieces with the same glueing process as in the previous two processes. Again, as before, apply masking tape around the perimeter of the curve so it retains its shape and wipe away any excess glue with a cloth.	PVA glue, masking tape and a cloth.	

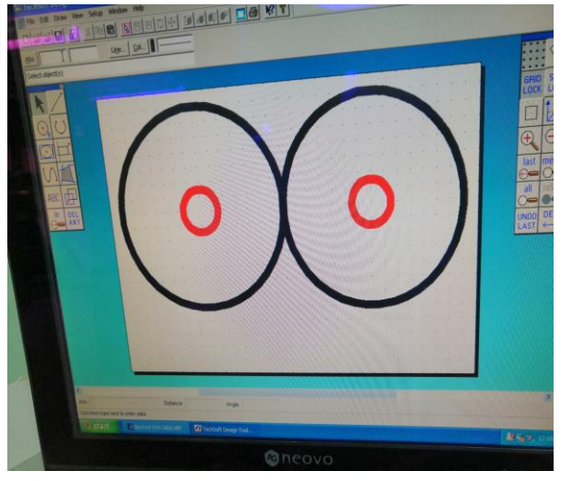


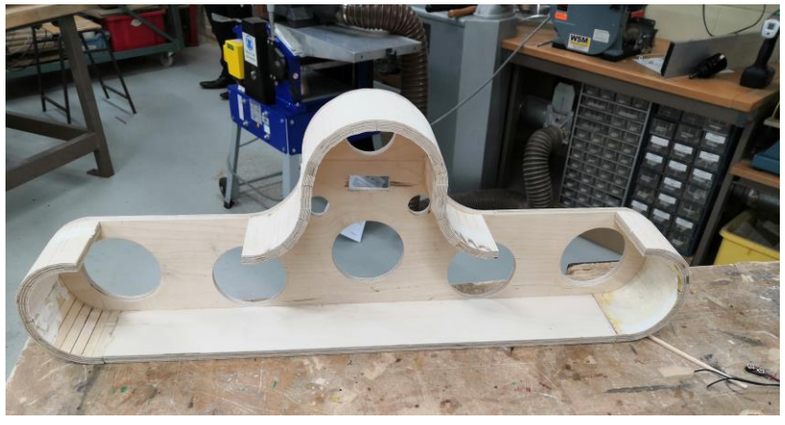


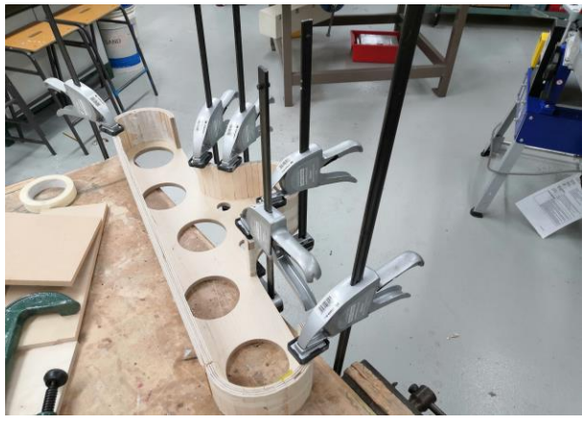
Step	Process	Tools and Machines used	Safe working practices
10	Carefully and accurately glue the curves to the corresponding edges of the front panel making sure the curved pieces follow the curved portions of the front panel as close as possible. Any difference at this stage will be rectified in later processes so they won't be noticeable. Once the curved pieces are glued on, clamp the side curves down to the front panel using G-clamps and a piece of wood to distribute the clamping force. With top concave and convex curves, use quick release clamps; whilst clamping, make sure the pieces are still in place.	Try square, G-clamps, quick release clamps, PVA glue and a cloth.	Ensure that the front panel and clamped pieces are stable, so that they don't fall over and cause damage to itself or other people working in the vicinity. I secured the product by clamping the whole piece to a workbench. Also, hands should be washed after all the glueing is finished.
11	A piece of marine plywood had to be cut to connect the two side joints together at the bottom. In the design the piece of wood is said to be 680 mm long however in practice it needs to be a few mm smaller in order to fit correctly. So a 675mm x 95mm x 12mm piece of marine plywood was cut.	Ruler, pencil, band saw, miter gauge, a push stick rod, and safety spectacles.	For all cutting, safety spectacles must be worn to prevent eye damage. Also, to prevent cutting yourself use a push stick rod to guide the wood along before getting to close the saw.
12	Cut two 190 x 95 x 12mm pieces of marine plywood, these will be the pieces at the top of the product which joins the side curves and the top curve together.		
13	The long piece and two shorter pieces now must be glued to the front panel and clamped down. Before the glue is applied make sure the surface you're glueing is clean and when glueing the pieces, make sure glue is spread appropriately.	G clamps, PVA glue and a cloth.	After finishing with the glue, make sure hands are washed to remove any excess glue that may have stuck onto them. Also, to protect yourself and those around you, clamp the main piece down to the workbench to prevent the weight of the clamps toppling the main piece over.
14	With the remains of the marine plywood sheet and offcuts, secure suitably sized piece to the bed of a CNC router. This is done by clamping a "spoil board" (made of thin plywood) to the CNC router's worktable and then placing the piece of marine plywood on top and nailing it down. After that insert a 6mm shank CNC drill bit into the bit holder of the router. Then design the maximum number of circles that will fit onto the marine plywood sheet (this is done in "2D Design"). The circles must have a 125 mm diameter (with a black circumference) and a hole in the middle measuring 24 mm in diameter (this will have a red circumference). Once drawn out in 2D Design port the file over to the CNC router's accompanying software.	2D Design (in this case it's being used both for the CAD and CAM software as 2d Design has inbuilt built CNC router functionality), a ball-peen hammer, a 6mm shank drill bit, a CNC router and safety spectacles.	When using the hammer, safety spectacles must be worn to prevent the possibility of small chips causing damage to eyes. Also, gently (but squarely) tap the nails into the wood and then proceed to move fingers away from the nail, permitting more force to be used to hammer the nail.

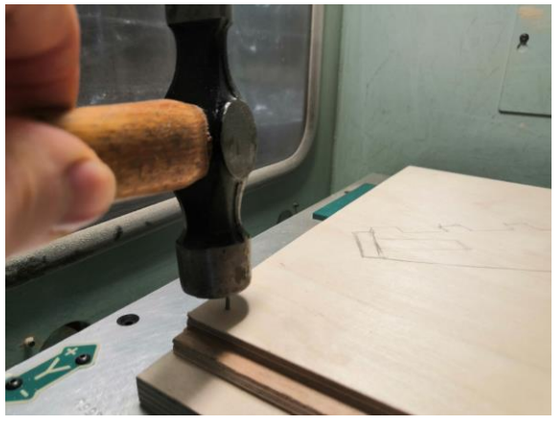




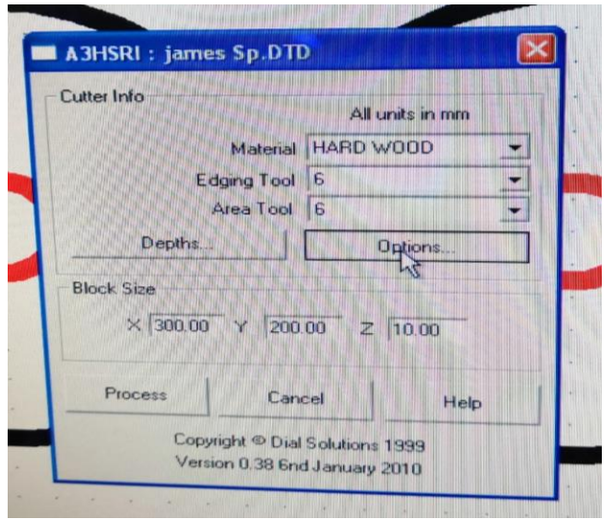


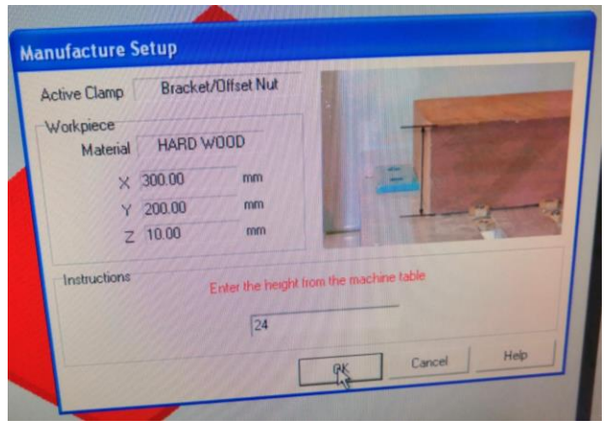




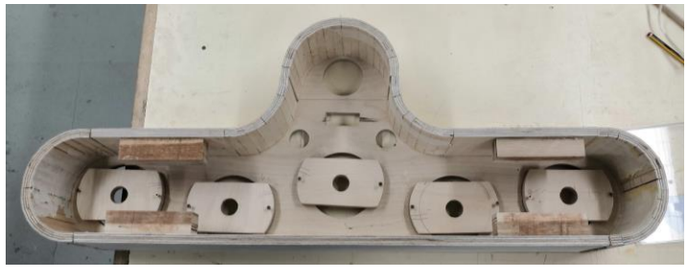


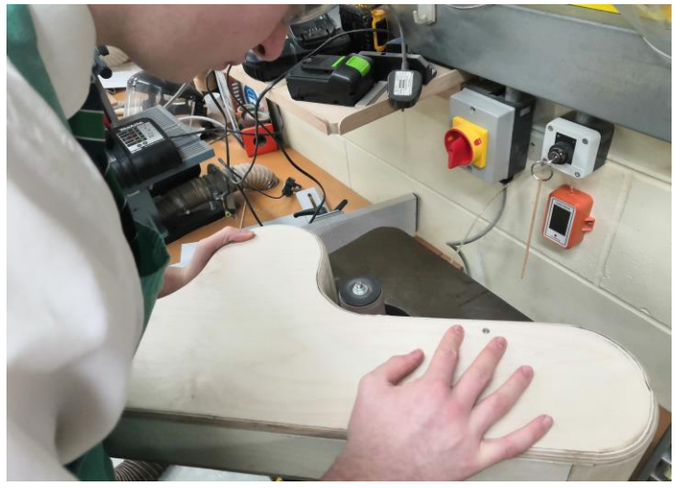
Step	Process	Tools and Machines used	Safe working practices
15	When inputting information into the CNC router's software, it should be as follows: Material = hardwood, Edging Tool = 6 mm, Area tool = 6 mm. The Block size measurement depends on the piece of wood used however here is an example of a sheet of wood I cut: x = 300 mm, y = 200 mm Z = 12 mm. Following that, go into options and select black as outside and red as inside. Once everything has been correctly inputted, check the preview to see if everything looks correct and if it is and the pre-start safety procedures have all been fulfilled (as stated in the corresponding safe work practices column) start the Cut. During the cut, I made sure to follow the mid-operation procedure (also stated in the corresponding safe work practices column. Repeat this process so 5 of the wooden disks are produced.	2D design, a CNC router a 6mm shank CNC drill bit.	Before starting to cut, Ensure that the extraction system is on and fully functioning to remove waste, the bit is securely and correctly mounted in the bit holder so that the bit doesn't dislodge mid-operation, the spoil board and the work-piece must be securely mounted so they also don't move during operation and finally the protective for should be shut to prevent the moving router from cutting fingers and perhaps pieces from flying out (which may cause injury to yourself or others). During operation do not leave the CNC router unattended and if a problem occurs, press the stop button to prevent problems arising/getting worse.
16	The disks at this stage may not be able to locate their holes in the front panel due to them being too big. To solve this problem, reduce weight and reduce material use (any cut wood can be recycled), mark out two straight lines to cut on the disks so their middle hole can line up with the centre of the front panel's holes. (These cut lines do not need to be matching on either side due to the way they'll be centred in the next process. Make sure this is repeated for all five of the disks.	Try square, pencil, band saw, miter gauge, safety spectacles.	Ensure safety spectacles are being worn to reduce the risk of eye damage. Due to the circular nature of the pieces being cut, you can't use a push stick rod so take particularly careful precautions when cutting near the saw.
17	To line the disks up centrally, inset the button into the front piece so the cylindrical button's disk sits flush with the back of the front panel (meaning it will slightly stick out the front). Then take one of the cut wooden disks and insert it through the thread of the inserted button at the back. After that, take a pencil and mark the perimeter of one side of the wooden disk. For later reference also mark the side you marked the perimeter of.	A Pencil.	Due to the weight of the product and the amount it's being moved around in this process, always ensure it won't fall over. A failure to do so could lead to the injury of yourself or someone else.
18	Drill holes for small screws in the wooden disk at either side. Then evenly apply PVA glue to one of the faces and stick the corresponding marked side on the back of the front panel. Then with a screwdriver, insert small screws into the drilled holes. These screws are to act as a clamp and need to be removed once the glue is completely dry. Repeat the previous and this process 4 more times so all holes of the wooden disks are centrally aligned and glued down.	A drill, a 3 drill bit, a screwdriver, PVA glue and safety spectacles.	The chuck guard must be in the down position and safety spectacles must be worn when drilling. Both of those safe working practices will reduce the risk of eye damage.

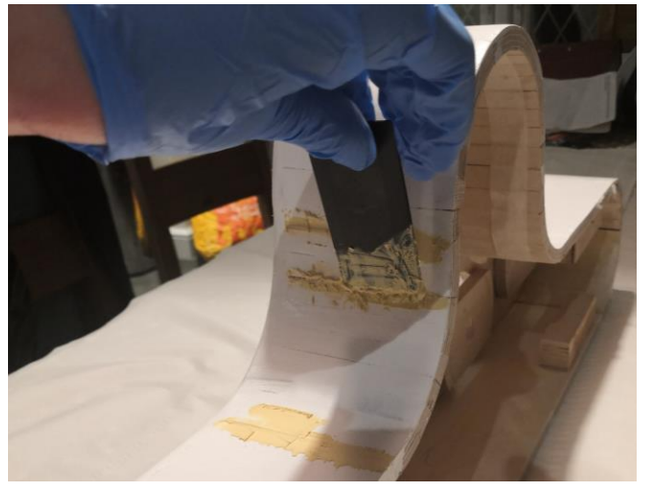




Step	Process	Tools and Machines used	Safe working practices
19	Cut 4 pieces of 115 mm by 28 mm by 28 mm pieces of square wood dowel. Then glue two of them in the centre of the straight top pieces and the other two directly beneath those. It's important that the square dowels are equidistant from the back of the product but not touching as when the back piece is inserted, it will need to be pulled in making the back-piece sit flush.	Band saw, miter gauge, PVA glue, safety spectacles, a ruler and a pencil.	Ensure that hands are washed after glueing work is complete to remove any glue that may have got onto them. When using the band saw, safety spectacles must be worn to reduce the risk of eye damage. Also, make sure fingers never get to close to the saw to prevent cuts.
20	Drill a pilot hole through the back panel and the wooden dowel and then change the pilot hole in the back panel for a clearance hole. Then countersink the surface-side hole of the back panel so that the screws sit flush. Repeat this process 3 more times for each of the square dowels. Finally insert an m4 screw through the holes made in the square dowels and back piece.	Drill, 3 drill bit, 4 Drill bit and safety spectacles.	Safety spectacles must be worn when drilling the holes to prevent pieces of wood from entering the eyes.
21	Then with the newly assembled piece, sand down the curved pieces so the curve they form is round. Then insert a round over bit into a router table. Next, turn the router table on. Then take the newly assembled piece and run the bit around the edges so that the ball bearing on the bit runs across the curved and straight sides of the product. Do this process slowly and with extra caution to prevent discrepancies in the bevelled edge. Repeat this process so both sides of the main piece are bevelled. Finally, smooth out any inconsistencies with a bobbin sander.	A bobbin sander and sanding block with sanding paper. Router table, round over bit, a bobbin sander and safety spectacles.	Ensure that the router table has an inbuilt extraction system that is on and functioning when the table is in operation; this is to prevent the inhalation of sawdust. Secondly, wear safety spectacles to prevent small pieces of wood from causing eye damage.
22	Detach the back panel and apply one primary coat onto the main piece. This primary coat will highlight any areas which need filling. Such highlighted areas should have exterior wood filler applied. Once the wood filler has dried, sand it down smooth.	A paintbrush, spatula and a sanding block with sanding paper.	Gloves must be worn when applying the wood filler to prevent it staining fingers and hands.
23	Apply another coat of white paint on the main piece and then two coats onto the back panel. Once dried, apply two coats of the outdoors blue paint to both the main piece and back panel. When the paint has dried, sand away the paint from the face that will contact the back panel.	A paint roller and paintbrush.	Overalls and gloves were worn when painting and all painting was done in a well-ventilated environment.

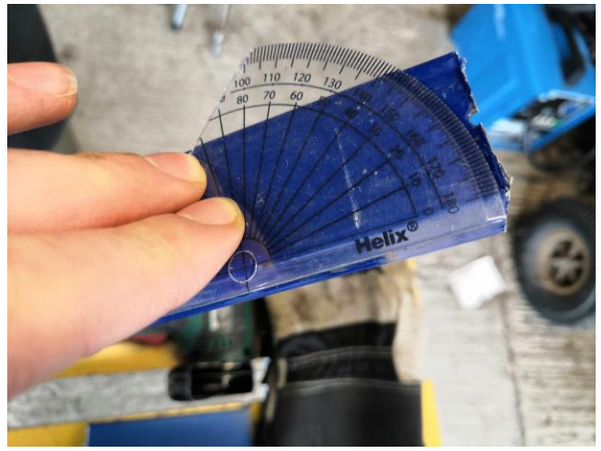


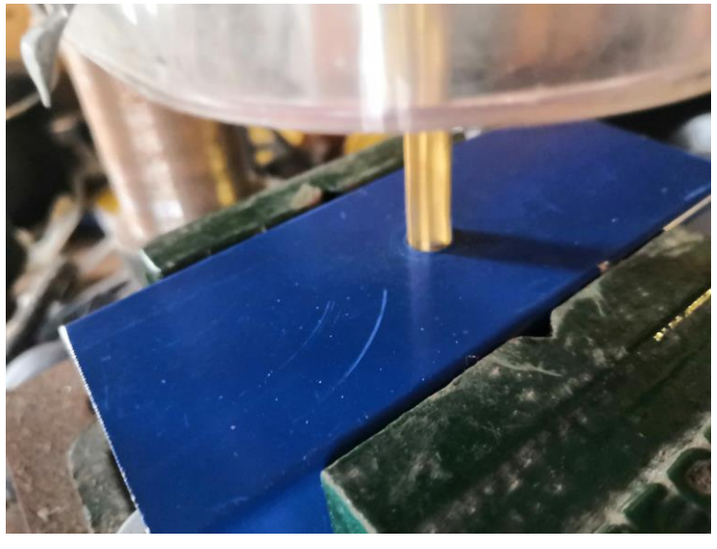




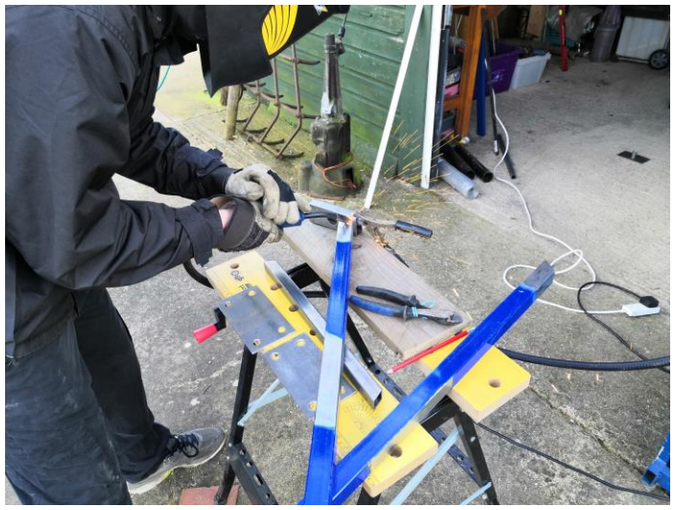
Manufacturing: (Stand)

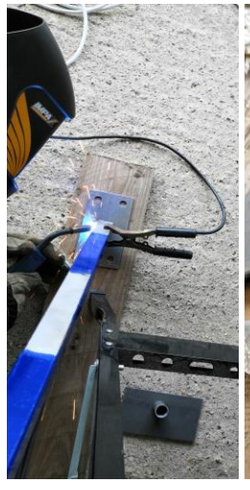
Step	Process	Tools and Machines used	Safe working practices
1	Marking out the cuts: Mark out all lengths and angles on the two steel box pieces, steel plates and steel pipe as in the final design section. Double-check the measurements to make sure they're accurate as more steel will need to be ordered if they're wrong.	A try square, ruler, pencil, protractor.	
2	Cut all the marked-out lines with an angle grinder. This should be done by securing the steel piece to be cut in a vice or workbench and then cut along the sides facing upwards. The steel plate cuts can be done in one go however the pipe and both steel box pieces will need to be rotated.	An Angle grinder, vice a file and safety spectacles.	Ensure that the product is well secured (won't move) to prevent an accident when cutting. Safety spectacles should be worn when angle grinding to prevent sparks from hitting the eyes.
3	Mark out centre holes on the rectangle steel box piece (with one the wide edge and the other on the narrow edge). Then plot the 4 holes on the bottom steel plates and the smaller steel plate which will ultimately connect to the main piece (dimensions can be seen in the final design section).	Ruler, try square and a pencil.	
4	Drill pilot holes on all the marks and then proceed to move onto the required drill bit / drill step (when using a step drill bit). Make sure that all the marked holes on the stand's pieces are drilled out exactly as shown in the final design. *Please note that I cut the holes in the smaller steel plate in a later manufacturing stage.*	Titanium coated drill bits and step drill bit. Also, a pillar drill and safety spectacles.	Make sure the chuck guard is in the down-position and safety spectacles are worn to prevent eye damage. Ensure the piece you are drilling into is well secured and slowly drill into the pieces to ensure the bit doesn't overheat.
5	Some of the steel pieces I ordered came from recycled sources so had paint pre-applied. Therefore, I had to prepare such pieces for welding by stripping portions of the paint where they'll be welds.	Safety spectacles, respirator, drill and a shaft mounted rotary wire brush.	Safety spectacles must be worn to prevent flakes of paint from damaging eyes. Also, the paint stripping should be done in a well-ventilated environment and a respirator should be worn to prevent the inhalation of paint dust.

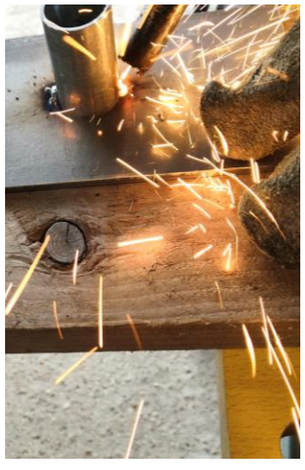




Step	Process	Tools and Machines used	Safe working practices
6	Line up one of the legs on one side of the face of the rectangle piece. Then weld the leg to the rectangle piece. Repeat this process with the other leg on the other side of the rectangle piece, ensuring that it has been correctly positioned before it's welded.	A MIG welder, protective glove a welding mask, pencil and a ruler.	Ensure that a welding mask is always worn when welding to prevent eye damage. Also, gloves and long sleeve clothing should be worn to prevent burns.
7	Slide up the centre bar on the triangle until it's flush on both sides. Then weld all four edges of both sides of the centre bar onto the triangle. The centre bar will provide more structural strength to the stand.		
8	Line up the ends of the legs with the centre of the base plates; its central alignment is vital so make sure the legs are correctly aligned by checking its position with a ruler. Once sure, weld all four sides of both the legs to the base plates.		
9	Secure the stand on its side and then place a nut over the side hole in the rectangle piece. Then Insert a bolt into the nut (this ensures the position is kept) and place a tack weld onto the nut. After that, remove the nut from the bolt and then permanently weld the nut to the rectangle piece.		
10	Mark out the centre of the smaller steel plate and then place the steel pipe over it. Then evenly weld the pipe to the plate. If the weld wasn't quite as even as it needed to be, as in my case, you should cut the uneven parts with an angle grinder.	(With the inclusion of an angle grinder)	
11	The final step in the fabrication of the stand is to clean the welds. To do this, sharp top sections of the welds should be cut. Also, the residue left behind from the welding should be removed.	An angle grinder, safety spectacles, drill and a shaft mounted rotary wire brush.	Safety spectacles must be worn to prevent eye damage. Also, a respirator must be worn to prevent the inhalation of paint dust.
12	Apply a primary coat to the stand and its components, making sure to keep clear of the thread of the nut. Next, paint the stand and its components with the outdoors green paint.	A paintbrush.	The painting must be done in a well-ventilated environment.

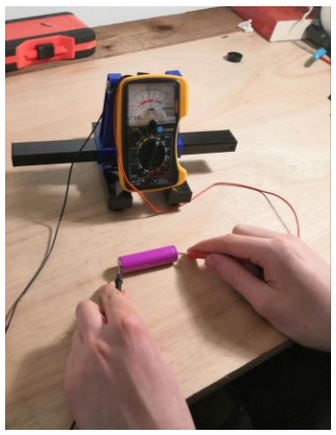


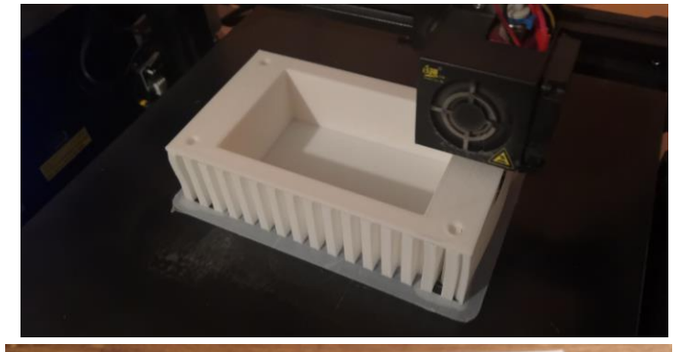




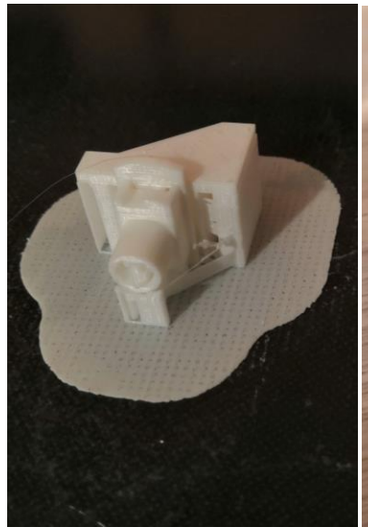
Manufacturing: (Electronics)

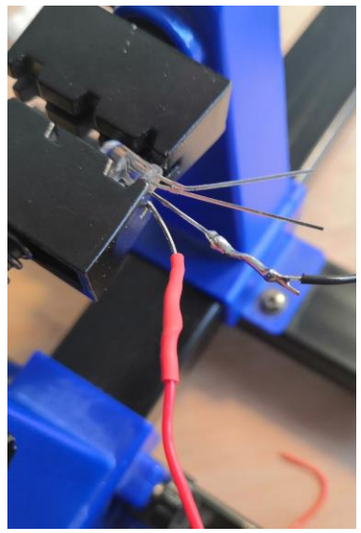
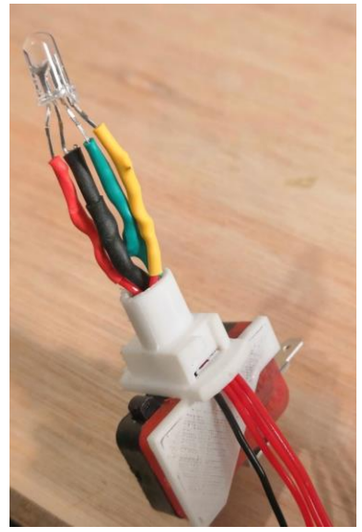
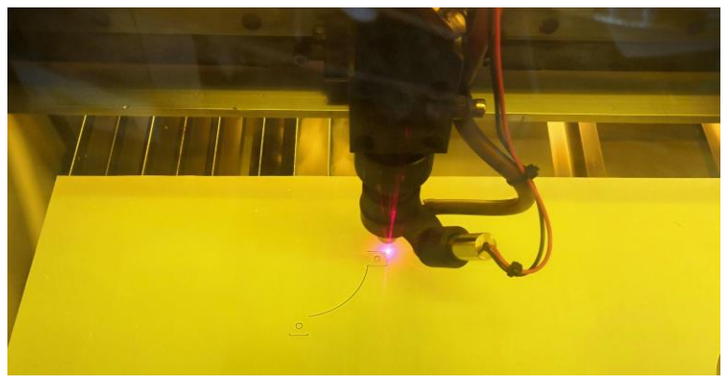
Step	Process	Tools and Machines used	Safe working practices
1	Obtaining the cells: To acquire the needed 18650 cells, they must be extracted from no longer working or just recycled laptop batteries. First, remove the top lid by twisting the laptop battery and then using a flat head screwdriver to lever it up. After that, the screwdriver is then used to lever up the cells from their adhesive. With the cells now out, use flush cutters to cut off the charging PCB and then use the flush cutters to separate the cells by removing the spot-welded nickel strips. The best way of doing this is by grabbing the strip with the flush cutter and then rolling the strip back.	Flush cutters, safety gloves, and a flat head screwdriver.	Ensure that safety gloves are worn throughout this process to prevent the sharp nickel strips from cutting hands.
2	Testing the cells: Clean up the ends of the cells and then test their voltages. Any cells that are above two volts can move onto the next phase of testing because they haven't naturally discharged much. Next, take the remaining batteries and slot them into an intelligent battery charger set to a charge/discharge test, this will give the mAh of the individual cells and this is to be marked on the battery. Since the battery will be periodically charged by solar panels another natural discharge test doesn't need to be carried out. This and the previous process should be repeated until 12 cells are found to have around 2000 mAh (+-200 mAh).	A small diamond powder file (for cleaning cells), sharpie, multimeter and Intelligent battery charger (Opus BT-C3100 V2.2).	When undergoing testing, the cells must be monitored for their temperature because if a battery is faulty, which may be the case for broken laptop battery cells, they don't overheat.
3	Connect the batteries with 2000 (+- 200) mAh in a two by six formation. All the cells must be connected in parallel. When connecting the batteries use specifically cut nickel strips and the correct force setting on the spot welder to ensure a secure weld.	A spot welder, nickel strips and flush cutters.	Wear safety spectacles when spot welding to prevent possible sparks from hitting eyes. Also, make sure the correct force setting is selected, in part, to prevent the cells ends from being perforated, which will pose a safety risk. Finally, wear protective gloves to prevent the sharp nickel strips from cutting hands.
4	Within tinkercad (a 3D CAD program), design the battery holder with the exact dimensions as in the final design section. The Battery holder file should then be imported into Cura (a 3D printer slicing application). Default Settings must be altered to the following: hot end temperature: 230°C, bed temperature: 80°C, and brim and supports enabled. Those settings should lead to a successful PETG print and to ensure the battery holder is durable, infill should be set to 100%. Finally, export the G-code (sliced) file to a 3D printer and start the print.	The following tools and machinery used will apply to this and the next process: A Creality CR10S 3D printer, tinkercad (a3D CAD program) and Cura (a 3D printer slicing application.	The following safe working practices will apply to this and the next process: Before printing, the preview generated by the slicing software should be reviewed to ensure there are no noticeable mistakes. Whilst the 3D Printer is printing, periodically check it and if problems do arise stop the 3D printer immediately.



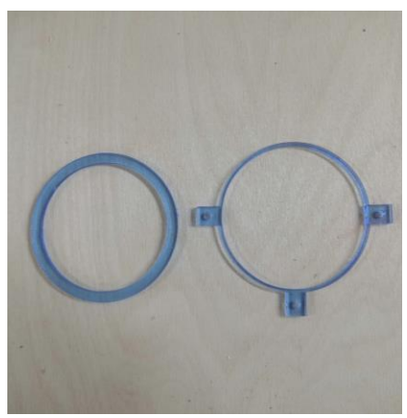


Step	Process	Tools and Machines used	Safe working practices
5	Since the button LED holder can't accommodate an RGB button a new different LED holder will have to be made. The file for such a thing can be found online. This file should be imported into Cura and then printed with the same settings as in the previous process except for the substitution of a raft instead of a brim. This process should be repeated four more times.	(Previous page)	(Previous page)
6	Once the battery holder and RGB LED holders have been printed the supports and raft/brim should be removed. Anything left behind by the supports should then be removed.	A small diamond powder file, cutting mat and flush cutters.	Ensure supports are being pulled away from you when using the flush cutters. This must be done because of the sharp point on the flush cutter.
7	Solder wires to the individual pins and then cover with heat shrink. Thread these wires through the RGB LED button holder, one by one, each time making sure to mark the corresponding colour (red, green or blue) on the wire using coloured tape. Long (approximately 1 meter) wires should be cut and soldered because they can be cut to exact size later. Repeat this process for the four remaining RGB LED holders.	Soldering iron, flux, hot air gun, wire cutters, wire strippers, respirator, safety spectacles and a soldering fume absorber.	A soldering fume absorber must be on and near where you are soldering, with the addition of a respirator, this means that toxic fumes will not be inhaled. During soldering safety spectacles should be worn and the iron should be correctly mounted in its stand after use.
8	Seven-segment cover: In 2D design, design the three pieces for the LCD screen cover to the exact dimensions as seen in the final design section. Then export the file over to the laser cutter's software and input the correct settings for 3mm thick acrylic. Cut out the two rectangles with holes in the middle out of black 3mm thick acrylic. After they're cut, reconfigure the laser cutter for 1mm thick acrylic, and cut the rectangle that needs to be clear. Once the pieces have been cut, glue them together and then sand the corners and edges down smooth.	Laser Cutter, 2D design, small paintbrush, Tensol (a plastic adhesive), a belt sander and safety spectacles.	Ensure that the laser cutter has the appropriate setting before it starts cutting. Also, ensure the lid is closed and the extraction system is turned on whilst in operation. Due to the potential fire risk, the machine should not be unattended during operation. Safety spectacles should be worn when using the belt sander. Gloves must be worn when applying the Tensol to prevent it from contacting with skin.
9	Speaker socket: Design the two pieces for the speaker socket in 2D design to the exact dimensions as in the final design section. The colour of the acrylic these are cut out of does not matter however the thickness must be 3mm. Once the pieces have been cut, glue them together with a plastic adhesive.	Laser cutter, 2D design, Tensol, gloves and a small paintbrush.	Gloves must be worn when applying the Tensol to prevent it from contacting skin. Ensure the laser cutter has the correct settings, is not left unattended during operation and the lid is closed. Also, the extraction system should be on.

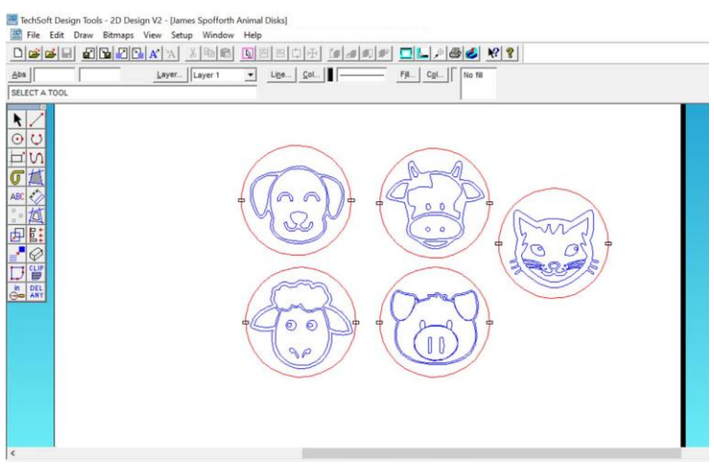


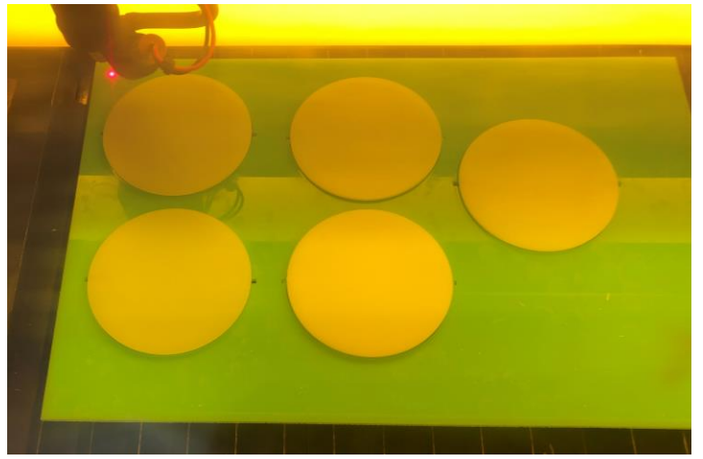




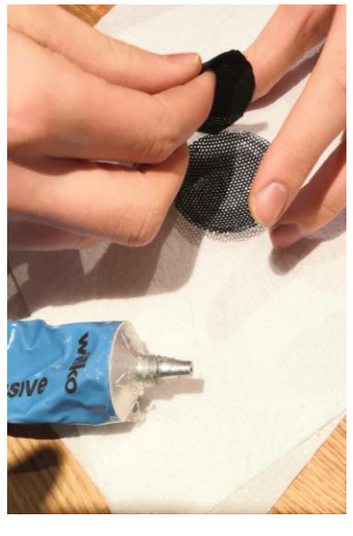


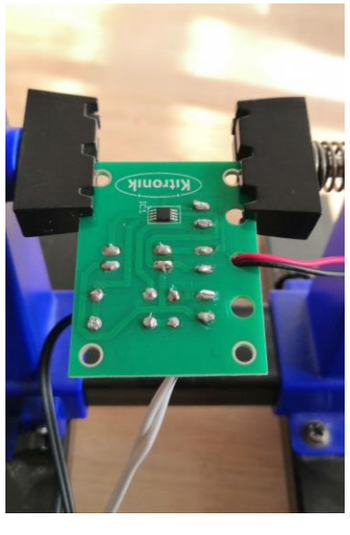


Step	Process	Tools and Machines used	Safe working practices
10	Disassemble all the buttons by removing the nuts and levering the clear dome up. Next, in 2D design, draw circles with the exact same diameter as the translucent white disks as well as the slots for the notches which are present on the disks. Then import and vectorize the animal faces onto the circles. Then set the notches to be cut and the circle and face to be engraved on a piece of acrylic, this will act as a template. When the template has been cut ensure you don't move it. Place the notches on the white translucent disks into the slots on the template. Finally, set just the animal faces to be engraved onto the disks. This means the animal faces are now engraved and centrally aligned on the disks.	Laser cutter, 2d design.	Ensure the laser cutter has the correct settings, is not left unattended during operation and the lid is closed. Also, the extraction system should be on.
11	To make the faces more visible, apply some water-soluble black paint and rub it around the disk. Then with a damp cloth, wipe away excess paint from the surface, just leaving it in the engraved grooves.	A damp cloth.	The paint used in the process does not have any harmful effects, so no precautions have to be taken in those regards.
12	The final step in the animal button modification is to take the button rim and mounting disk pieces. The thread of the rim pieces must be masked before paint is applied. First, apply a primary coat to both pieces then a coat of orange paint on the button rims and yellow paint on the button disks. Once the paint has dried, the buttons should be reassembled but without the yellow disks.	Masking tape and spray paint.	Ensure spray painting is done in a well-ventilated area and that a respirator is worn to prevent the inhalation of harmful chemicals.
13	Cut out an appropriately sized circle of speaker fabric and glue this to the inside of the speaker grill. Then glue the speaker grill to the rim of the speaker cover.	Superglue.	Gloves must be worn when applying super glue due to its adhesiveness. It should be applied in a well-ventilated area.
14	Make two 24mm circles in diameter in Microsoft word. One of the circles should have centred white text reading "START" and the other reading "Select/Quit". Also, the "START" circle should be green and the "Select/Quit" circle should be blue. Then print out these circles on white inkjet waterproof self-adhesive vinyl. Once printed, apply a coat of clear enamel to the circles to give them more UV and weather protection. Finally, cut the circles out and stick them to the arcade buttons.	An inkjet printer and spray clear enamel.	When spraying the enamel, wear a respirator to prevent any from being inhaled. Also, it should be done in a well-ventilated environment.
15	Since the seven-segment display module came in separate pieces it must be soldered. First, solder the pins of the display to the seven-segment board and then to the board solder the five-pin header. (I had previously done this process in the development stages).	The following applies to this and the next process: A soldering iron, flux, helping hand, soldering fume absorber, a respirator and safety spectacles.	Ensure the soldering iron always returns to the stand after use and avoid putting hands near it to prevent burns. Also, a respirator must be worn, and a soldering fume absorber should be used to prevent the inhalation of hazardous fumes in addition to safety spectacles.
16	Solder all the components that come in the speaker kit to the speaker PCB. Also, solder wires to the speaker and power holes but don't connect the ends of these wires to anything yet. These wires should be reasonably long (they will be cut down in assembly).	(With the inclusion of wire cutters and wire strippers)	



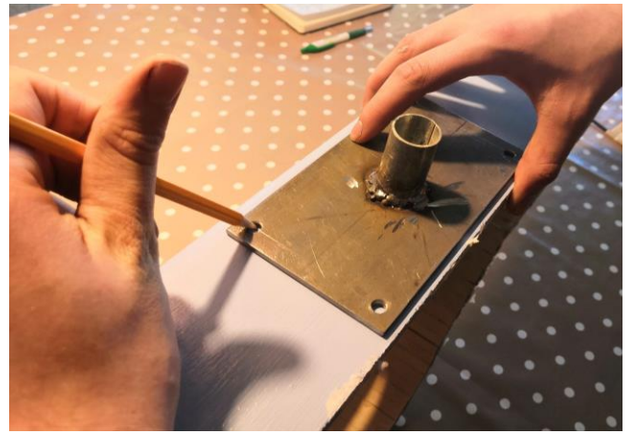


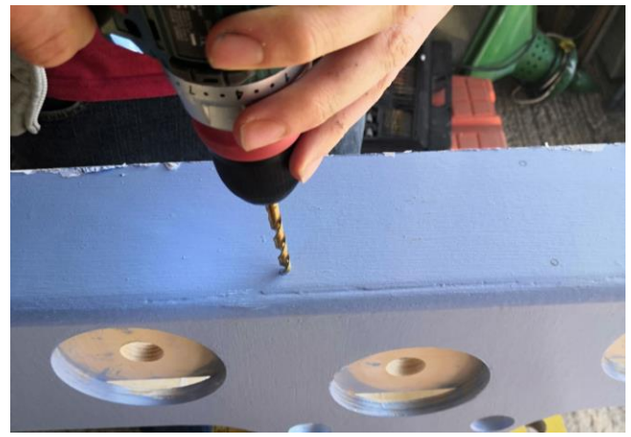


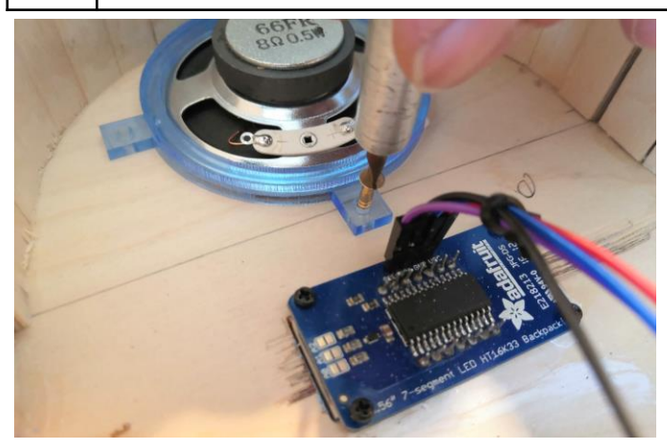


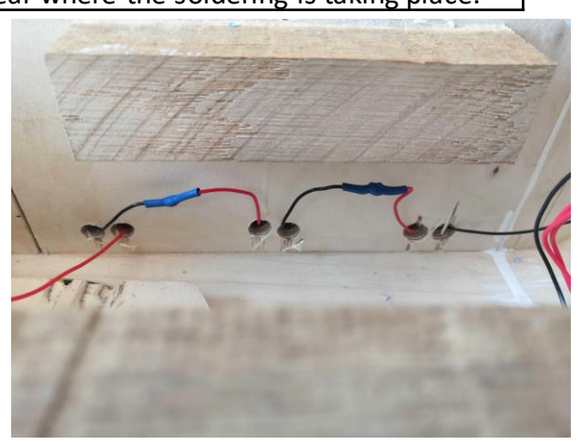
Manufacturing: (Assembly)

Step	Process	Tools and Machines used	Safe working practices
1	Use them stand's swivel piece to accurately mark holes in the centre of the bottom section of the main piece. Then drill these holes using a 6mm drill bit. These holes will allow a bolt to be inserted through and will attach the main piece to the mount. To the left of the mounting holes, mark and drill a 20mm hole for the on/off button.	Drill, 6mm drill bit and safety spectacles.	Safety spectacles must be worn when drilling to prevent eye damage.
2	Insert all five yellow disks into the five holes of the main piece in the order (from left to right): cow, pig, dog, cat, sheep. The order is important due to the code and wiring layout. Once the buttons have been inserted, tighten down nuts on the other side. The on/off, start and select buttons should then be inserted into their respective holes.	A rubber mallet.	Keep fingers away from the disks when they're being hit with the rubber mallet.
3	On the inside of the main piece mount the speaker using the mount that's been made and also attach the seven-segment display with screws. All screws should be short enough, so they do not penetrate the front of the main piece. On the front, the speaker cover should then be screwed in and the seven-segment display cover attached via superglue.	Superglue, a drill, 3mm drill bit, safety spectacles and a screwdriver.	Ensure gloves are worn when superglue is being applied. Also, safety spectacles must be worn when drilling guide holes for the screws.
4	Mark out the 12 holes for the solar panels, 6 on each side. I did this by making a template of the solar panels (with its holes) out of cardboard which allowed me to accurately mark out the holes for a solar panel and then slide it across and do another one. After that, drill out the holes, ensuring they're big enough to accommodate the slight solder outdents on the solar panels. Next, sand away patches of paint where the solar panel will be glued and then correctly thread the pre-soldered wires through the holes and glue the solar panels down. Sanding away the paint where epoxy is being applied will allow for much greater adhesion (to the product itself).	Pencil, drill, 6mm drill bit, sanding paper, two-part Epoxy and safety spectacles.	When drilling out the holes, ensure safety spectacles are worn to prevent eye damage.
5	The wires of the solar panels should then be soldered in such a way so that the three solar panels on each side are wired in series and the two groups of solar panels should be wired in parallel. Cover up these solders and other exposed wiring with electrical tape or heat shrink where appropriate.	A soldering iron, flux, solder fume absorber, wire cutters, wire strippers, a hot air gun, electrical tape, heat shrink, safety spectacles and a respirator.	After using the soldering iron put it in its stand to prevent burns. Wear safety spectacles to prevent airborne solder from entering the eyes and a respirator to prevent toxic fumes from being inhaled. A soldering fume absorber should be on and near where the soldering is taking place.

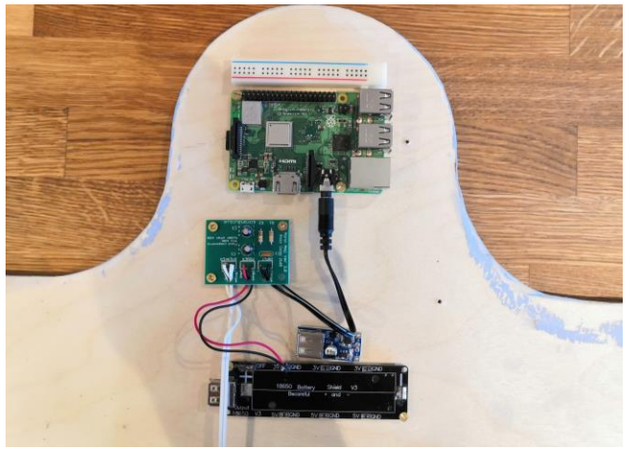


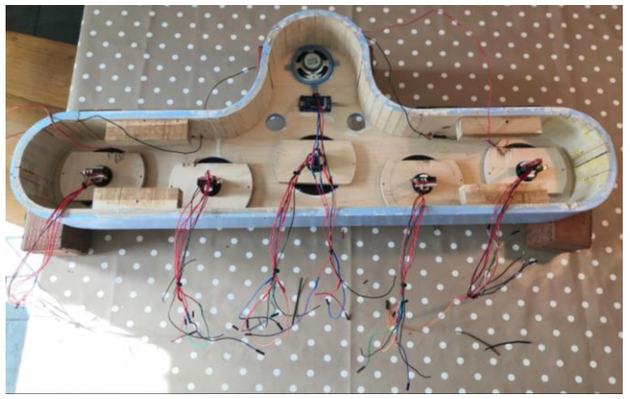


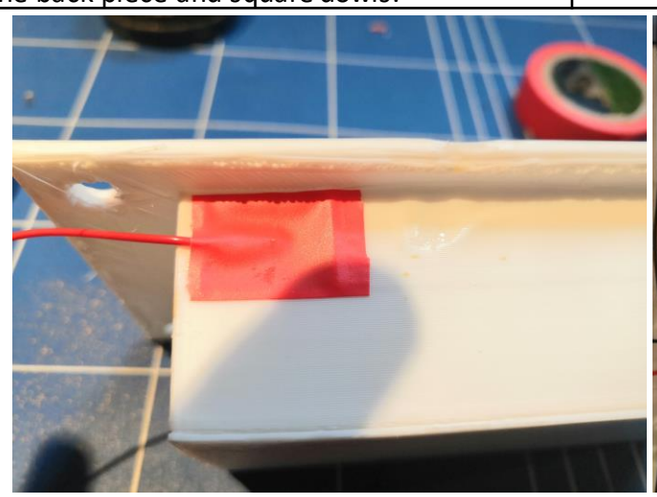


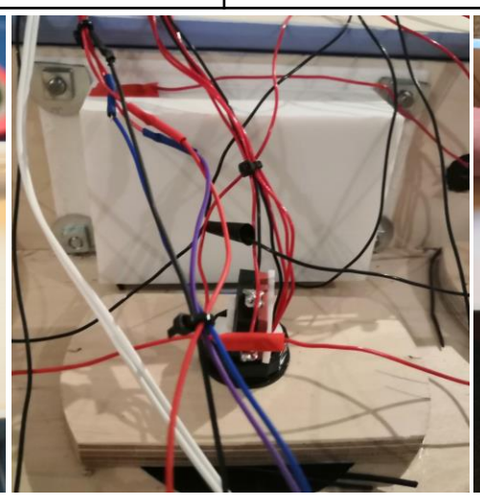


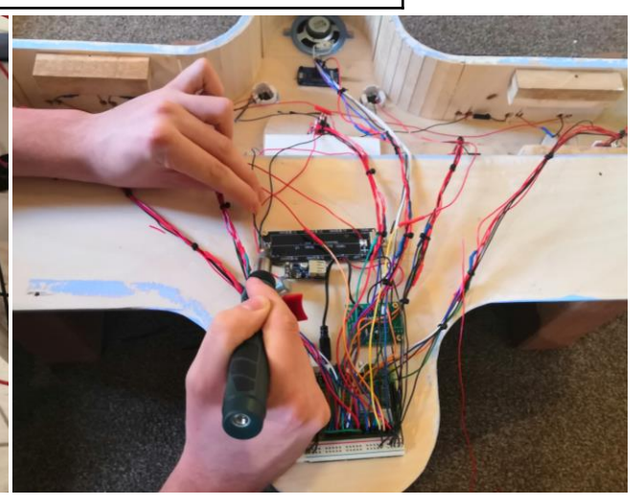
Step	Process	Tools and Machines used	Safe working practices
6	Mount the pi, breadboard power slot, speaker board, solar panel charging board and battery board to the back panel in appropriate positions (Positions that won't interfere with other components) The appropriate positions can be seen in one of the photographs. The back panel should then be propped up in respects to the main piece in the same way as can be seen in the photographs.	A drill, 3mm drill bit and a screwdriver.	When drilling, wear safety spectacles to prevent eye damage.
7	Wire the button switches and seven-segment display so that they have female connector ends. Also, solder female ends to the RGB LED wires (except for the ground wires which need to be male). Then connect all the wires with a female end to the GPIO pins on the raspberry pi. Connect one of the ground pins on the pi to the ground row on the breadboard power slot and then insert all of the ground wires into the pins on the row.		
8	With the position of the PCB know cut the power and speaker wires on the speaker PCB to a suitable length. Then solder the speaker wires to the speaker and the power wires to a 3V output on the battery board. After soldering cover exposed wiring with heat shrink. At this stage we connect the USB output of the solar panel charging board to the micro USB input on the battery board. Next, the USB output of the battery board should connect to the micro USB input on the raspberry pi (3b+).	Soldering Iron, flux, a wire cutter, wire stripper hot air gun, heat shrink.	Wear safety spectacles to prevent hot solder balls from causing eye damage. Put the soldering iron back In its stand immediately after use. Ensure a respirator is worn and a solder fume absorber is on and is close to where the soldering is taking place.
9	Solder positive and negative wires to the battery in its holder. Then secure the battery holder to the main piece by running a bolt through the holes of the swivel piece, main piece and battery holder. Wire the positive and negative wires from the battery to the terminals on the battery board. Then solder the positive and negative wires of the solar panels to the solar panel charging board.	(With the inclusion of a spanner)	
10	Flip over the back panel and reinsert the screws to attach it to the main piece. Finally, lock the swivel piece to the mount (using the locking bolt). It is then up to the client to decide where the products going to be mounted by inserting the concrete bolts. Make sure that wires don't go between the back piece and square dowls.	A screwdriver.	Be careful when reattaching the main piece to the mount because at that point the mount has not yet been secured to the ground.

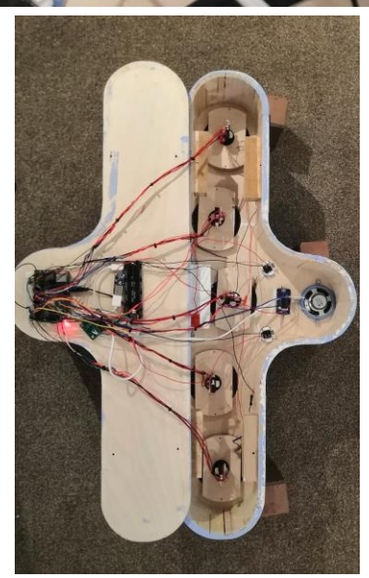












Final prototype and Evaluation plan:

Here is a link to the product in use:
https://bit.ly/3d6k91l
Please Note: During the time that the photos where taken and the video that there was an accident during moving. The only major damage done was to the select/quit sticker(this would not happen in normal use).

Evaluation Plan:
As part of the evaluation, I will be evaluating the final prototype against all the final specifications in detail and ensuring that it still meets all the general specifications. To test the dimensional accuracy of the product I will be using a 1-metre ruler and measuring tape where needed.
To measure the weight of the product I will place a plank of wooden a set of weighing scales. I'll then zero the weighing scales and place the product on them After the weight is known I will create a data sheet that comes with the product.
To see whether the product is reasonably priced I will ask the client and others if they would buy the product for £210.
To test the function final specifications, users will test the product and any problems with the products function will be flagged up and also enjoyment when using the product can be tested. Please note the due to the COVID-19 lockdown situation, I am unable to get potential users to test out the product, instead, I will be doing it myself.
To see if the animal faces are large and recognisable I will put a short-sited person three meters away from the product, I will then ask them to tell me what the animals are from left to right (having not seen them before); if they get them all correct then the faces are defiantly large and recognisable enough when the products in use.

Evaluation:

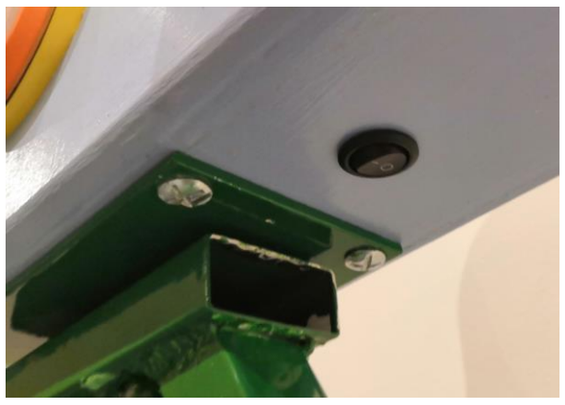
Green = meet **Black = N/A**

Function:

The game must be fully functional:

From this photo, we can see that all the lights and seven-segment display are fully functional. Every aspect of the game can be seen working in this video: https://bit.ly/3d6k91l
I sent this video to my client as he would know if it would appeal to children aged 4 – 6 and he said it would.

The game/product must be able to be switched on and off with a switch:



The switch connects to the battery and the raspberry pi meaning the product is off when the switch is in the off position (0). When switched on, the raspberry pi boots up and automatically starts up the game.

The product must be able to rotate on its stand:

These two photographs show the main piece can rotate on the stand. Also, due to the rotating mechanism, it can easily rotate through 360°.

The product must be able to lock into the stand, stopping it from being able to rotate:

When the bolt is tightened down with a spanner it presses down on the pipe and prevents it, and therefore the main piece, from being able to rotate. The locking mechanism also means that the main piece can't be lifted off the stand and therefore the ground (when the stand is bolted to the ground).

The product must be able to charge and run without external power:

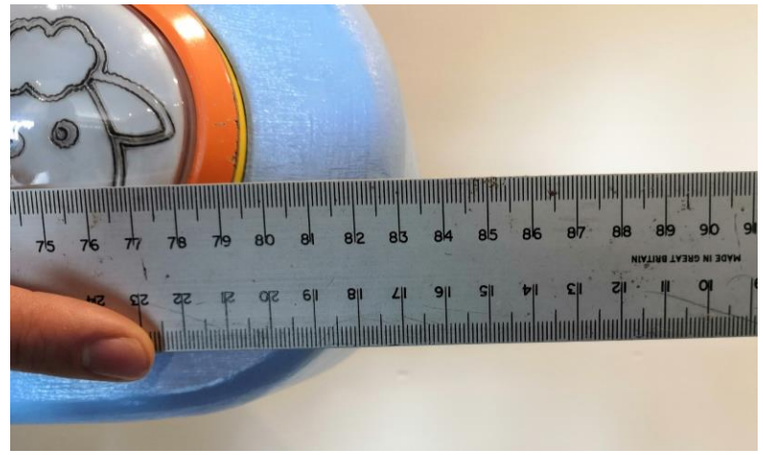
Since there is a battery, when the product is not in use, it's charging. The charge it receives from the solar panels should be enough to keep the battery always above 20% which will mean it won't run out of power. Also, the use of the battery means that the product's function does not rely on it being sunny.

Form:

The products two outer buttons must have their centre points 818 mm from the ground:

This dimension was very slightly out (only by a few mm) but due to the button height still being comfortable for the target user group, the product comfortably meets this specification.

The product must be 83cm long:

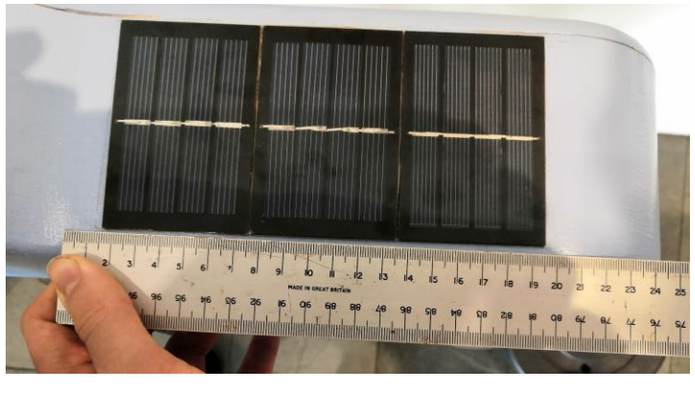


The stand must be 74cm tall:

The animal faces must be large and recognisable:

Please refer to the evaluation plan. The short sited person got all the animal faces correct at a distance showing that the animal faces are large enough and suitably recognisable.

The flat edges on the main piece must be 20cm in length:



The flat edges were long enough to accommodate the solar panels which is why it needed to be 20cm in length.

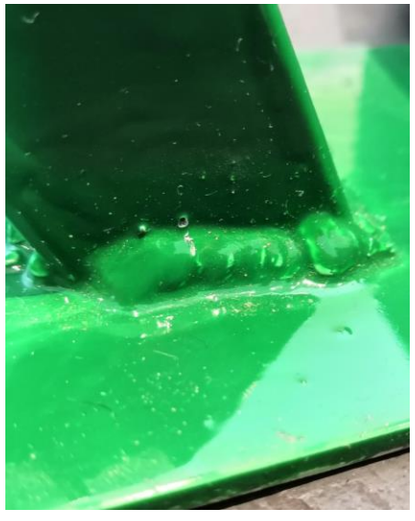
All holes cut must be correctly sized for the component they hold:

As can be seen from the photo, the button disk fits snugly within the hole, this is the case for all the holes and buttons. Also, the required tapping with a rubber hammer emphasises how snugly the button fits within the hole, preventing water from entering.

The 7-segment display's centre must 1005 mm from the ground :

Performance requirements:

There must be no sharp points on the product (especially where there are welds):



These pictures demonstrate that all the welds are smooth. Furthermore, there are no sharp points on the entirety of the product

The product must be waterproof:

Due to the Covid-19 lockdown situation, I was unable to access the school's workshop meaning I couldn't implement the final waterproofing measure, that being a piece of rubber running across the back panel, which would act like an O-ring – preventing any water from being able to get in. However, apart from that, it's important to note that all the other waterproofing measures were able to be implemented, such as the LCD cover, correctly sized holes and the speaker grill.

The stand must be strong enough to reliably hold the main piece:

The welds have been strategically placed so that they are addressing all the areas of the stand which are under compression – increasing structural integrity. Furthermore, the mild steel used is very able to support the weight of the main piece and this, as seen in the demonstration video.

Everything must stay secured to the product:

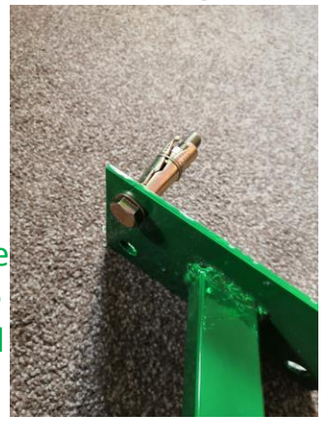
After attempting to, nothing on the front panel was able to be removed. This was achieved through a combination of glue or button securing mechanisms.

The product must not be able to rust:

Anything material that is able to rust has been coated with an oil-based paint. The pipe, which was predicted to have its paint stripped off, is made of stainless steel – meaning that to won't rust.

The stand must be able to be suitably secured to the ground:

The image to the left shows that a 14 mm concrete bolt can be inserted through the holes on the base plates. It will be up to the client to insert all 8 concrete holes into the respective holes on the base plates (4 in each) and secure the product to the ground. The bolts the stand is designed for are heavy-duty and unlikely to ever break/stop functioning.



User requirements:

The speaker must be suitably loud for a playground environment:

Please refer to https://bit.ly/3d6k91l (volume might vary with speakers). I adjusted the volume so it is loud enough so it can be heard over playground noises. The volume can be adjusted if it's too loud or quite.

The LEDs must be suitably bright

As can be seen by the following video: https://bit.ly/3d6k91l and the picture below, showing the LEDs are suitably bright. They were also tested in direct sunlight (simulated by shining a torch directly at them) and (change in) colour could be noticed with ease.

Materials/components:

Any weights/electrical information of the product must be displayed:

The weight of the entire product came to exactly 10Kg.

Now the weight of the product was known, in order to meet this requirement I made this data table/sheet that will come with it:

Net weight:	10.0kg
Mounting drill size:	14mm
Max current draw:	2333.3 mA
Battery capacity:	24000 mAh
Max Charging Current:	500mA

The product must be reasonably priced:

After showing the pictures and video of the product to the client, they said that £210 is a reasonable price. I also asked two other headteachers and they both said that price was manageable within the budget they have to spend on playgrounds. It's also important to note that the cost of the product could be significantly lower if a raspberry pi zero was used and it was manufactured at scale (lowering material costs).

Evaluation: LCA

Through conducting a life cycle assessment on the prototype I will be able to evaluate its sustainability and environmental effects.

Extraction and manufacture of materials:

The marine plywood comes from a local business which ensures sustainable practices like planting new trees for every one cut down. Another positive thing about the product is that all the metal used to construct the stand came from recycled sources meaning that useable metal isn't being sent to landfill which negatively impacts the environment. Also, the 18650 cells came from old laptop batteries, these cells contain harmful chemicals and if they weren't recycled they would also end up in landfill. Furthermore, the use of recycled materials means that the carbon footprint for the product is lower as no energy is needed for the extraction of the materials. Recycled PETG filament was used rather than virgin material, this lowers the carbon footprint especially because less crude oil has to be extracted. However, the extraction of raw materials for acrylic – and its manufacturing process- can negatively impact the environment, however, very small amounts of acrylic used so it won't negatively affect the LCA too much. A better alternative to acrylic could be recycled PETG.

Transporting materials and Manufacture:

Where possible, materials and components where sourced from local businesses and all materials/components were manufactured in the UK. This means that the materials require less transport to where manufacturing takes place, thus lowering the carbon footprint of the product and increasing its sustainability. The manufacturing of the product does not require much energy meaning that it's more sustainable and doesn't negatively impact the environment as much.

Use:

Provided that it's situated in a suitable place, during the products life it does not impact the environment in any way. This it is powered of its own environmentally friendly renewable energy – solar panels. The materials used in the product should mean that it's very durable – even in a fully exposed environment. During its use, the stickers for the start and select buttons may need to be replaced (due to how much they get used) meaning new ones will have to be ordered. A way to solve this problem would be to have extra vinyl stickers sent with the product so they can be easily replaced, negating the need for the delivery of more stickers and thus reducing the carbon footprint. The solar panels on either side of the product are made up of three more solar panels each, this modular design means that if just one breaks, a single panel can be replaced. Alternatively, if larger singular panels where to be used, when they broke they would have to be fully replaced, demanding more materials, which is bad both environmentally and sustainability wise, and would cost more.

Disposal:

When the product has reached the end of its useable lifespan it will need disposing of and the more of the product that can be recycled the better. Marine plywood, used for the main piece, can be ground down and used for MDF. If that weren't to happen to the marine plywood it isn't too much of an issue because wood biodegradable and therefore harm to organisms. Unfortunately, acrylic and PETG used is non-biodegradable so will persist in the environment if it is not recycled but this is not problematic due to the relatively small amounts of those materials use. It's likely that many of the cells in the battery are still usable and, just like what I did, they can be easily recycled. All the electronics used are able to be recycled at e-recycling centres but its important to factor in the transport miles getting them to one of those locations.

Conclusion on LCA:

Overall this product would be deemed to be both sustainable and environmentally friendly. This is because the majority of the materials/components, if they didn't come from recycled sources, came from local businesses abiding by sustainable practices. Also, the batteries where recycled, something rare in product involving electronics, and are powered by the product's own solar panels which is an emission-free and renewable form of energy generation.