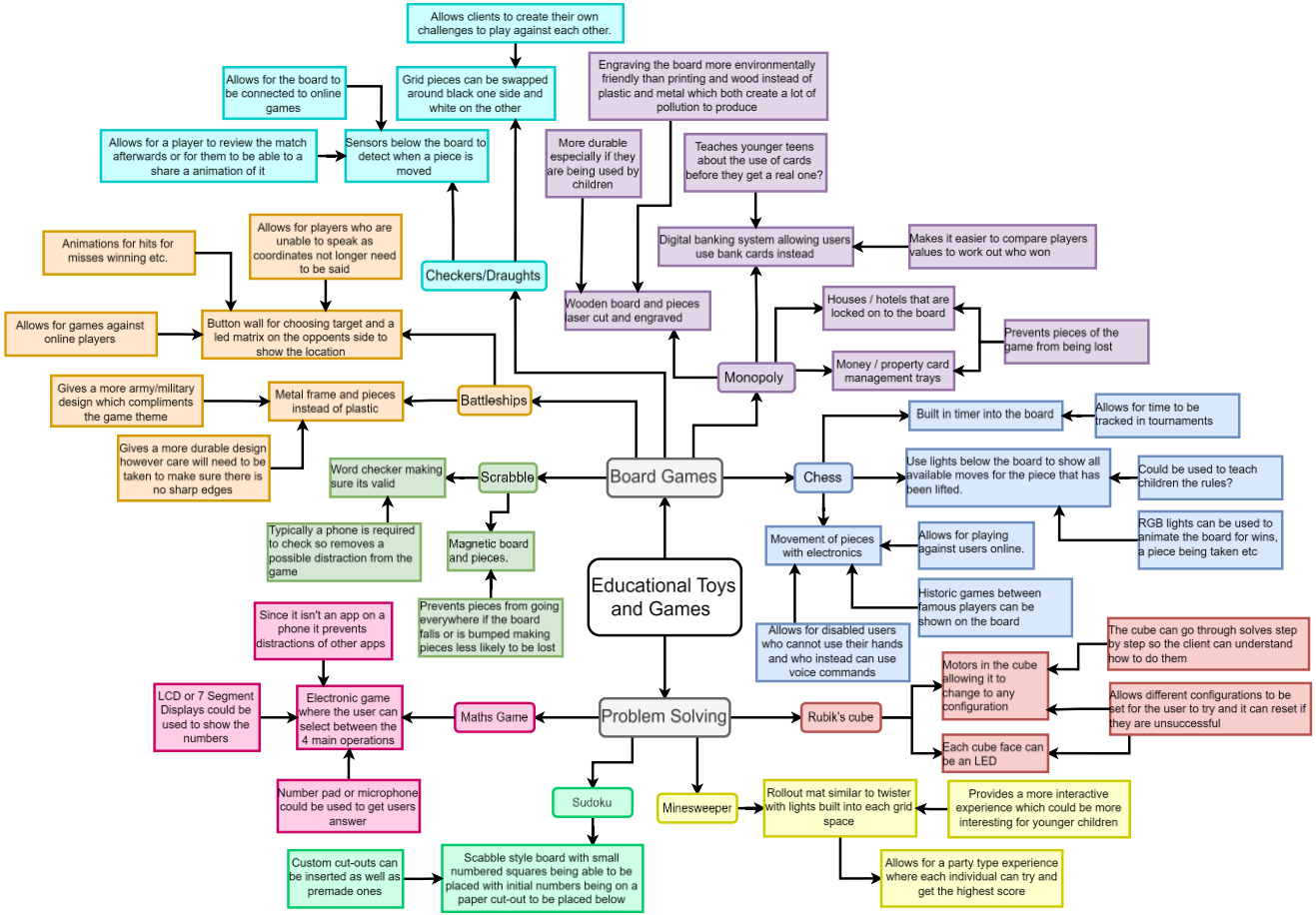
Educational Toys and Games

James Dillon

Centre Number: 17401
Candidate Number: 3044

Task Analysis

I divided my research into two categories: Board Games and Problem Solving. For Board Games, I analyzed popular mainstream games to find ways to give them better longevity, focusing on designing games with fewer components or parts that are less likely to be lost. For Problem-Solving, I explored products that emphasize critical thinking, including addition-based games and puzzles like Sudoku, as well as games such as Minesweeper for its problem-solving elements.



Meet my Client…

My mother has worked at Busy Bee's Nursery for the past six years, joining during the peak of the Covid-19 pandemic when attendance was notably low. Since then, the nursery has expanded by renting the floor above their original space after the previous occupants vacated. This expansion has significantly increased the number of children attending especially the amount of the younger children.

However, despite the larger play area, they have yet to invest in new toys or equipment. This creates an excellent opportunity for me to design a product specifically designed for the four-year-olds she works with. Which both educates children preparing them for primary and allows them to have fun.

Name	Kerry Dillon (Mother)
Age	37
Occupation	Level 3 early years educator
Works with	4year olds (pre-primary)

Busy Bees 40 years of best beginnings

Client Interview

One evening after school, I had a discussion with my mother and asked her the following questions about current toys in her nursery and things I could improve over existing toy

Are there often durability issues with existing products in the nursery?
In the nursery, durability issues with toys are common due to the robust way children play with them. This includes activities like throwing, stomping, and chewing. Depending on the materials, toys often have a limited lifespan and need to be replaced after a certain period.

What price does your nursery normally spend on a toy?
The nursery typically spends between £100 and £300 on toys, usually purchasing them in bulk annually, with around 10 items per order. These toys are sourced from various suppliers, including Amazon and TTS Group.

What size toys do children most enjoy using?
Children tend to enjoy larger toys, but they must be manageable for them to carry. For example, a large dinosaur figure that they can easily hold is a popular choice.

What kind of educational benefits would you want from a toy?
Due to their limited time till primary, it's beneficial for toys to have subtle links to core subjects e.g. Maths and Phonics. However, children often lose interest in these subjects when presented on their own. Toys that focus on teaching broader skills, such as problem-solving, are more engaging to them. If core subjects are incorporated, the connection should be minimal and integrated in a way that keeps the focus on fun and interactive learning.

Are there any toys currently used by children which you would like to see more of?
We've recently introduced new wiring boards where children can plug wires into various contacts to turn on lights, and they really enjoy it. However, incorporating more challenging elements like buttons and levers could make the experience even more fun. Adding some form of randomness to make the toy different every time would also be cool.

What kind of materials do you think would work best in your environment?
The best toys are those that are easy to clean and versatile for both indoor and outdoor use. From experience, plastic toys tend to be highly durable and easy to wipe clean, while varnished wood is also a good option for durability and cleanliness.

Would they need to be sustainable?
While it's ideal for toys to come from sustainable sources, longevity and practicality are more important. Sustainability is a bonus, but it shouldn't cause a significant increase in price, especially if it compromises durability.

Is there any safety concerns when a child a using a toy?
Safety is crucial, and toys must be age-appropriate. Key factors to consider include:

- Choking hazards (small parts)
- Ingestion risks (non-toxic materials)
- Weight (to prevent injury from throwing)
- Durability (to prevent sharp edges if the toy breaks)
- Hygiene (easy to clean and safe for contact)
- Secure battery compartments and hidden wires

Any other thoughts you would like to add?
If the toy can be used by multiple children at once, that would be a plus, one of the main teaching points in nursey is to encourage socializing and collaboration, which is heavily used in primary. However, at this age, communication can be challenging due to their limited ability to hold conversations. Sometimes, the best way for friendships to form is through playing games together.

Summary

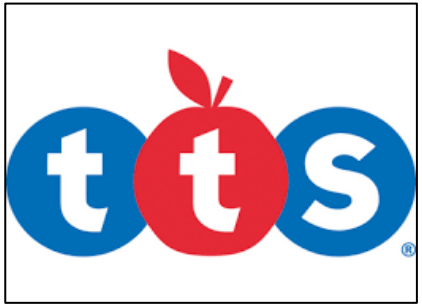
Here is the summary of what my clients' suggestions and ideas were.

The nursery faces frequent durability issues with toys due to children’s rough play, making regular replacements necessary. They typically spend £100-£300 annually on bulk purchases, with suppliers like Amazon and TTS Group. Larger toys are more popular with children however workers want them to be a manageable size so that the child doesn’t hurt themselves or have issues with taking it on the move.

Durability and easy cleaning are top priorities, with plastic and varnished wood preferred for both indoor and outdoor use. Sustainability is a secondary concern—important but not at the expense of durability or affordability.

Safety is critical, with focus on avoiding choking hazards, using non-toxic materials, ensuring toys aren’t too heavy, and having secure components. Hygiene is also key, favouring materials that can be easily cleaned.

The product can incorporate key primary subjects like Math and Phonics however the emphasis should be on wider skills such as problem solving, creativity and collaboration between children. The use of core subjects to a heavy extent causes the child to get bored and see the toy as work rather than fun.



Nursery Environment – Busy Bees

Nursery in Letchworth | Hertfordshire Childcare | Busy Bees

This room is normally used by 1-2 year olds. It has a collection of different wooden toys, that are all age related. The children in this room normally look for more additional adult support with toys.
This room has an amazing story book area, where most days you find the Gruffalo and his friends.

The preschool room, caters for 3-4 year olds. Children here enjoy getting ready for their next big steps into school. Learning through play and a breath-taking imagination.
Toys in this room consist of.

- Little Lego
- computer tablets
- Robot toys
- Bikes/ and scooters

This room is for 2-3 year olds. This large area has a great space for the toddlers to engage in play.
Toys here include plastic large jungle animal ideal for small hands to play with.
The Home corner with a selection of wooden pretend play food. Most toddlers seem to experiment by putting items in their mouth, so it's great these are easy washable.

Potential Safety Issues

According to the Child Accident Prevention Trust, a key safety concern with electronic toys is the design of the battery compartment. UK regulations mandate that these compartments must be secured with screws, ensuring that children cannot easily open them and access the batteries. This measure prevents potential hazards such as ingestion or tampering with the batteries, which could lead to serious injuries.

Another significant risk comes from the use of magnets in toys. If a child swallows two or more magnets, it can lead to life-threatening internal injuries. Therefore, any toy containing magnets must ensure that they are securely fastened and cannot be easily removed or swallowed by children.

A third concern is the risk of children coming into contact with live wires. This is particularly dangerous if a child touches them with sensitive parts of their body, such as their tongue. To reduce this risk, toys with exposed wiring must either:

- Operate at a low current and voltage that, while potentially causing discomfort, would not result in serious injury, or
- Use sensors to detect the connection of different cables and prevent the exposure of open contacts.

The Toy Retailers Association specifies that the maximum output for any toy must not exceed 24V. Other examples given where this regulation matters includes model railways and cars, where exposed electrical contacts may be touched but must not pose a danger to children.

child accident prevention trust

Toy Retailers Association
The voice of Toy Retailers across the UK and Ireland

Toy Retailers Association | Electric and Chemical Toy Standards.

Toy Safety | Child Accident Prevention Trust

Existing Products

Fisher-Price Silly Sounds Light-Up Piano

ACCESS-FM

Fisher-Price

[Amazon | Fisher-Price Silly Sounds Light-Up Piano]

Aesthetics	The colorful keyboard enhances visual appeal for children, but the rainbow keys also allows the device to teach colors. The integrated lights are a fun addition, although their current form in stars might seem somewhat babyish for a three-year-old. Similarly, the animal design on the front might not fully align with the preferences of older children.
Cost	The product itself costs £19.99 which seems to be in line with the other companies who sell similar products. It is also commonly on featured in bundle deals.
Customer	The product focuses on Numeracy and Literacy on top of the games built in which provides both a recreational and educational use case for the toy. However, the recommended age is 6months – 3years which might full just under the 4-year-old mark.
Environment	The whole construction is plastic which provides the limited recyclability after it has finished its lifespan. The use of electronics inside further complicates the process as they have to be removed. However, the use of a single type of plastic may help.
Size	The product dimensions are 200mm x 130mm x 210mm this is large enough to feel substantial for a child but small enough for them to carry around. The weight also compliments this at 300g which is not too heavy but also not too light.
Safety	The small gaps between the keys may make cleaning a challenge. The brittleness may also be a problem as cracks could form when dropped leading to sharp edges that could possibly cause a risk of getting cut.
Function	As said before the addition of many modes makes it fun and less likely for the child to get bored. The inclusion of a volume switch is a thoughtful feature for moderation which might offer greater flexibility for the worker watching.
Materials	While the choice of plastic is good for cleaning, the type used may be prone to brittleness; a softer plastic could be better.

Lily The Pink

★★★★★ **Fun baby keyboard**

Reviewed in the United Kingdom on 27 March 2021

Style Name: UK-English | Verified Purchase

We love this little piano.
Bright colours, easy to use switch that my one year old can operate. Three settings to play music including duck quacks, cow moos and normal piano along with a song setting to learn numbers, colours, shapes. Sturdy construction. Overall it's great.

The reviewer found the product's construction to be sturdy and durable. They appreciated the vibrant colours, which made it fun and visually appealing for their child. The selector tools were highlighted for being easy to use, even for a one-year-old. Additionally, the various modes offer a wide range of learning opportunities, making the product both engaging and educational.

Customer reviews

★★★★½ 4.7 out of 5

1,175 global ratings

5 star	82%
4 star	12%
3 star	4%
2 star	1%
1 star	2%

The reviewer expressed concerns regarding the product's intuitiveness for children. They highlighted that the use of stickers is a poor design choice due to potential quality issues during manufacturing. Stickers could easily tear or become damaged during regular use by children. The reviewer emphasized that children of this age are already familiar with swiping on phones and tablets, suggesting that similar principle be used which is more user-friendly.

zubzubuk

★☆☆☆☆ **Fisher Price USED TO BE Synonymous with Quality**

Reviewed in the United Kingdom on 17 August 2024

Style Name: UK-English | Verified Purchase

What on earth happened to Fisher Price quality between the years from my children to grandchildren? This arrived with a lump where one of its stickers had been applied poorly and was therefore not suitable to give as a gift but in general the functionality was very underwhelming and unclear. I think this would be very hit and miss for child operation even when they know how to swipe a phone or smart watch by 4 months! It was all a bit muddly and didn't seem at all educational as I expected it to be.

Overall, the product is highly rated, with most users giving it 4 or 5 stars. However, some recent reviews reflect negative feedback, suggesting potential issues with newer batches

Miss May

★★★★★ **Not just a toy .....**

Reviewed in the United Kingdom on 15 May 2024

Style Name: UK-English | Verified Purchase

I bought this for a 10 month old with cerebral palsy - He has poor muscle control and they want to encourage him to use his hands With the piano he has to lift his hands and press the keys
He ADORES the piano - definitely his favourite toy - AND its helping him tone his muscles
Thank you!

The reviewer has a young toddler with a condition that limits muscle control. Even so, they found the switches and keys easy to press, allowing their child to engage in activities that most products typically don't accommodate.

Montessori Busy Board

[Amazon || Konijiwa Montessori Busy Board]

Aesthetics	The product features vibrant colours for the switches and wires, making it visually appealing and intriguing for children. The use of laser-engraved elements on the wooden surface adds detail, offering context for the components. For example, the LED is framed with a lampshade, and the switch is connected to a clipart battery, enhancing the overall design.
Cost	The price is similar in price to competing products however it does seem to be slightly lower by around £1-2 pounds or so. The price itself is £12.99.
Customer	The manufacturer's recommended age range is 18 months to 3 years, which is slightly younger than my target age of 4 years. The product is marketed as enhancing hand-eye coordination and fine motor skills, with limited emphasis on literacy or numeracy development.
Environment	The main body is made from oak, a material that is easy to recycle. However, the electronic components appear to be glued into the block, which complicates the recycling process.
Size	The product is 175mm x 148mm x 53mm allows for a child to pick up and move around with it with relative ease further as the product weighs 310g, similar to the Piano.
Safety	The battery is held behind a metal plate with striped hazard paint this may make it an appealing thing for children to touch and tamper with, making it more subtle could improve its function. The two screws securing it this provides good protection however could the job be done with only one?
Function	The variety of switches and buttons creates many combinations for the child to try however their outputs are fixed meaning once a child has tried them once they know what's going to happen every time which could make it boring after a few uses.
Materials	The use of wood provides a more natural feel to the product however this may provide some concerns about outdoor use. Furthermore the switches have lots of gaps and crevasses in them which could be hard to clean properly.

The reviewer's daughter loves taking the product everywhere, highlighting its excellent portability. The switches and buttons are well-made and provide a satisfying click when used. The inclusion of wood in the design is appreciated, offering a alternative to the more common plastic materials on the market. The product is seen as great value for money, although the reviewer mentions they received it through a free tester, which might affect their perception of its cost.

Their daughter continues to enjoy the product, showing no signs of boredom. However, the reviewer points out one minor flaw, the key switch is not attached to the main body, leading them to tie it with some string. This could be an area for potential improvement. Additionally, the reviewer refers to their child as the "little one" without mentioning their age, so they may be slightly younger than my product's target age group.

Lord Chevallier

★★★★★ **fabulous toy**

Reviewed in the United Kingdom on 15 July 2024

Colour Name: 01 | **Vine Customer Review of Free Product** (What's this?)

The little one has been fascinated by this for a couple of weeks now and takes it everywhere with her - on the bus, out for lunch - everywhere. Wherever we go other other mums come over and say how cool it is and ask where we got it. It really is a fabulous little toy, made of wood instead of plastic which makes it even better and suits the type of toy really well. It's really well made and all the switches and buttons have satisfying clicks. We like that the key is tied on so it won't get lost. It's the perfect size for little fingers and for just £21.99 it's one of the best value educational toys we've ever found. We really are very pleased with it and there's no sign of our little girl being bored with it, it's perfect for young minds and so much nicer than giving them a screen to watch. Easiest 5 stars I've ever given anything :)

Overall the reviews are primarily positive however it does have less reviews than other similar products.

Design Brief

I am designing an educational toy for my mum's nursery. It should prioritise durability to withstand the wear and tear of daily use by young children. The product will be priced between £20-30, making it affordable for bulk purchases by her company, and it will be designed for mass production to meet such orders. It will be constructed from materials that are non-toxic, safe for children, and easy to clean by her and other workers, ensuring hygiene is maintained during both indoor and outdoor use, as my mother mentions that children often wander in and out with them.

Safety will be a top priority, with all components designed to eliminate any risk of choking hazards. While the toy will have a minimal focus on maths and phonics, as my client says children tend to get bored with these subjects quickly, it will strongly encourage problem-solving and collaboration among children—skills that my mum's nursery promotes the most.

Design Specification

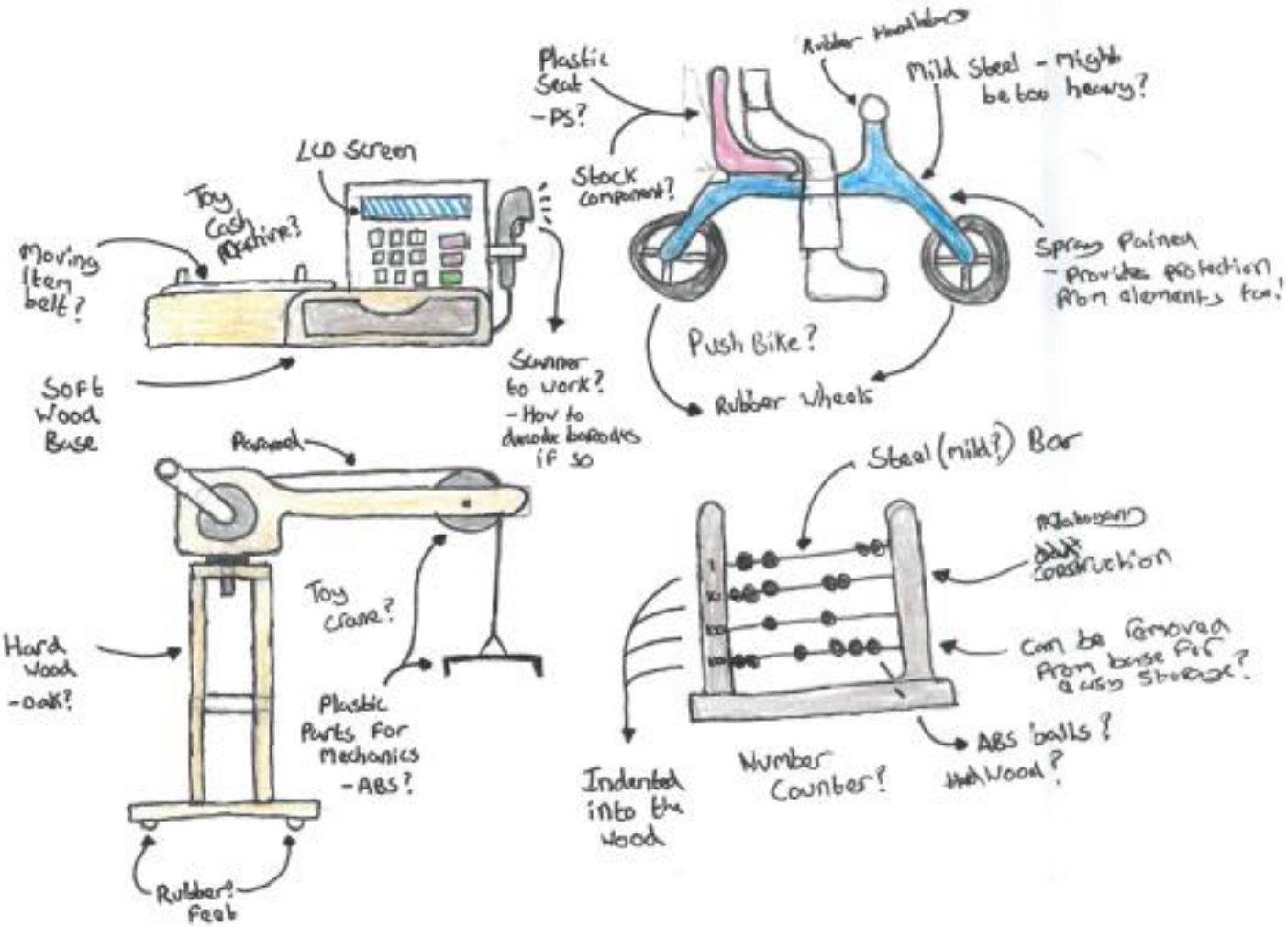
Specification Point	Why is it Important?	How I will achieve this?
The product should be durable against daily use by children	Children are often rough with the toys with a lot of wear and tear being put on current toys.	• Use of strong impact resistant materials • Strong joints between parts.
Product should be capable in surviving harsh weather such as rain.	Children in the nursery often go in and outside normally bringing toys with them, sometimes they are accidentally left outside for prolonged periods.	• Use of waterproofing around any electronic components to prevent any shorts. • And the materials used should not be damaged or weakened by water.
Product should be able to be carried with ease by the child with limited effort.	Children are often running around with toys often not staying put.	• Grip areas or handles should be added to allow easy with carry of the toy. • Low enough weight to not put strain on the child • Limited size can be held with one hand.
The product should be priced around £20-30	The nursery has limited budget for toys and therefore needs them to be priced accordingly	• Using cheaper materials and making them less wasteful e.g. 3D Printing – Minimising unnecessary infill
Product should be able to be produced in mass.	Nurseries like my mum buy items in amounts of 10, sometimes more therefore its important that production can keep up.	• Limiting the number of individual parts • Use of PCBs for Electronic elements.
The product should use non-toxic materials.	Children often lick and bite on toys in the nursery's it is vital they don’t get ill from it.	• Checking the safety of materials used and making sure the they don’t have particulates.

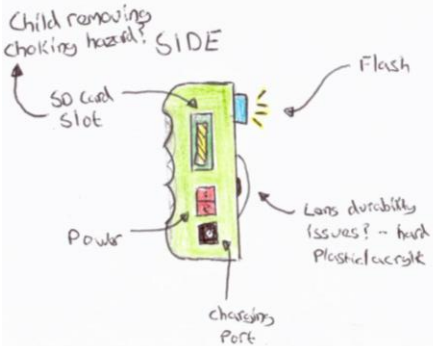
Product should be easy to clean	Workers have to clean toys after their use however they have access to anti bacterial spray and wipes	• Make sure cleaning chemicals don't have the a reaction on the materials of the product • No small gaps that could accumulate dirt and bacteria.
The product should have no small parts which a child could choke	Incidents have happened at my mum's nursery where children have choked on parts from toys. It is a major health and safety risk!	• All parts are attached to the product securely • Parts should be large enough in diameter that is cannot get stuck.
Toys should have a limited focus on Phonics and Maths	Children often lose interest in these subjects when presented on their own as they see them more as work than fun.	• Use of educational elements should be presented along side other more fun items.
Target age group of product is 4-3 years	Year group my mums work with, pre primary school so can sometimes still be quite rough in play but are also starting to gain a high intelligence	• Product should not be easy to use with an intuitive interface.
Product should be unisex and be friendly for both genders	The split of girls and boys in my mum's nursery is around 50-50	• Themes should be gender neutral. • Use of colours should steer away from normal gender colours i.e. Blue for Boys, Pink for Girls
Products should strongly encourage problem-solving and collaboration	Main thing my mum's nursery promotes, especially collaboration which is seen as a key skill required for in primary school	• Product can be used multiple children at the same time and is large enough for it to be comfortably shared between them

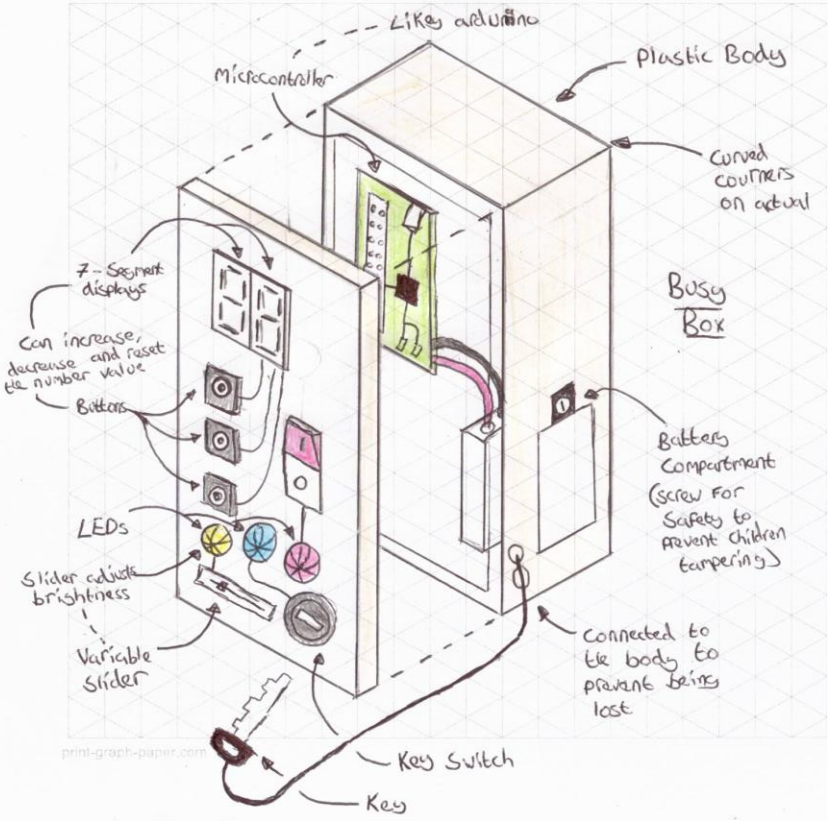
First Ideas

One issue I did find with the Cash Machine, crane and bike is they are quite large which could be quite costly for the nursey and may not be in their price range. The Number counter may also be a little too educational for children who might get bored of it over a longer period of time.

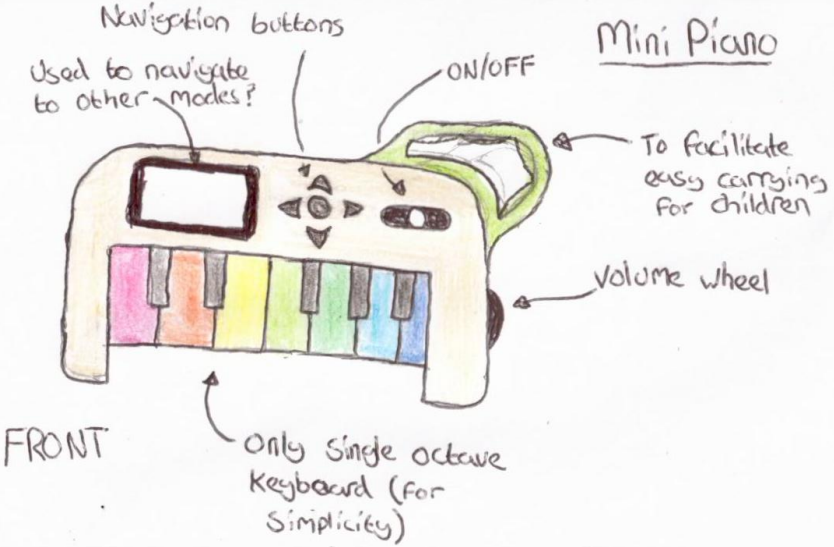
Existing Crane Toy

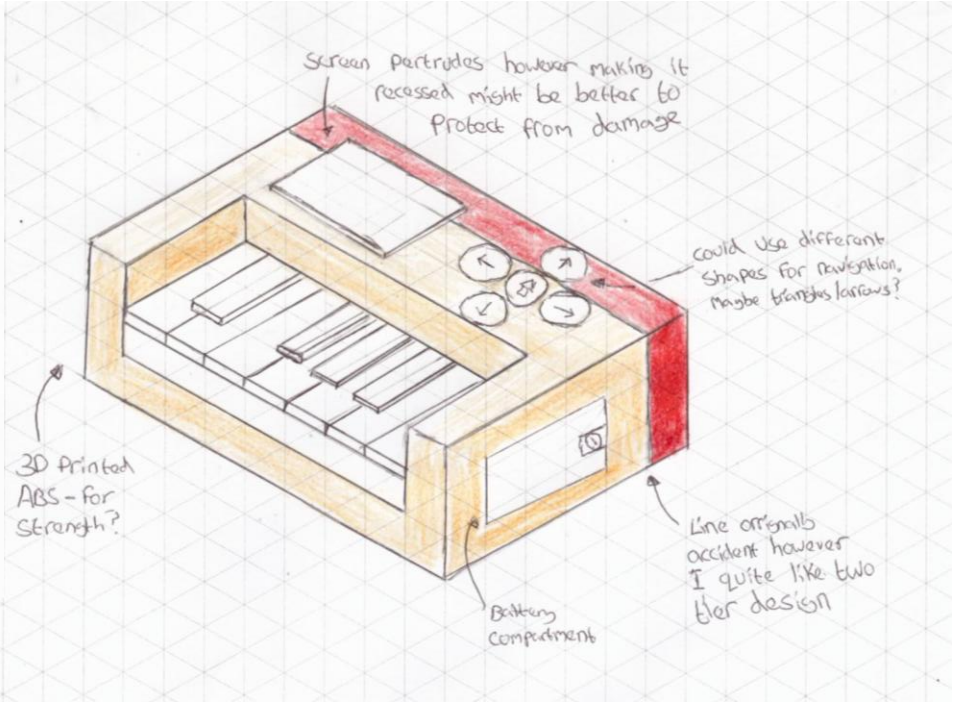


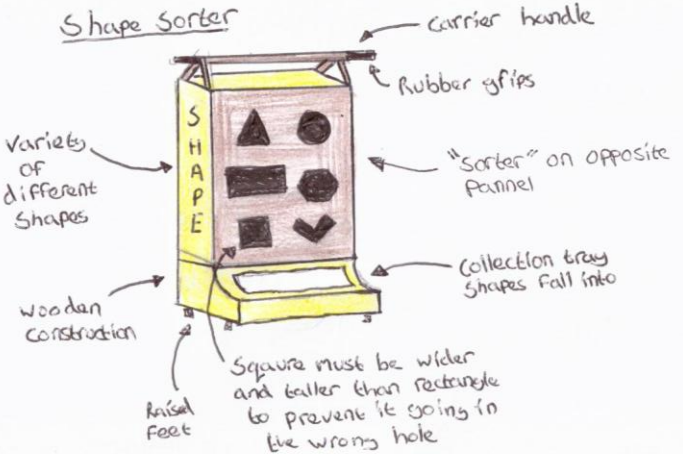




Recently when visiting my cousin, she had a similar toy camera however it contained receipt paper which printed black and white pictures. This allows children to have a similar experience of a polaroid camera which have risen in popularity recently without wasting costly polaroid sheets. Possibly something that I could add?







The designs which my client has shown the most interest in after seeing them all is the:

- Camera
- Busy Board
- Mini Piano

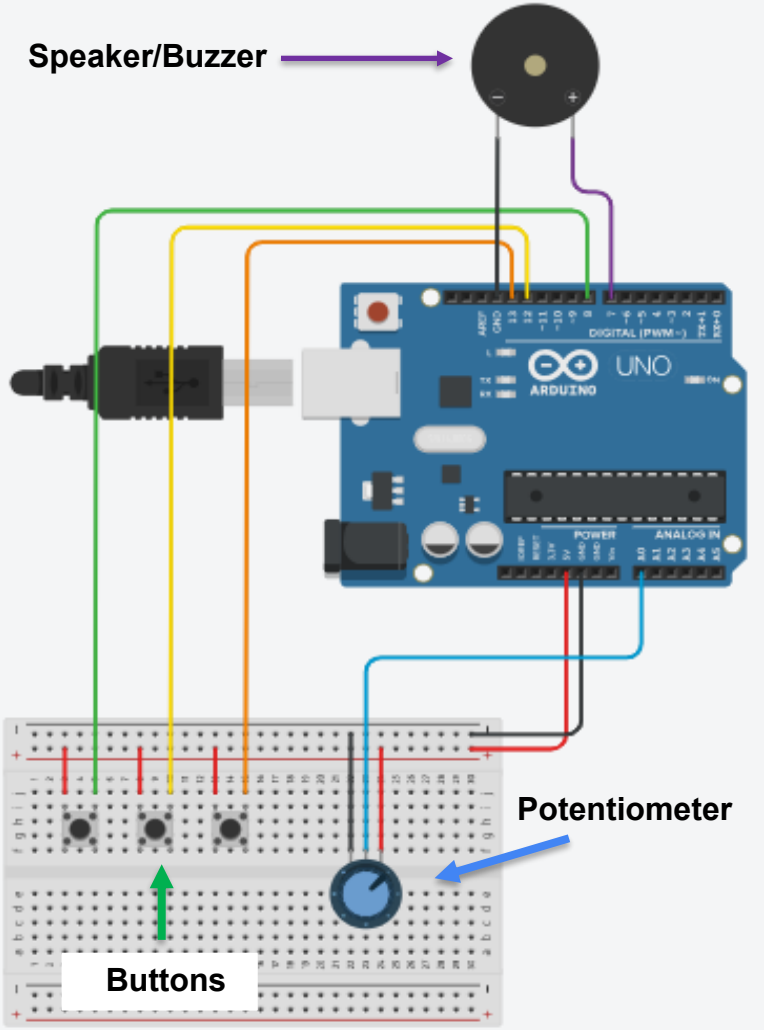
I'm going to develop two of them now with models and further sketches to a get a better idea how I would make them and to get further feedback from my client about them.

Idea Development – Mini Piano

I really like the idea of a musical toy, especially since my client currently doesn't have anything like it. Musical toys are often overlooked until late primary school, when music becomes a designated subject in the curriculum.

In this model, I focused on the ergonomic design ideas from both previous drawings and tried to merge them into one. I decided to not include the battery compartment to better focus on the overall shape. The keys are movable, which helped me establish a frame of reference for how the higher and lower notes would interact, particularly in with the cut-outs and spaces that would be required to give them a full range of motion.

I focused primarily on the curvature of the handle and sides, which wasn't well represented in my paper designs. The handle is lower than the main body, making it slim enough for smaller children to grasp comfortably. There were a few mistakes in this design; One was not allowing enough space in the top section above the keys for all the navigation buttons and the second was having no curve on the inside area by the keys. However overall, it still effectively shows the concept.



I want to create to a basic concept of the electronic components that would in a Mini Piano, so I did an initial design in a program called Tinkercad. The overall aims of this concept would be:

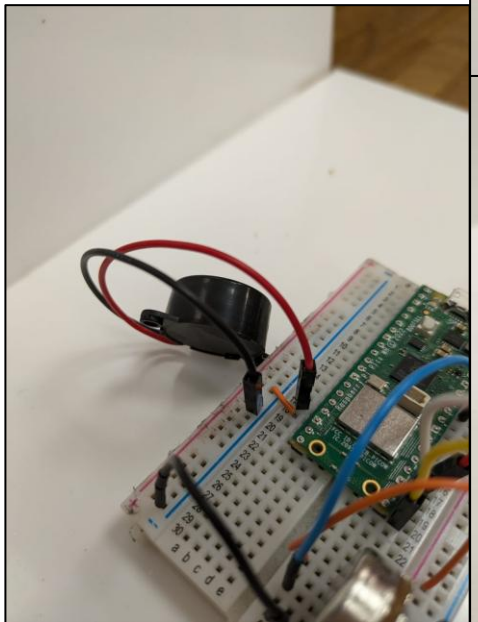
- Variable sound control through a the use of a slider or potentiometer
- A number of buttons which play different notes or tones. Which could be switched for more complex sounds in the future.

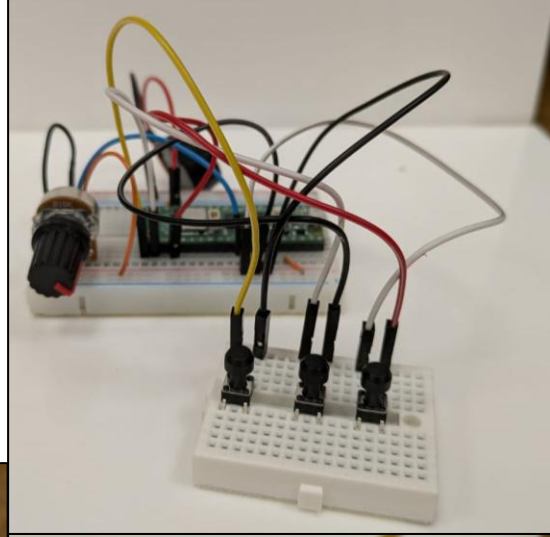
While a Arduino in used as the microcontroller in the online design I planned to use a Raspberry Pi Pico W in the physical mockup as its more powerful, I have experience in developing with them and its slightly cheaper. Furthermore it also has Wireless capabilities including WIFI and Bluetooth which could allow for the creation of a companion app for a phone which could allow the customization of different sounds so it can be used as a educational aid or just for fun!

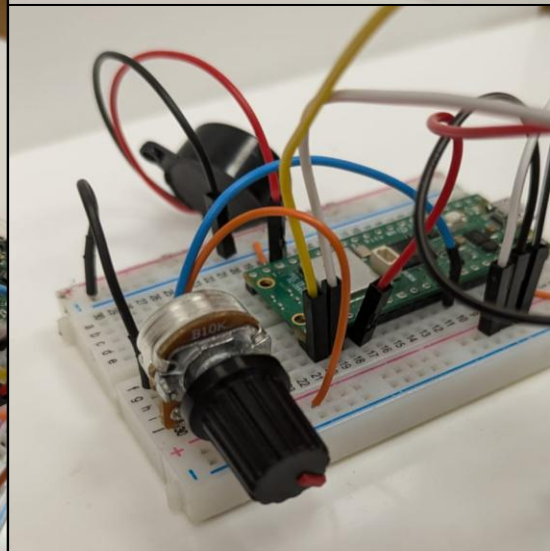
The physical mock-up met both aims; however, there were a few minor issues. First, instead of using a proper speaker, I used a buzzer. While this was suitable for a concept, turning the volume very high resulted in a high-pitched squealing sound which would very unappealing to children if they were using it due to a higher sensitivity. This was likely due to my directly inputting the value from the potentiometer into the buzzer.

Overall this model allowed me to gain an idea of the space the components would take up and prove the concept of the electronics and that its within my ability to program. If I was to continue with this concept I would need a better speaker and some form mode change to allow multiple different types of sounds.

```
import machine
import time

buzzer = machine.PWM (machine.Pin(13))

buttonOne = machine.Pin(16, machine. Pin.IN, machine. Pin. PULL DOWN)
buttonTwo = machine.Pin(17, machine.Pin.IN, machine.Pin.PULL_DOWN)
buttonThree = machine.Pin(18, machine.Pin.IN, machine.Pin. PULL_DOWN)

potentiometer = machine. ADC (machine.Pin(26, machine. Pin.IN))
volume = 20

while True:
    volume = potentiometer.read_u16()
    if buttonOne.value():
        buzzer.freq(1000)
        buzzer.duty_u16(volume)
    elif buttonTwo.value():
        buzzer.freq(750)
        buzzer.duty_u16(volume)
    elif buttonThree.value():
        buzzer.freq(500)
        buzzer.duty_u16(volume)
    else:
        buzzer.duty_u16(0)
```







Idea Development – Busy Board

In my initial interview with the client, we discussed the importance of developing motor skills in children. With this in mind I wanted to create a product which enhance motor skills but also make them think by implementing some problem solving elements

The model features a variety of control surfaces, ensuring that children engage with different types of interactions. By introducing various buttons, switches, and a scroll wheel, children will be challenged to explore and understand the functionality of each component.

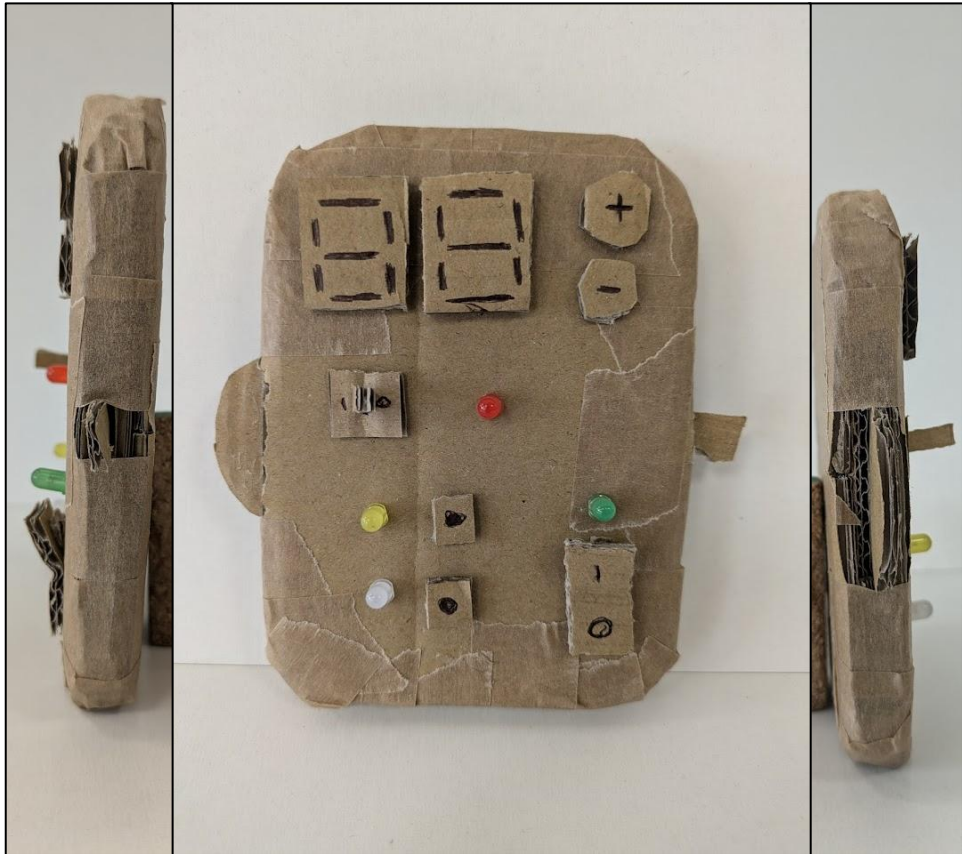
Additionally, I want to integrate two 7-segment displays that can increment and decrement values from 0 to 99. This not only adds an element of numerical problem-solving but also introduces basic math skills in a very minimal way

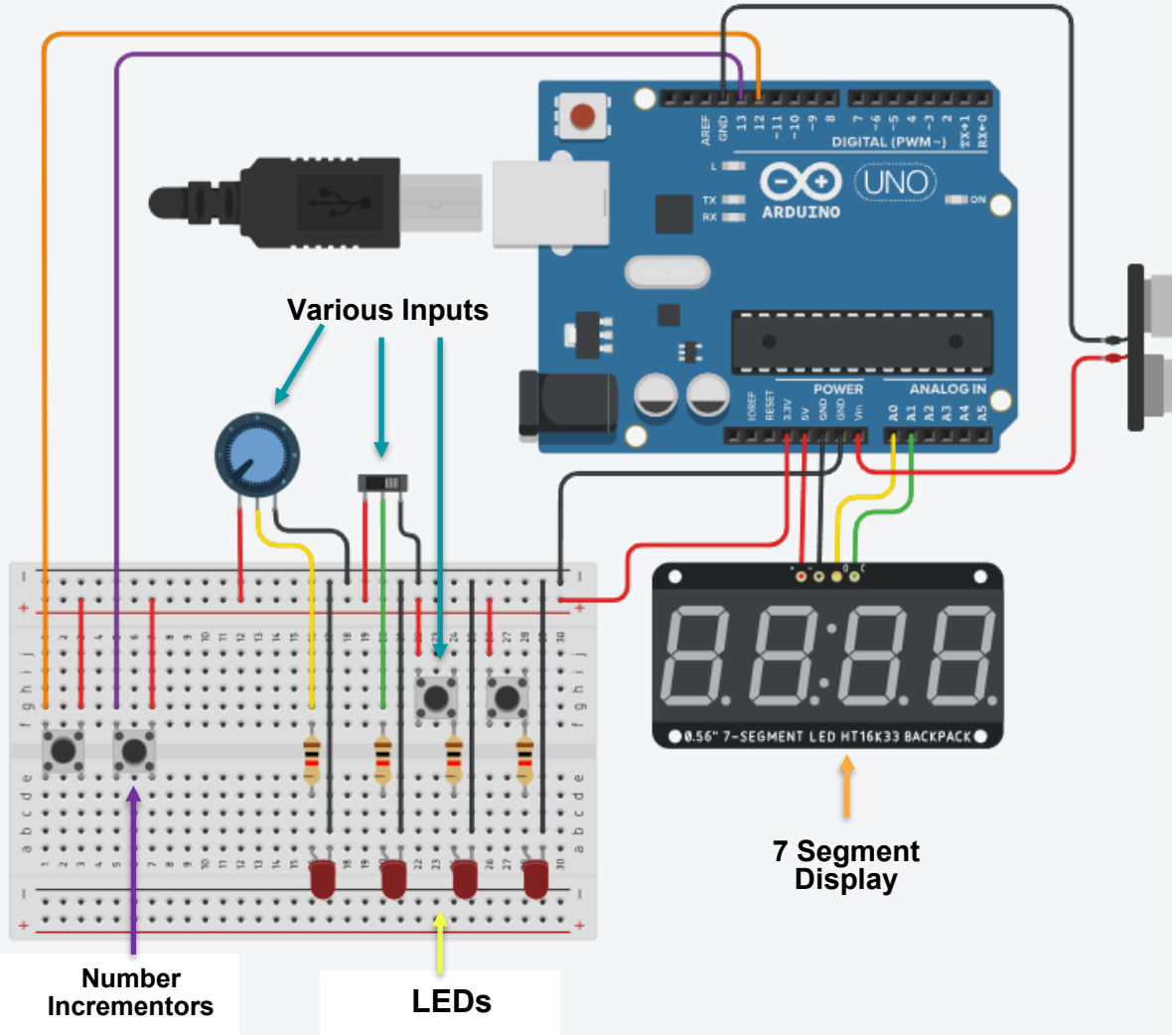
I focused primarily on the different inputs and did not pay much attention to the ergonomics of the design, which may make the sides look a bit rough. The use of actual LEDs provided a good representation of what the electronics would look like; however, it would have been nice to do the same for the other components as well.

Side

Front

Side





Below is a rough concept of what the electronics inside would look like. I tried to make as many components as possible independent of the microcontroller to simplify the design. While the concept shows the use of a large Arduino microcontroller, I would use something much smaller in the final model, as it would only need to handle the display. The microcontroller would still handle Power distribution for all electronics

A 9V battery would be used to power the components; however, if I were to redo this design, I would add a power switch so it can be turned off when not in use.

Client Feedback

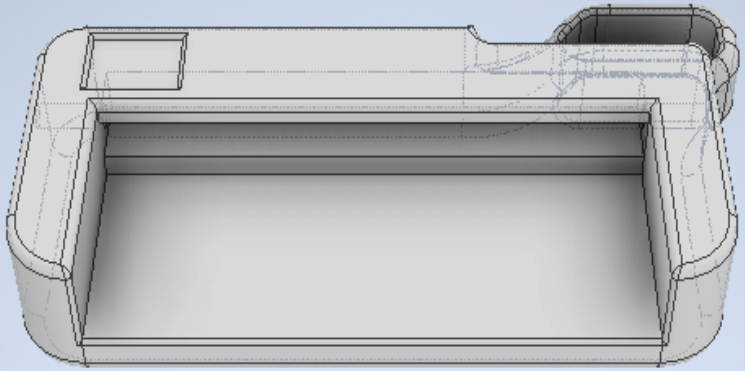
I showed my client my two developed ideas and asked for her opinions on both and which one she thought was better

	Busy Board	Mini Piano
Likes	She liked the many different inputs and the variety among them. She appreciated its simplicity compared to other electronic toys, which often have many different menus that younger children get confused by while navigating through.	She loved the electronic demo for the keyboard, even in its basic form, spending a good few minutes playing with it. She found the cardboard body to be a good shape, liked that it had no sharp edges, and thought the mini handle on the right was a 'cute addition.'
Dislikes	The current placement of the LEDs and switches, she said, was very open and not well protected. She noted that other similar toys have been broken because the components can easily snap off.	She did say that while the handle was a good way to carry it when not in use, children often play with it while moving. Some form of strap that they could wear, so they could play on the go, could be fun.

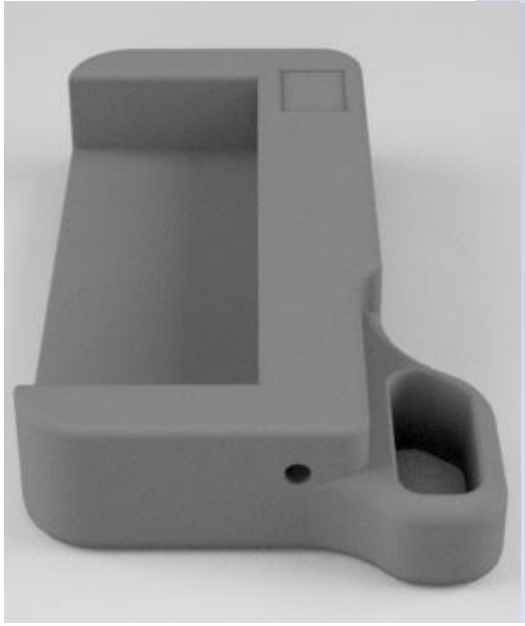
Overall, my client preferred the mini piano out of the two developed designs. She found it to be a more fun toy to play with. She liked the overall shape and direction of the design was going, finding it to be both comfortable and “very professional looking“.

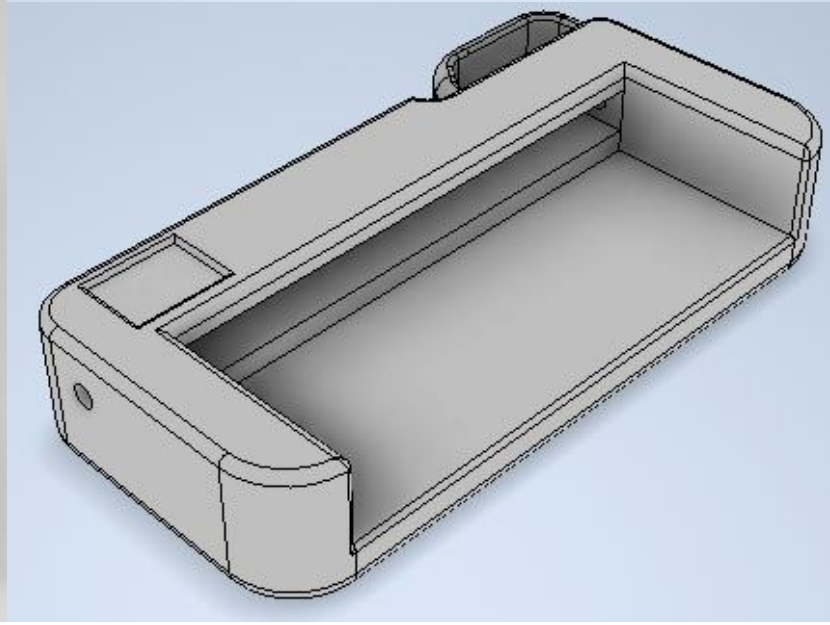
Initial CAD – Keyboard Body

While the initial cardboard model gave a good overview of the general shape, I needed greater precision, so I kept the same half-scale size and refined the measurements to rounded numbers. Using Autodesk Inventor, I created the design maintaining the smooth curves and lack of sharp edges. This also allowed me to start thinking how the keys—particularly the black sharps and white naturals—would interact and connect with the body."



Currently, my idea for connecting the keys is to use a rod running through the body, allowing the keys to connect or rest on it. This design would also make removal easier, as you would simply need to pull the rod out to remove all the keys. However, this could make assembly more difficult. For the initial concept, I plan to use wood, but in the future, I may switch to metal for better durability. As for the body itself, I will 3D print it.



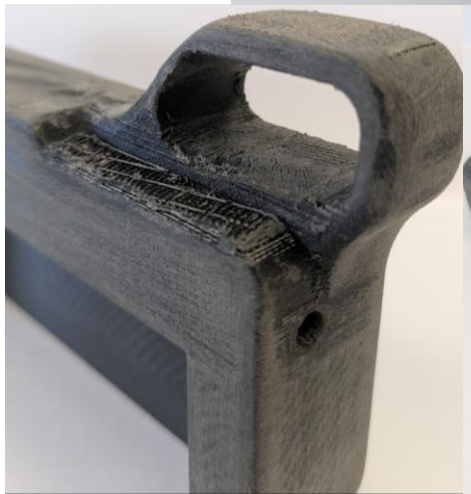


3D Print – Keyboard Body

To make the removal of support filament easier, I printed the model with the handle facing down towards the print bed. While this orientation required more support than others, it was much easier to remove because other orientations would have required support in the internal sections where the keys are located.

After printing, I noticed that some of the supports had fused to the main body, mainly on the top. To address this, I gently heated the model at the support areas, which allowed them to come off much more easily. Even though some supports had fused completely with the body, I was able to sand them down. I finished the process by wet sanding which gave a more smooth, clean finish.

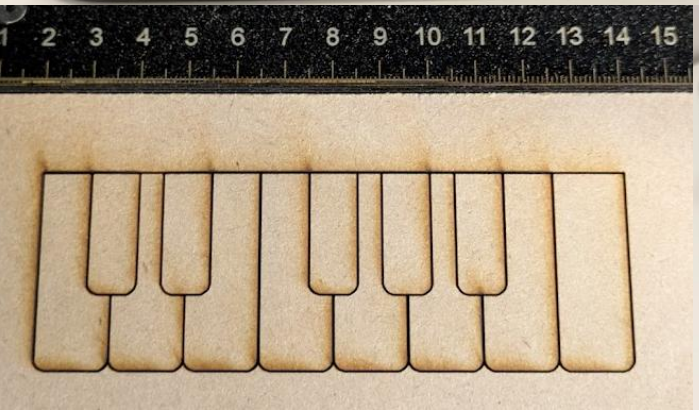
In future prints, I would split the body into two parts to remove the need for support. This would also make it easier to add space for electronics, providing better access during assembly. However, this would require me to find a method for joining the parts, possibly using screws or clips.

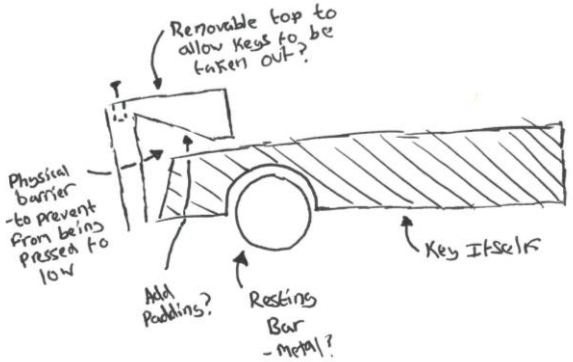


Connecting Keys to Body

Initially, my idea was to have a semi-circle indent on the bottom of the keys, which would allow them to rest on top of the bar, locked in by the body itself. While this concept had potential, I found that after printing, there wasn't enough space at the back for the keys to fit properly, as the rear section would hit the top. I also found manufacturing keys at such a scale proved more challenge than I had anticipated. So instead, I glued a piece of plastic tubing to the end of each key allowing them to move.

For the key themselves I used MDF as it was easy to laser cut and is cheaper which is essential at this prototyping stage. I also added vinyl on top of the keys allowing to me to see how visually appealing it was in real life as coloured keys originally were an idea in my initial concept.





Broken Keyboard Teardown

While talking to my Music Teacher about my product he made me aware that the department had some old electric keyboards which I could teardown and take apart. This allows me see how existing products are designed especially with the handling of the key mechanisms and reuse working parts from it.

The electronics only take a up a small amount of space within the main body with a majority being empty space. The main PCB is quite intricate with lots of traces. But the two secondary boards (beige coloured) are much simpler and very basic in comparison. This shows the shrinking the body while still containing similar components is possible and manageable especially since my keyboard won't have extra features such as a headphone jack

The product can operate using either battery or mains power, it requires six large batteries, which adds to its overall size. The keys are connected to the main board via a thick ribbon cable. For audio, two speakers are used for stereo sound—one for the left channel and one for the right. However, the large size and power of each speaker, would be excessive for my product, especially since kids are unlikely to notice the difference in stereo sound to mono. Mono would be enough, making a single speaker a better choice, reducing both size and power consumption.

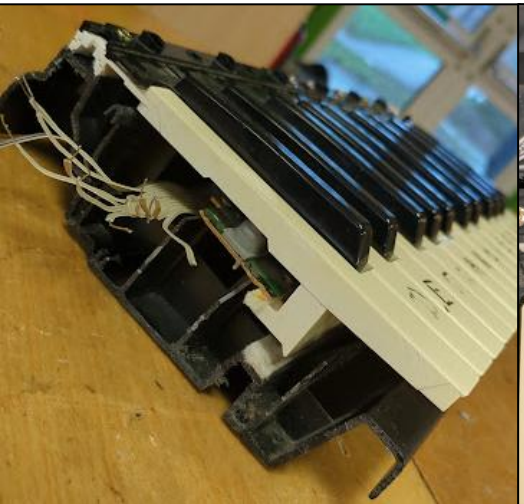
Broken Keyboard - Body Material Choice

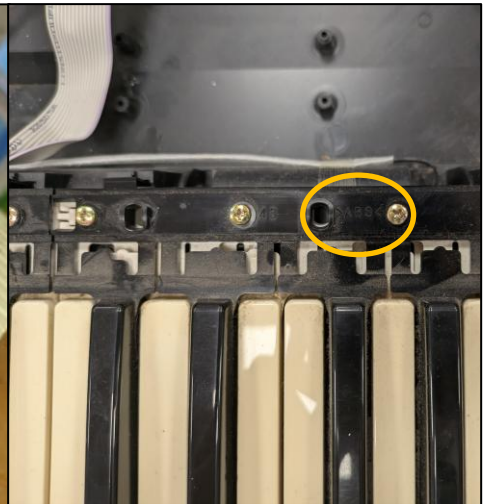
The main body of the product is constructed from Polystyrene (PS), a cheap plastic known for its affordability, which helps keep production costs low; It's easy to form and mould due to its relatively low melting point buts its not best material for outdoor environments due to it being a poor barrier against air and water vapor e.g. Rain, making it more suitable for indoor use. Due to the need in my specification for the product to perform well in both indoor and outdoor environments it may not be the best.

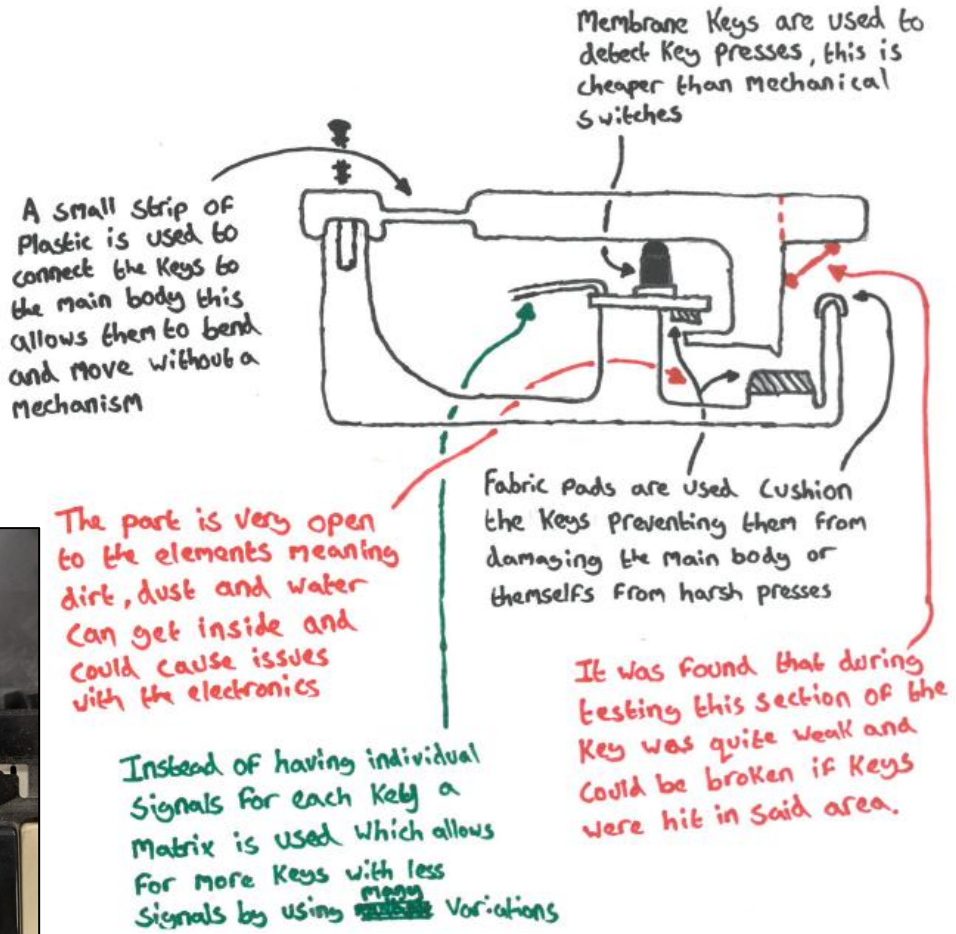
In terms of durability, PS is quite brittle, making the product likely to be broken, especially if handled roughly by children. The body is manufactured using injection moulding, as there is clear witness marks and sanded connecting joints. The exterior has a textured surface, which both improves the aesthetics but also provides a more secure, comfortable grip, making the product easier to handle and move around. Furthermore, the product had feet, which protrude slightly to prevent direct contact between the bottom of the product and the surface its on, reducing the risk of damage to body.

Broken Keyboard Teardown - Key Design

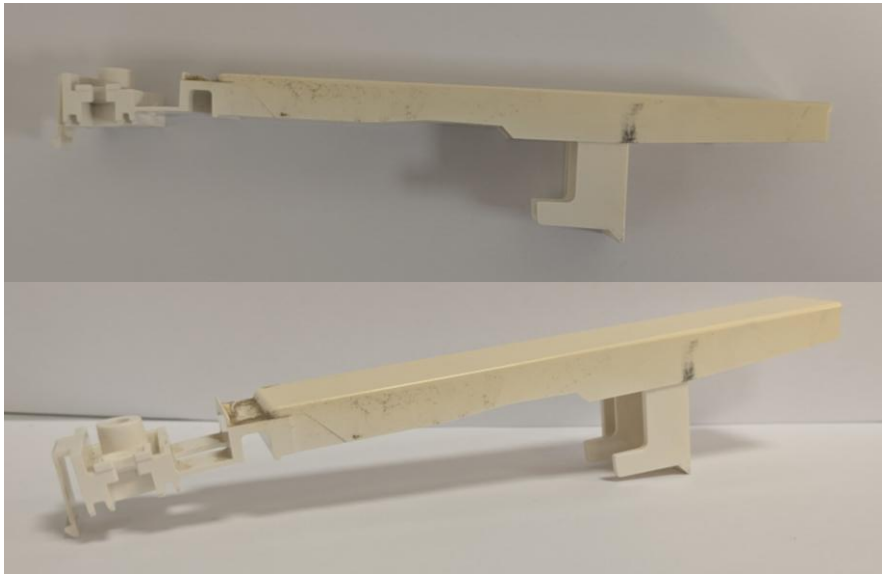
The keys themselves are made from Acrylonitrile butadiene styrene (ABS). It has high impact resistance, toughness and rigidity compared to other common plastics. This makes them good for handling with children due to its strength, it also could be suitable for the body material. Using the Yamahas key design as I base, I will now try to design my own one based off theirs, my main focus of improvement will be strengthen to the end of the key to prevent breakage.



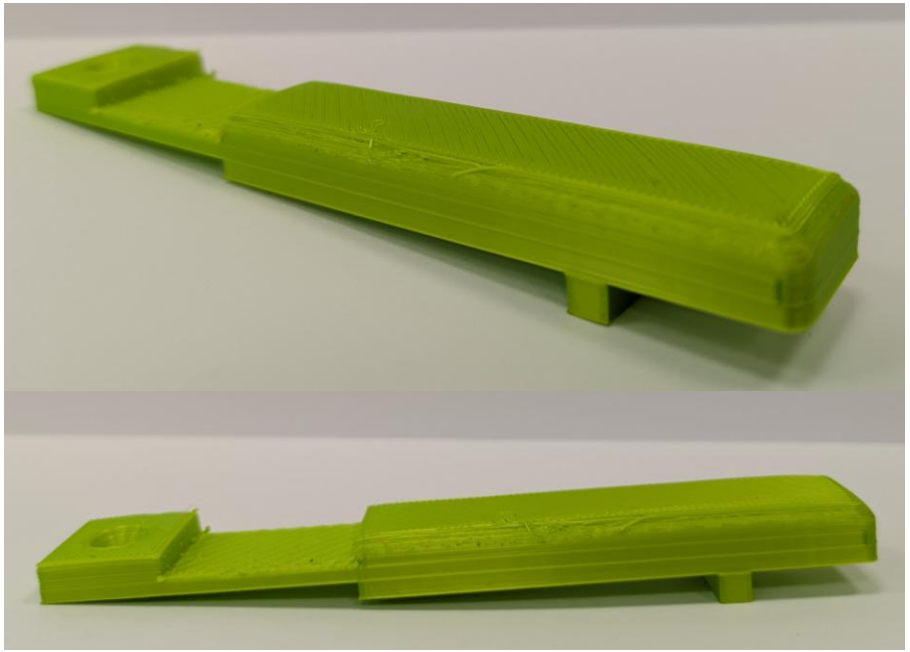




Key Design Iteration

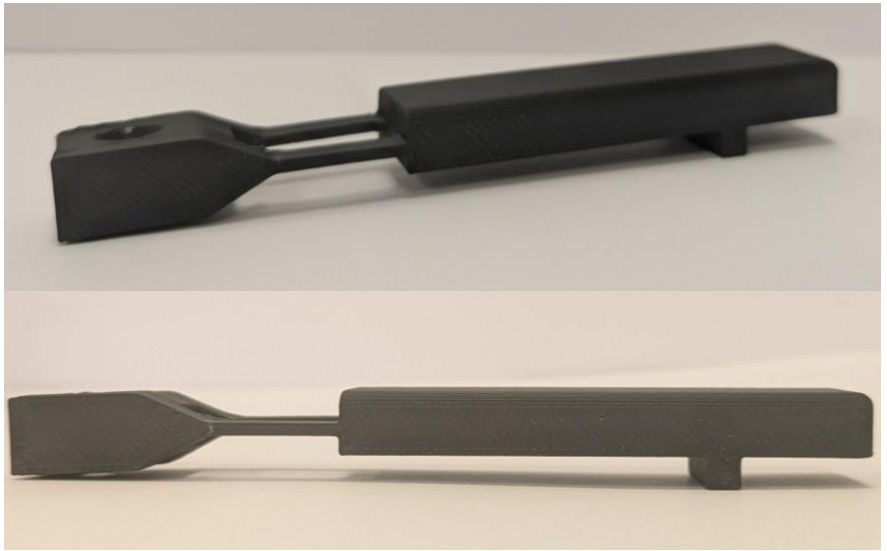


The original key uses a small strip of plastic to allow it to bend this works quite well and allows it to bend to around 70 degrees below its original height before the resting point starts to move. The bottom ridge which makes contact with the pads seems to be a weak point with the front of keys often breaking



My first revision made use of a small strip as well, but it was found to be too stiff to allow it to bend appropriately; In the next iteration I will make it thinner. However, the chamfered screw hole worked as expected, with the screw lying flush with the body. The bottom bump also seemed to create no structural issues, but this is likely due to it being 3D printed rather than injection moulded. I also had concerns that PLA might not be strong enough for long-term use, so I will try printing in ABS next time.

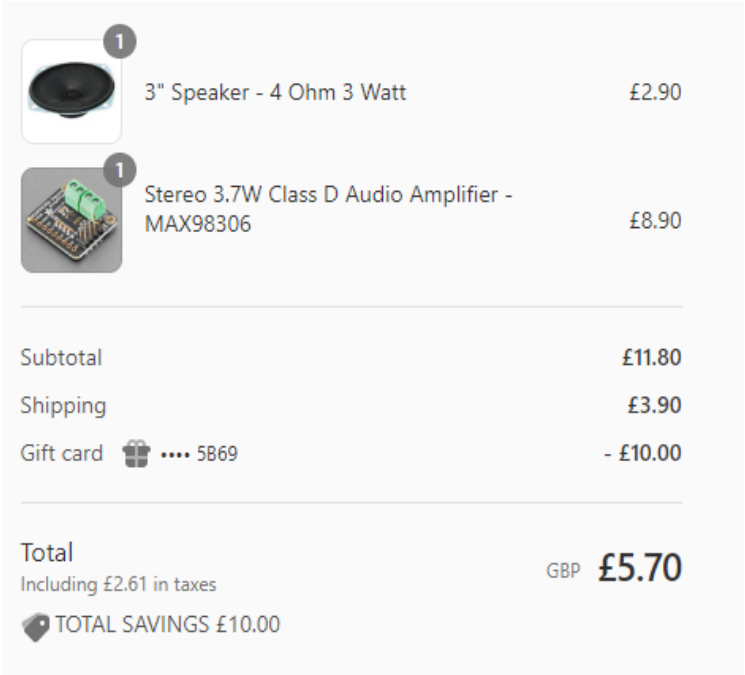
After thinning the connecting strip, I found that it was now too weak and would snap quite easily at the point where the back section connected to it. This issue occurred in both the PLA and ABS printed versions showing it to be a design issue rather than a material issue. In the next iteration, I plan to make the angle at the connection a smooth transition to evenly distribute the stress, rather than concentrating it at a single point.



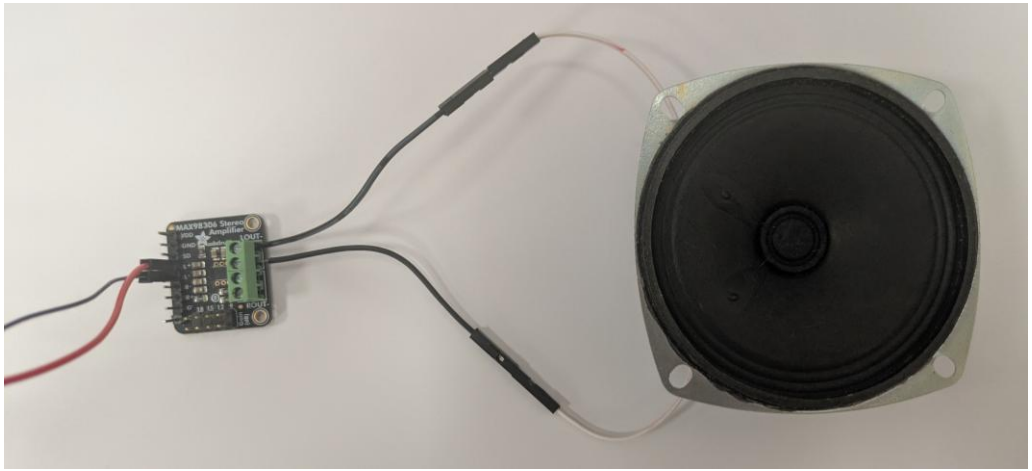
This final design addresses the previous issue of the force being concentrated at a single point, ensuring it is now evenly distributed during movement. I also got inspiration from the teardown of the key which seemed to improve flexibility by reducing the amount of material in the centre, while still maintaining structural rigidity. However, I still having some issues when printing in ABS where the it has not stuck to the hotbed causing it to warp slightly on the screw side. But this was resolved on my second print of it with a few printer setting changes.

Electronics Development

Currently on my current electronics proof of concept use a different frequency buzzes to show the different notes while this is functional the sounds themselves are not very appealing and don't sound like an actual piano. Also, when talking to my client the idea of learning elements such as the names of different colours and or animal sounds, this would require a higher quality speaker and amplifier for it.



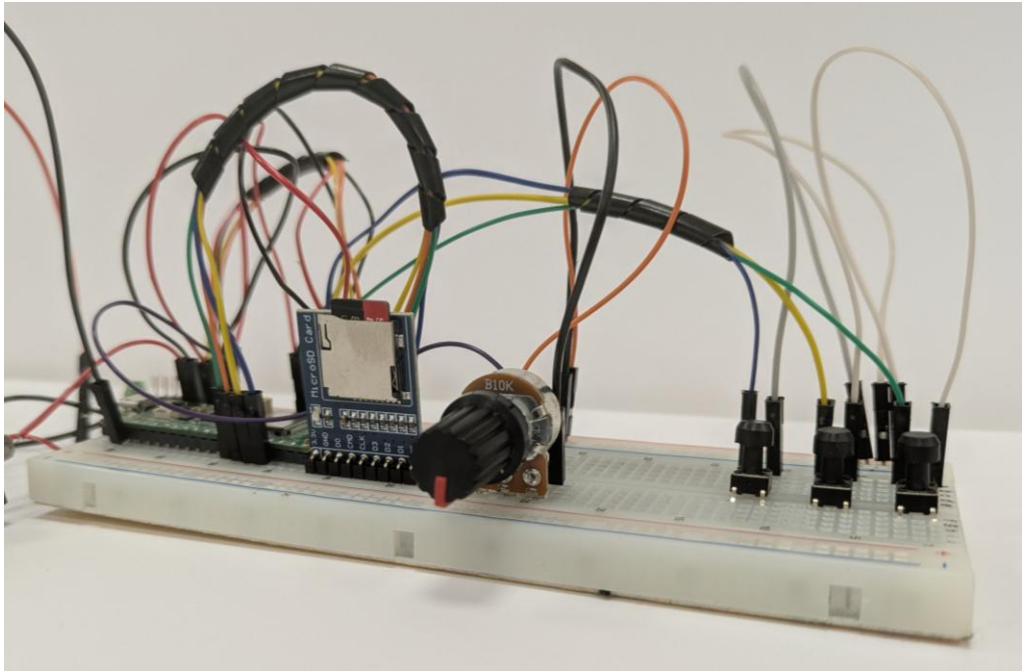
I found a suitable AMP and Speaker on an electronics website called 'PiHut'. The AMP itself is Class D which still uses PWM for signals so is of a lower quality but it small form factor and its good documentation made it a clear choice.



1	Full-Size Breadboard - White	£5.00
1	2 x AA Battery Holder with Premium Jumper Header Wires	£1.70
1	Premium Female/Male 'Extension' Jumper Wires - 20 x 6"	£1.70
1	Premium Male/Male Jumper Wires - 20 x 6" (150mm)	£1.70
1	Micro-SD Storage Board	£4.30

Subtotal	£14.40
Shipping	£3.90
Total Including £3.04 in taxes	GBP £18.30

After connecting the new speaker and AMP I found that I could not play any sound files as the micro controller has a limited amount of storage meaning the software only allows you to upload program files. However, the Raspberry Pi Pico has a library that allows you to connect Micro SD Cards. Allowing me to have a large database of sounds. And the ability to load new ones onto the drive by my mother or other nursery workers in the office.



From James Dillon <JamesDillon_@outlook.com>
Date Sat 11/01/2025 11:35
To mk@deltabeard.com <mk@deltabeard.com>

Hi Mahyar,

I hope this message finds you well.

I am currently working on a project to play WAV audio using a Raspberry Pi Pico. At the moment, I'm using a PWM pin connected to an amplifier, but I'm finding the audio quality isn't high quality enough for what I need.

After researching alternatives, I found that using an I2C or SPI DAC before the amplifier could improve the audio quality. During my research, I found your project on GitHub: MCP4725 WAV DAC.

I was wondering if you could share your experience with this project. Were you able to achieve sound playback with WAV files? If so, how would you describe the audio quality, and do you have any tips or for someone attempting a similar project?

Thank you for your time and any advice you can provide

Best regards,

James Dillon

From Mahyar <mk@deltabeard.com>
Date Mon 13/01/2025 11:19
To James Dillon <JamesDillon_@outlook.com>

Hi James,

Thank you for your interest in my project.
I think that the MCP4725 will be unsuitable for playing audio, despite the description of the project. As I last worked on that project about ~9 years ago, I cannot recall if I ever managed to get it to play any audio.

My suggestion is to use an audio codec chip or audio amplifier chip with integrated DAC. Examples include PCM5100A (e.g. Pimoroni Pico Audio Pack) and MAX98357, respectively. The MAX98357 is basic, and an example of its use can be found in https://github.com/YouMakeTech/Pico-GB/ which is a fork of one of my projects. I have used it and I think the audio quality was good, but I was playing Game Boy games and not proper music, so it isn't easy to compare the audio quality. The PCM5100A, at least on the Pico Audio Pack, seems to be headphone only as there is no integrated speaker amplifier. I have previously used the PCM5102 with headphones on a Raspberry Pi Zero, and the audio quality was excellent.

I have recently used the NAU88C22 which is very cheap, good quality, and includes both headphone and speaker amplifiers (with automatic switching between the two when headphones are inserted and removed), but there is a lack of open source libraries to get it to work, and you will need to make your own circuit as there are no breakout boards available for it.

I hope this helps! Good luck with your project.

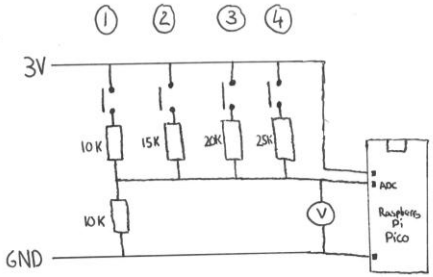
Kind regards,
Mahyar

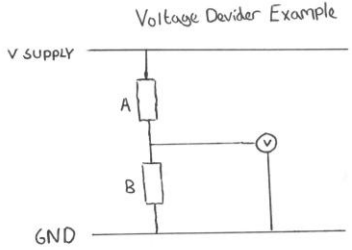
While I could store wav files, I found that the quality from the speaker wasn't enough for understandable speech or complicated noises. After speaking to the author of a similar project on GitHub he suggested using a different amplifier which had a built in DAC (Digital to Analogue converter) which would provide a crisper sound. It also uses I2C which is a communication protocol that is faster allowing for a higher bit rate also improving overall sound quality.

Mahyar Koshkouei

University of Warwick
Verified email at warwick.ac.uk

Lithium-ion Batteries Intelligent Vehicles Communication Systems
Computer Systems Engine…





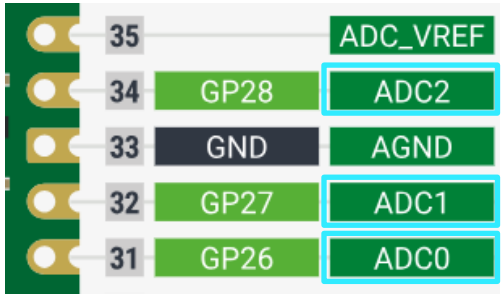
$$\frac{B}{A+B} \times V_{SUPPLY} = V_{OUTPUT}$$

① $\frac{10}{10+10} \times 3 = 1.5V$

② $\frac{15}{10+15} \times 3 = 1.8V$

③ $\frac{20}{10+20} \times 3 = 2V$

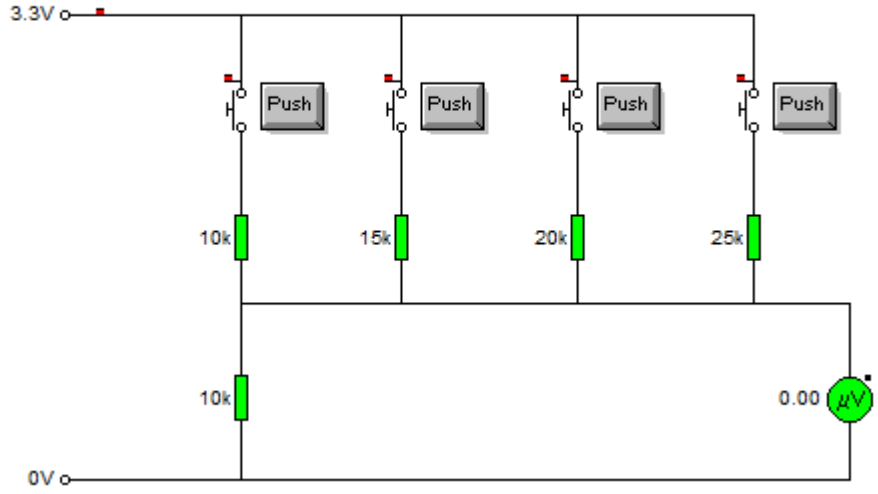
④ $\frac{25}{10+25} \times 3 = 2.14\sim V$



One potential issue I may have is that I might face is the difference in voltage between buttons is quite small only around 0.1-0.3V my controller may not have a high enough resolution to accurately detect these differences and background static and such might also cause the voltage to jump this amount. To avoid this in my physical prototype I would use different resistor values to have a greater change between each and or increase the voltage to 5V rather than 3.3V

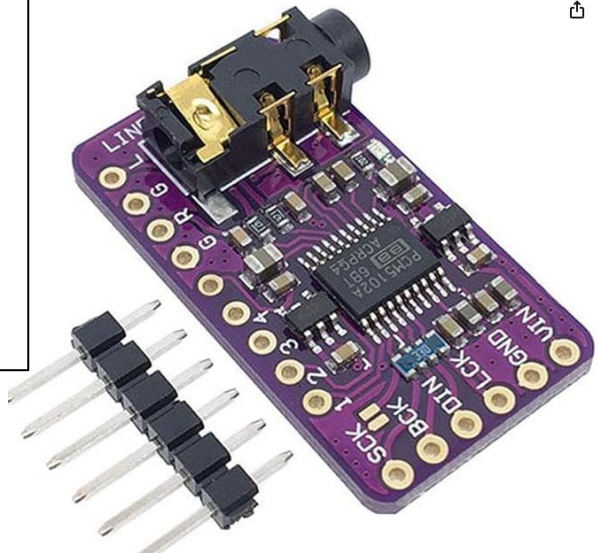
I have already added a few keys to my project however the microcontroller does not have enough inputs for me to directly connect each button. My teacher suggested using something called a voltage divider which would allow me to have a different voltage per button so they can be differentiated while only using one pin. Using an ADC (Analog Digital Converter) Pin on the controller I can measure the voltage

CAD Circuit Diagram



To integrate the chip with the audio chip, I had to replace its existing firmware (MicroPython) with a more advanced one called CircuitPython, which already included built-in libraries for audio. This switch allowed me to program the chip to play audio files. However, I had some issue when moving over.

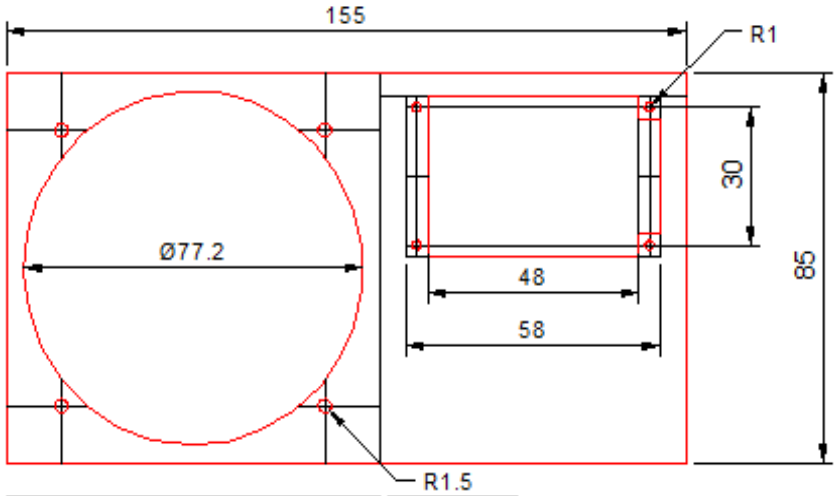
On the back of the board, I there're contact pads that control various settings, such as mute and audio smoothing. Initially, I didn't solder these pads, as I assumed they weren't required. However, the chip wouldn't work without them properly configured. After fixing this I also realized I mistakenly set the XSMT pad to low, thinking that the soft mute feature would help reduce static when no sound was playing. Annoyingly on my board, enabling soft mute effectively acted as a full mute, completely cutting off any audio output. I was unable to the setting to re-solder the pad to the high pad so instead I broke the connection pulled the debug pin to high which had the same effect but required me connect it to the microcontroller 3.3V line.



On the back (non-component side) there are 4 sets of 3 pads for the 4 functions:

1. FLT - Filter select : Normal latency (Low) / Low latency (High)
2. DEMP - De-emphasis control for 44.1kHz sampling rate: Off (Low) / On (High)
3. XSMT - Soft mute control(1): Soft mute (Low) / soft un-mute (High)
4. FMT - Audio format selection : I2S (Low) / Left justified (High)

Integrating Electronics into Body

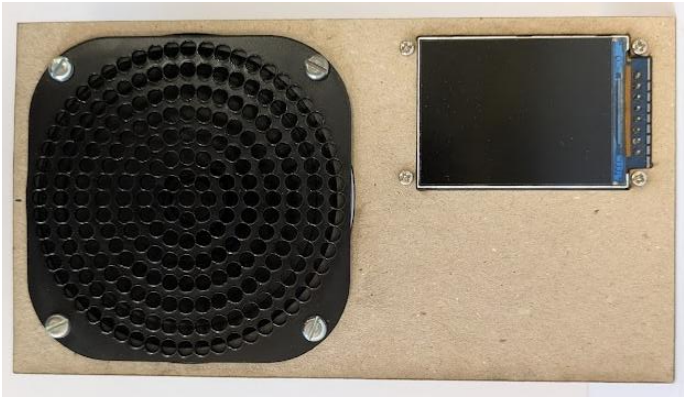


Now that all the components are working, I want to start integrating them into the body. I decided to start in 2D to get the dimensions of the parts correct, as laser cutting allowed me to rapidly prototype and make minor improvements with each design.

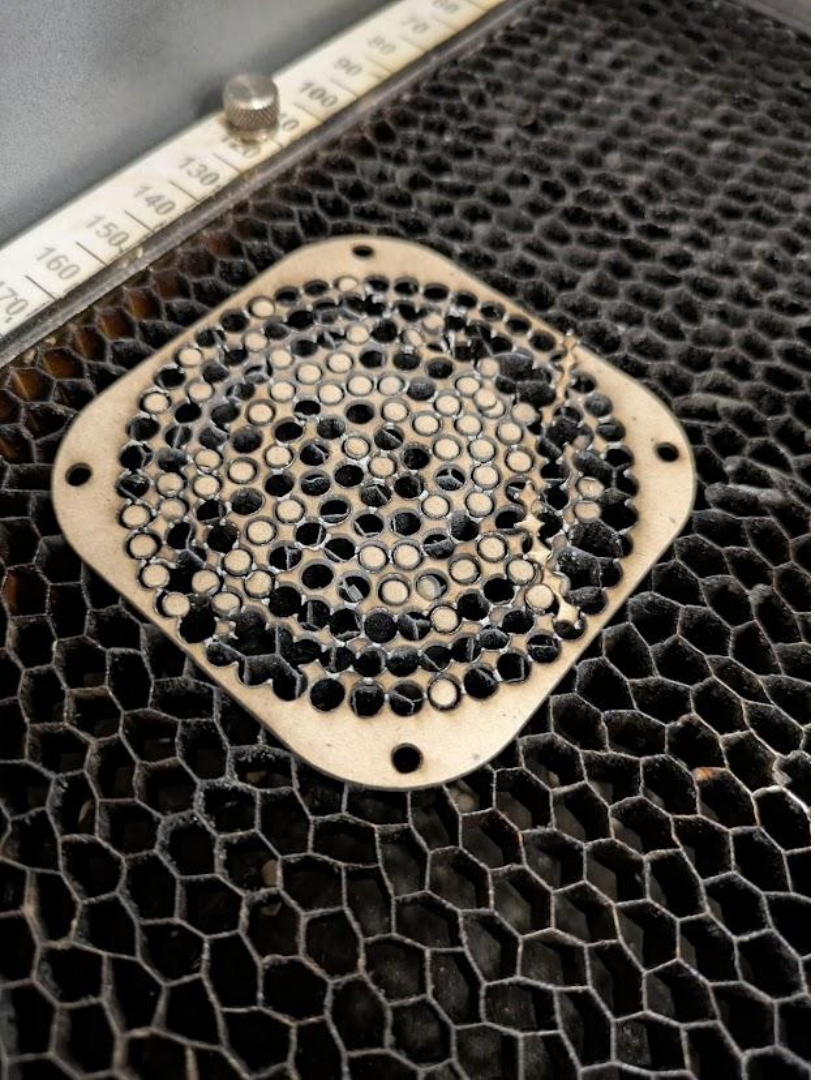
The main challenge was the speaker, as I couldn't find the dimensions of the screw brackets online. This meant I had to create several iterations before they fit correctly. I also wanted to start improving the speaker's aesthetics and durability, ensuring it's better protected, as that was part of my client's specifications.

For future iterations, I plan to add the navigation buttons, the volume knob, and possibly the power switch (however I might place it on the side). However, this will require me making the design in 3D CAD. I would also make the speaker grill slightly bigger as currently a small selection is outside.

Front



Back



To improve the aesthetics and durability of the speaker, I added a grill to the front. I initially laser cut the grill out of cardboard, but I found that the holes were too close together, causing the laser to burn the small sections holding them together, even on lower power settings. My teacher suggested using polystyrene sheets that we had in stock, which had a nice matte finish. After slightly shrinking the holes to increase the material between them, I found the result to be much better. The polystyrene has a low enough melting point to melt together any sections did separate.

For future iterations, I plan to add even more material between the holes to further strengthen the grill preventing it from being broken by children when they try pressing or touching it, as any broken parts could pose a safety risk; Especially the sharp connections between each hole which could cut them. The part is also designed to be replaceable meaning if it is damaged it can be replaced. It also allows for future customisation through custom designs on the speaker grill (possibly of a popular character) or different colour plastics

PCB Manufacturing

Currently my school has limited capabilities in making PCBs due to a lack of the chemicals on hand and a general age of equipment, so I looked into local companies who are able to manufacture them. I found one near me called ‘ABL Circuits’ I emailed their sales department as was emailed back by their Director. He recommended a company called ‘PCBWay’ as his company would not suit the single PCB prototypes needed as they are more of a batch production company. While I had heard of the company before his recommendation reassured me of it being the best choice.

JD

James Dillon

To: Will Leverett

Wed 13/11/2024 17:27

Hello Will,

Thank you for your quick response.

I am a student at The Knights Templar School, currently working on my GCSE in Product Design. As part of my project, I am planning to design a PCB, though I do not have a finalized design ready for manufacturing at this stage.

I wanted to inquire about your average costs for a small board with rough dimensions of 250mm x 50mm currently. If possible, I am interested in the feasibility of ordering in small batches, ideally one board at a time, though I understand this may not always be viable with standard production processes. With around 2-3 prototype designs/batches throughout the next 6 months

Thank you for any information you can provide.

Best regards,

James Dillon

WL

Will Leverett<will@ablcircuits.co.uk>

To: You

Thu 14/11/2024 10:

Hi James,

Thank you for reaching out. It’s great to hear you’re working on your GCSE in Product Design, I also did Product Design for my GCSEs! And I loved it.

I would suggest going to a company like PCBWay, https://www.pcbway.com/. They’re incredibly cheap and pretty good. We’re not quite setup for single PCB manufacture, so we would be very costly.

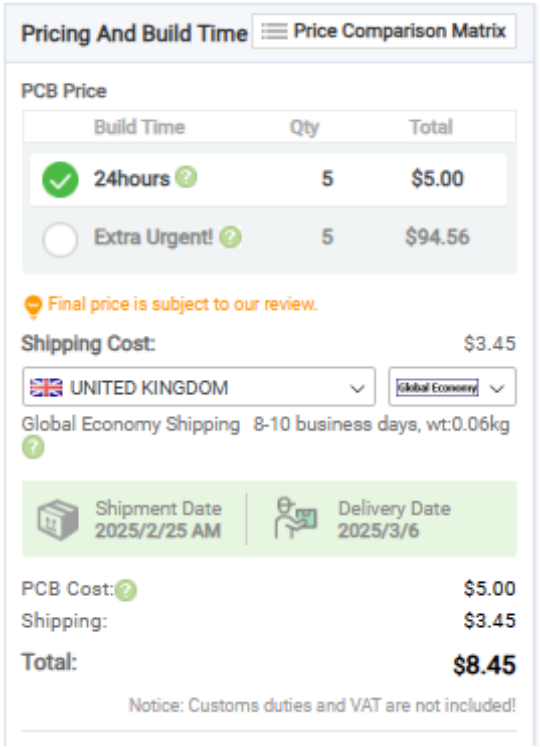
If you have any issues please let me know as I’ll be happy to help.

Kind regards,

Will Leverett

Director

ABL CIRCUITS



After using PCBWay's online calculator, I found that ordering a batch of five prototypes for a single circuit board design would cost £5. While this isn't too expensive (especially compared to other companies), I planned for my project to use up to three different circuit boards, which drastically increases the cost. Also, if I needed to make design changes, I would have to pay again for a new batch, along with separate shipping costs each time.

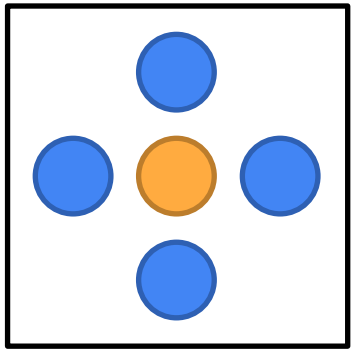
My teacher suggested an alternative called stripboard (also known as Veroboard), which is much cheaper. Stripboard is a type of prototyping board with a grid of holes and parallel copper strips running across it. By cutting strips and bridging strips, you can customize the circuit layout without needing a custom-printed PCB.

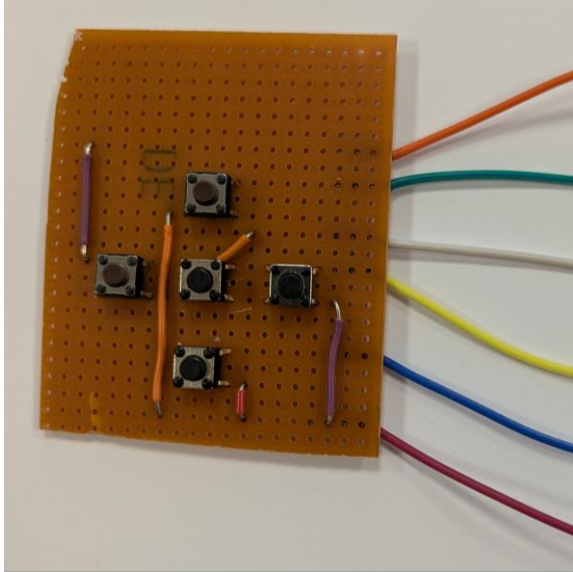
A couple sheets of stripboard cost around £5, making it a far more cheaper choice for rapid prototyping. It also allows for quick design changes however they are more breakable but due to their fixed positions on the design this shouldn't be a drastic issue. It also only allows for basic components which shouldn't be an issue as my boards will only contain basic parts such as buttons and resistors

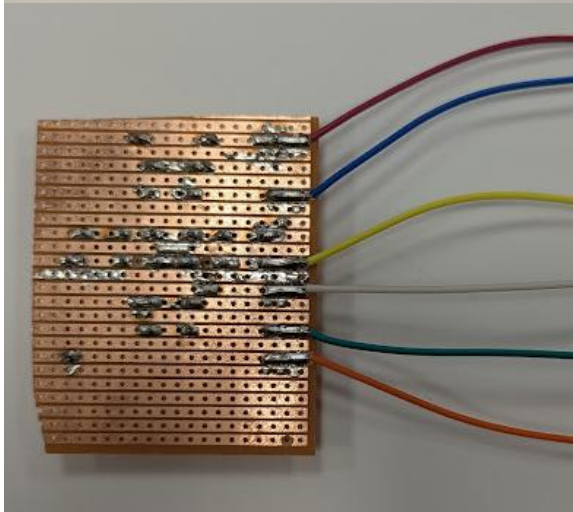
Navigation Pad

I need a way for children to easily interface with the screen to change modes. So I came up with the idea of using a game-style controller, inspired by the Sony Dual Shock, since children are likely already familiar with it through video games. Using stripboard, I was able to quickly make a prototype; The buttons are all connected to a common 3.3V wire, with individual wires for each switch output. Next, I plan to add screw holes so I can attach mounting brackets to the front.

Allows for easy selection between modes however selection might be unintuitive if you have to hold a certain button – possibly having a centre button for dedicated selection.



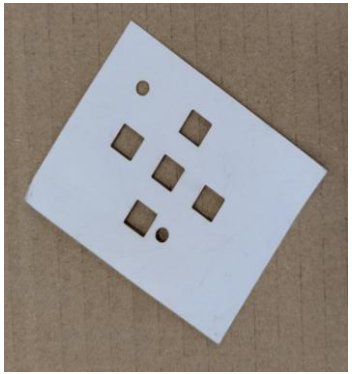




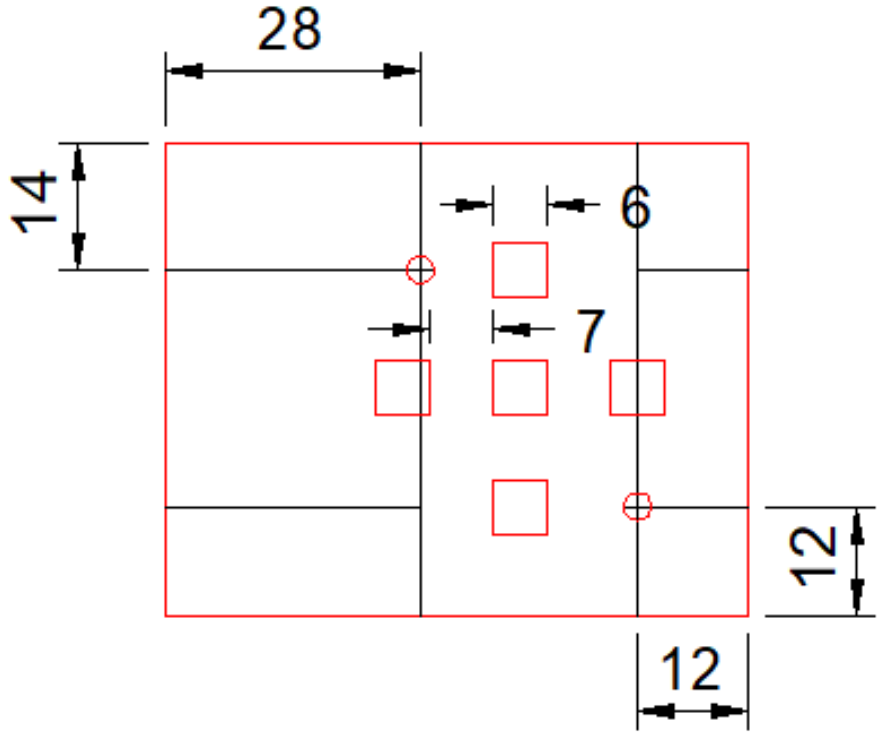
Connecting the Selection Pad

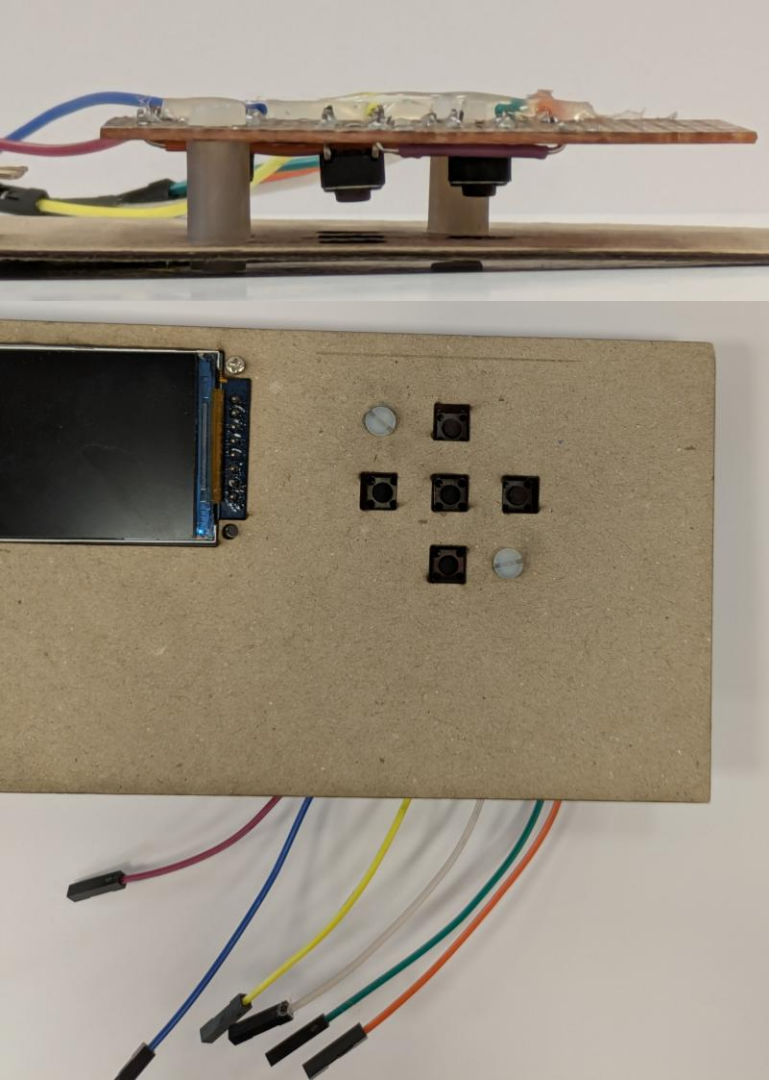
Now that I have the selection board, I began connecting it to the body. I started by measuring all the dimensions of my board using a calliper and sketching them out quickly by hand before moving over to 2D design. I then laser-cut the pieces, which allowed me to rapidly prototype. It took a few iterations to get the buttons aligned correctly with the holes.

One of the main challenges I faced was ensuring the wires were oriented in the correct direction, so they wouldn't face into the wall of the piano meaning they couldn’t be plugged in Next, I plan to integrate it with the other electronic components.

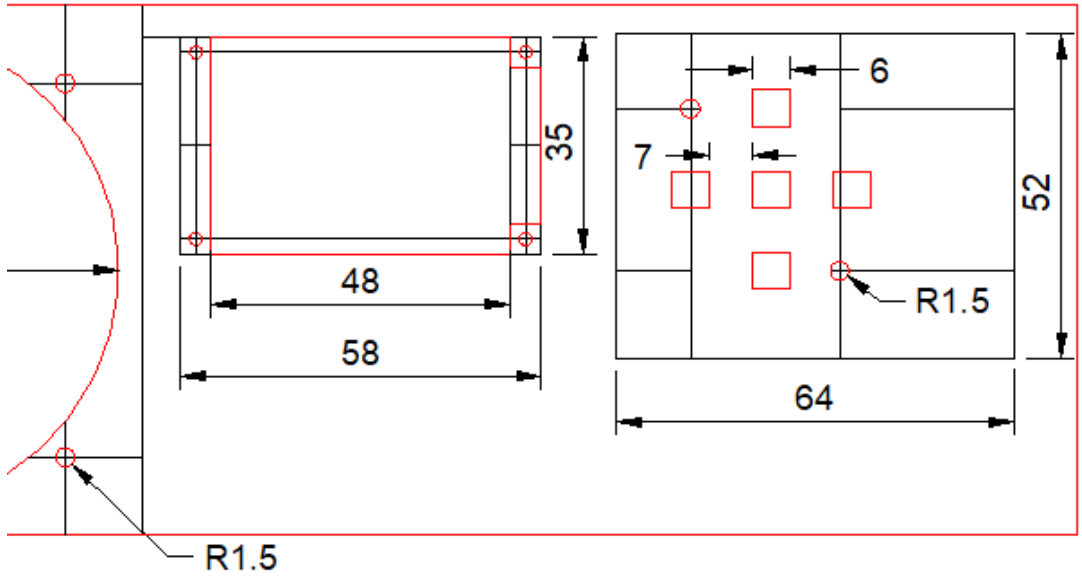


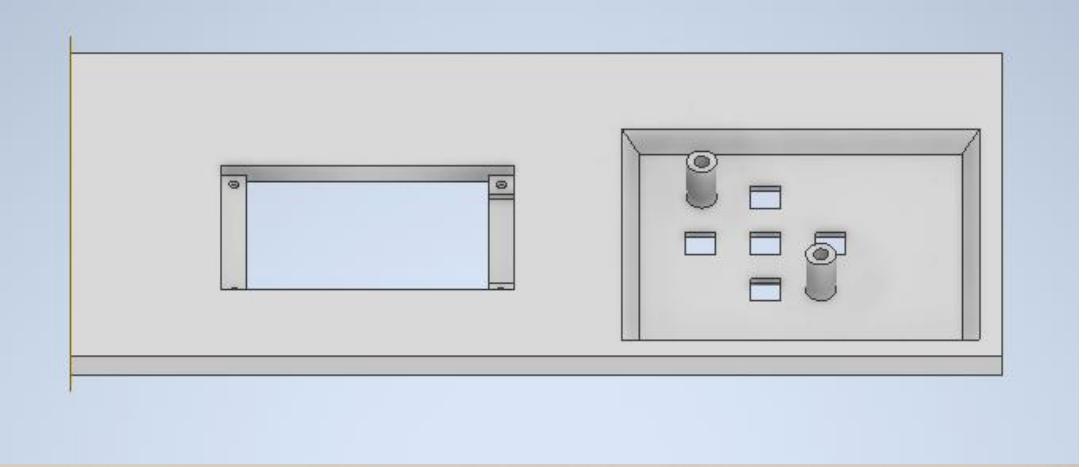
To the left is one of the paper test template that I placed on top of the button pad to test tolerances it took a few attempts to get the measurements exact. I initially printed it allowing me to place it over the board to check before then laser cutting another with the holes to let me see if the buttons fitted through correctly.

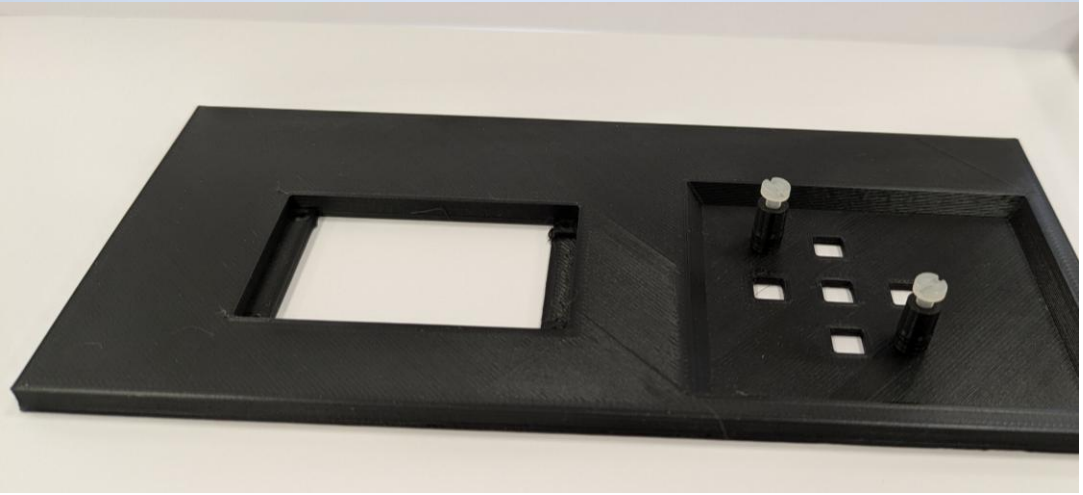




Integrating it was fairly simple, as it only involved copying the existing design from the other file and repositioning it. However, I found that the buttons not being aligned with the screen was visually unappealing, so I plan to change this in my next design. I also had to figure out how to raise the board, which led me to use screw spacers to create space for placing caps on the buttons. These caps increase the press area making it easier for a child and improve the visual look. Finally I used nylon screws to ensure the board wouldn't short circuit as metal screws would. short the tracks together.







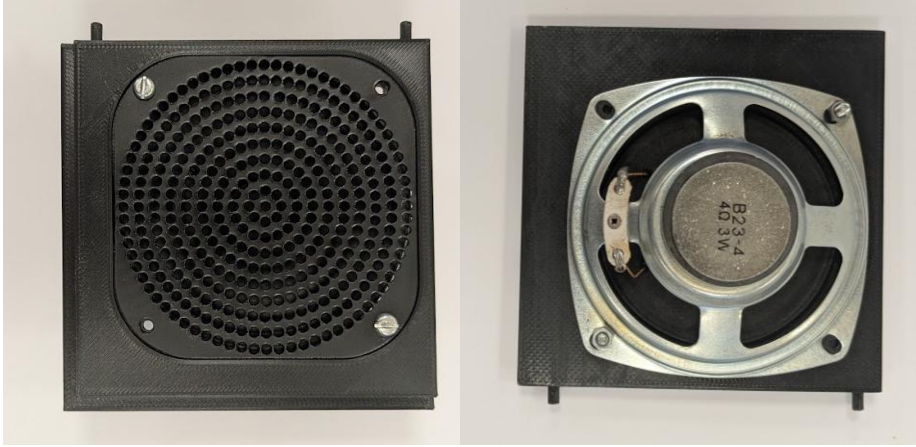
After moving over to 3D CAD, I aimed to make the best use of vertical space now that I have the extra dimension. Ways I did this included adding a cover over the solder connections on the display and indenting the selection pad board to take up less space. I also introduced curves to the holes for the buttons and screen, giving the design a smoother appearance. However, I had a few issues with my design:

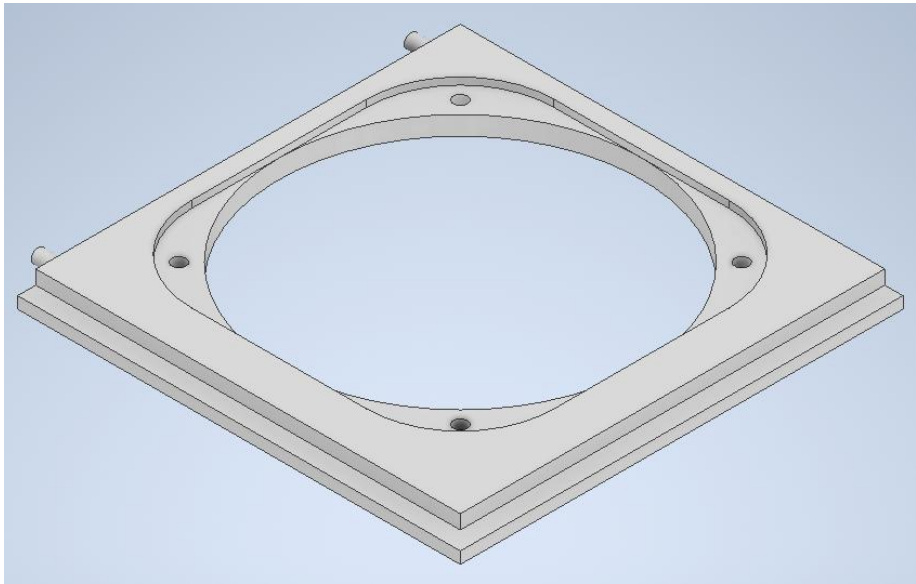
1) I mistakenly placed the risers on the wrong sides, which prevented me from screwing in the board.
2) I didn't realize that the tolerance for 3D printed parts is much higher, which caused the screen not to fit, even though the same dimensions had worked fine with the laser cutter
3) The curving of the edges wasn’t large enough to fit in the printer's resolution.

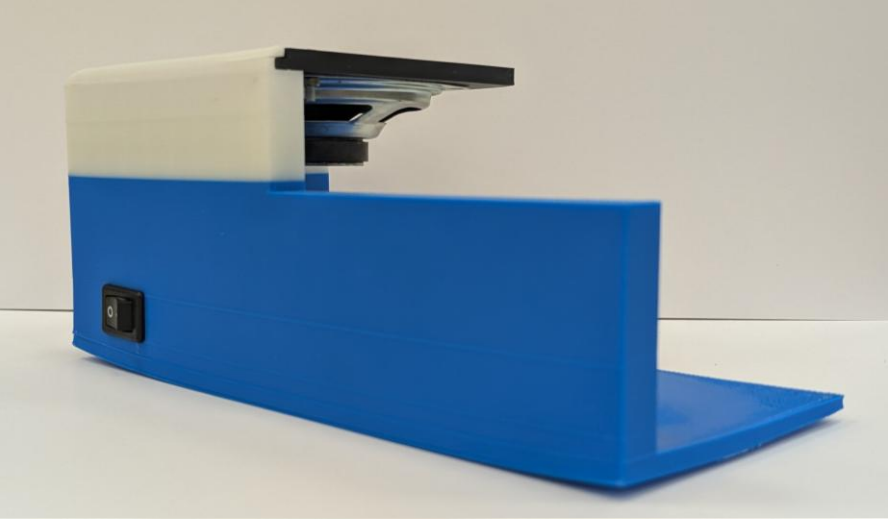
3D Printed Speaker Mount

This part has no major issues however I did add features that need to be included on the control panel as well. I added a rim around the part, allowing it to be slotted into the body, and I added pegs that will inset into the control panel, creating a strong, modular piece. This should effectively withstand hits from children while still allowing the piano to be disassembled if a key needs replacing or if the internals need to be accessed for another reason.

My client also mentioned that children often insert objects into toys, so making it easy to remove obstructions is a useful feature. The speaker grill is now indented into the design, giving it a clean look while also allowing the grill to be swapped out for different designs. In this prototype, I also laser cut the grill with smaller holes and wider spacing between them. It remains flexible while being more durable and resistant to breaking.







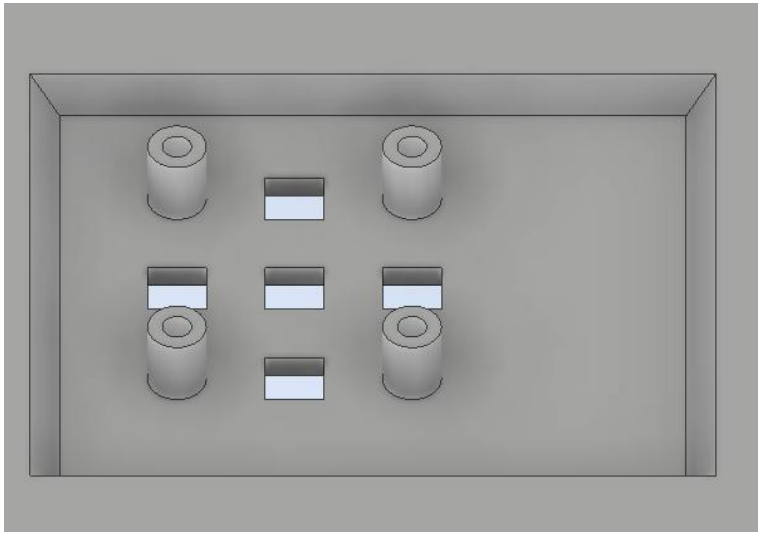
I originally wanted to print the body as a single piece; However, neither my printer or the school's had a large enough bed to accommodate it. So, using the *Split* function in Autodesk, I divided it into two separate parts, using pegs and holes to hold them together. There was some minor warping in the design, but with adjustments to its location on the hotbed should be able to minimize it.

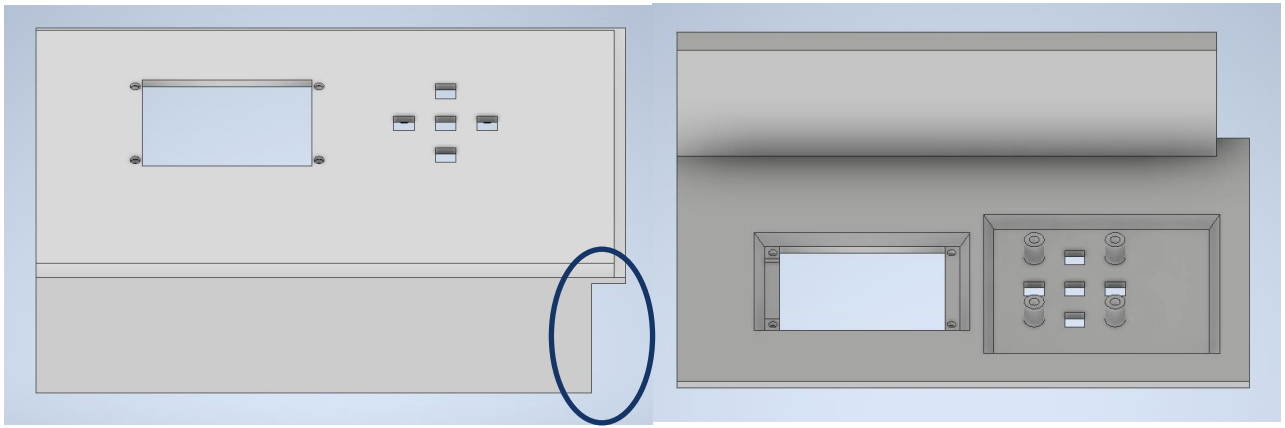
The speaker element slots into the top, but when removing the supports, I noticed minor cracking on the curved portion. In future iterations, I will add more material to reinforce this area. This section also houses the power button, which fits perfectly and feels very secure. However, for the final body, I plan to use hot glue to ensure it remains fully fixed.

When printing, the filament ran out halfway through, so I had to switch to a different color. This resulted in an interesting two-tone design. I could do this to future designs to give aesthetically pleasing look without affecting the structure by using separate parts.

While addressing the issue of the risers being on the wrong side, I decided that I would add one on all fours to make it stronger especially against heavy presses which may come from children

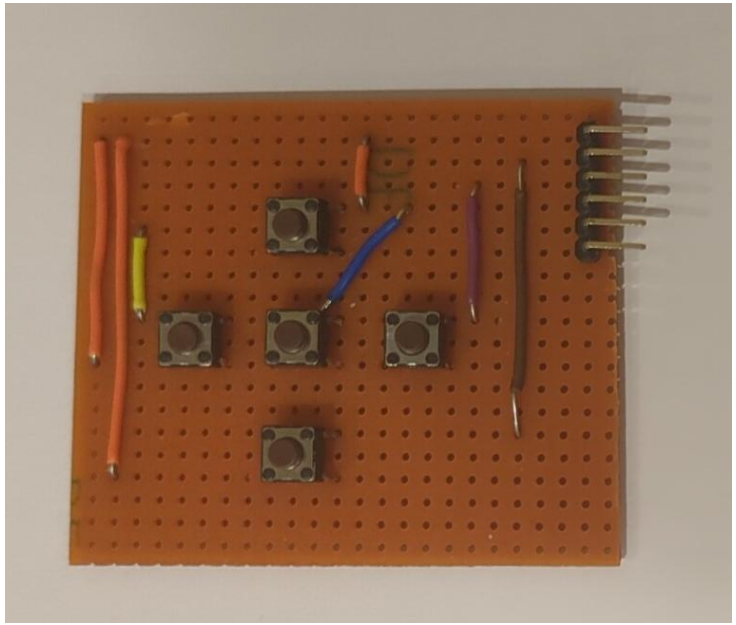
Then I added the rim and the holes for the pegs to insert to. I resized the screen allowing it have enough tolerance to fit. I also removed the curves round the screen element as it allows the screen to be flush with the body instead which looks more professional. Finally, I added a front panel section that blocks access to the electronic components giving a more atheistic look and protecting them

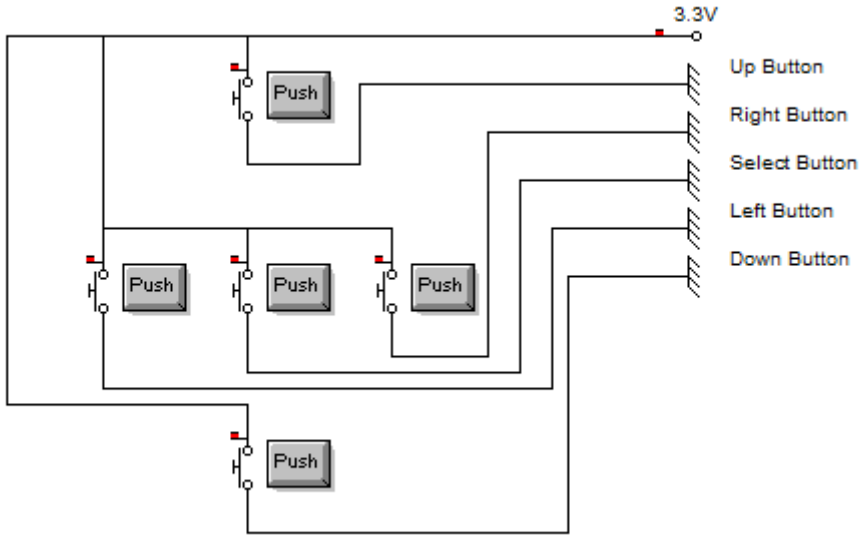


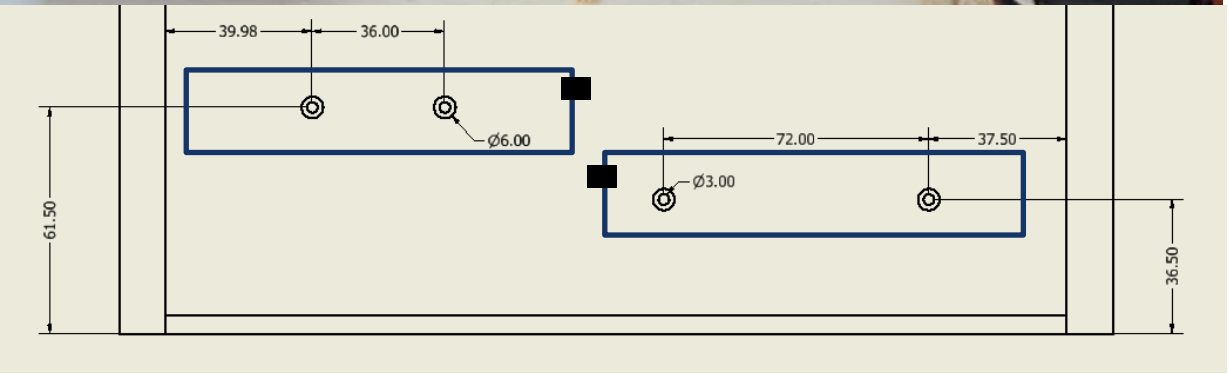


Initially I didn't add a cutout for the walls on each side of the body meaning I had to redesign it with a cut out portion before reprinting it

While the initial selector pad worked, it had a few issues. First, the jumper cables began to show weakness after being disconnected from the microcontroller multiple times. When I attempted to resolder them, part of the track lifted off the board. As a result, I decided to remake the board, this time using JIC connectors, like I had on the other boards, to make cable swapping much easier. I also grouped all the connectors together for better organization and color-coded the wires. However, the new design introduced some challenges when drilling the mounting holes.

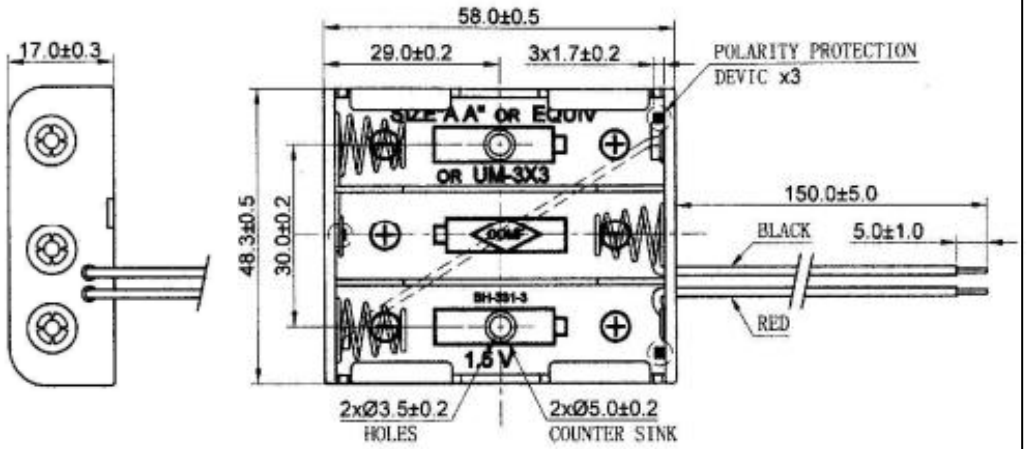






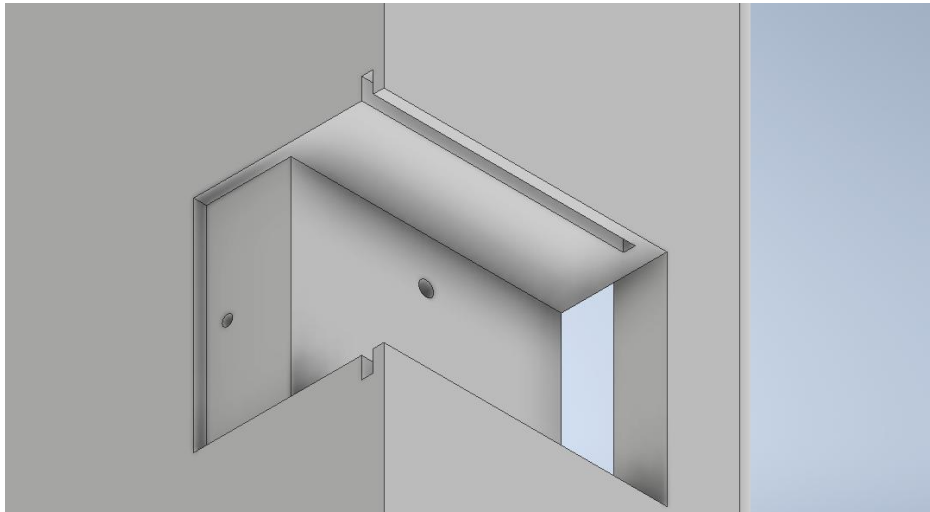
Connecting Key Buttons

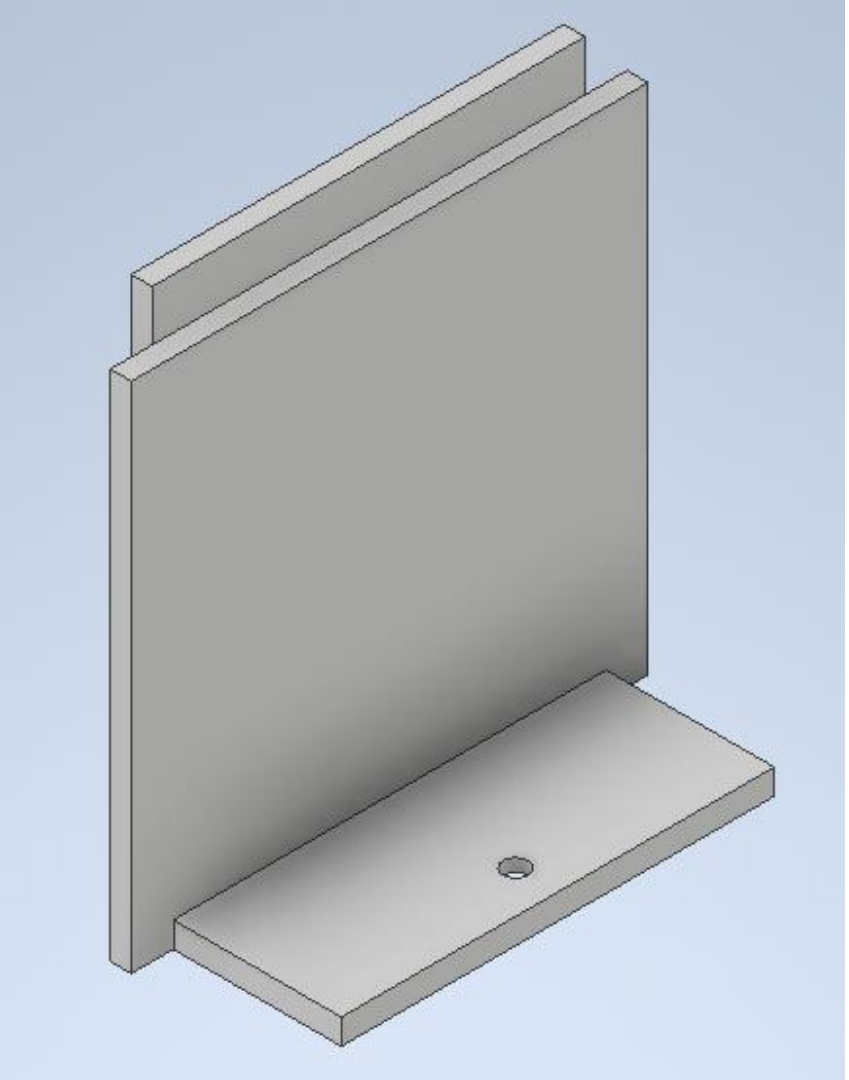
The buttons are split between two boards with three buttons on one and four on the other, this is because of the limited length of the stripboard. I used two individual resistor ladder for each board which connected to two different ADC signal pins. Two screws were used to mount each board keeping them secure however I did find that the ends did slightly bend with pressure. Due sticking out of the jumper cables I had to had to have each boards at different positions with one board further back and one further Infront.



The need to keep the piano plugged in limits its portability, making it less appealing to children who are always on the move. To address this, I using a standard 3xAA battery holder, which we already have in school for other projects. This setup provides 4.5V, which falls within the microcontroller's input range of 3.3V to 5V. The common battery type makes it easy to staff to find or buy spares and their large size compared to something like coin battery makes then less likely to be a choking hazard. If a child gained access

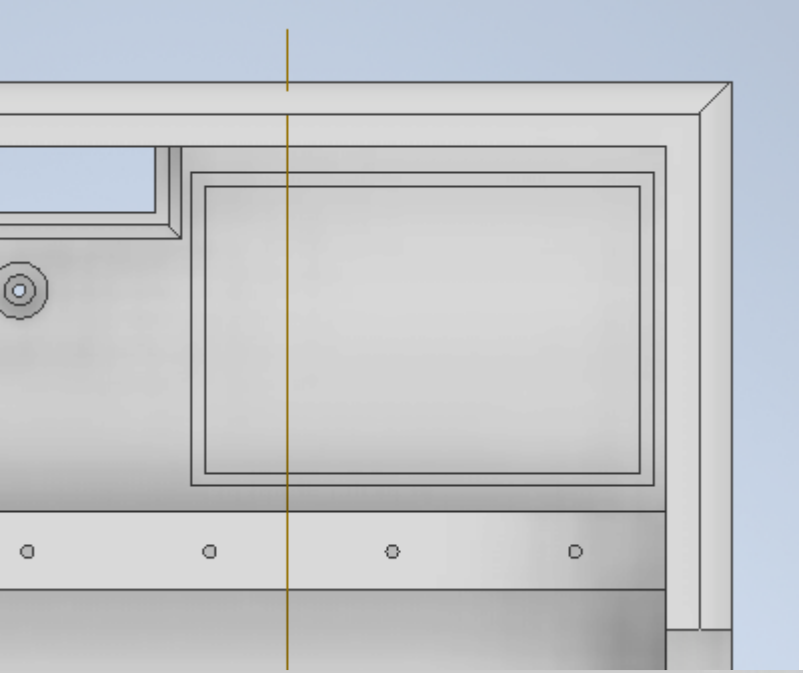
I decided to use a sliding cover with a single screw, making it easy for staff to access by only needing to unscrew one component. However, it remains secure enough that children won't accidentally open it while playing. The rails on both sides prevent it from being pried open and ensure its seamless with the body. The battery holder itself is secured to the body with two M3 screws, and it is surrounded by material on all sides. This design prevents access to the internal electronics, which could be damaged accidentally and provides a sturdy structure for it to be mounted too.





I tried to reduce the complexity of the battery cover so the tolerance with the body has a few points of failure one concern I did had was the button and its small area of collection with the vertical panel in the future I may add a chamfer to increase the surface area however I must make sure it doesn’t collide with the battery holder due the small gap between them. The screw hole is designed for an M3 screw which will be used to secure it to the body.

After printing and inserting it, I found that it got stuck halfway due to the tolerances not being large enough. I also miscalculated the bottom extrusion, causing the screw hole to not align properly with the one on the body. Once I redesigned it with the corrections and reprinted it, it fit perfectly.

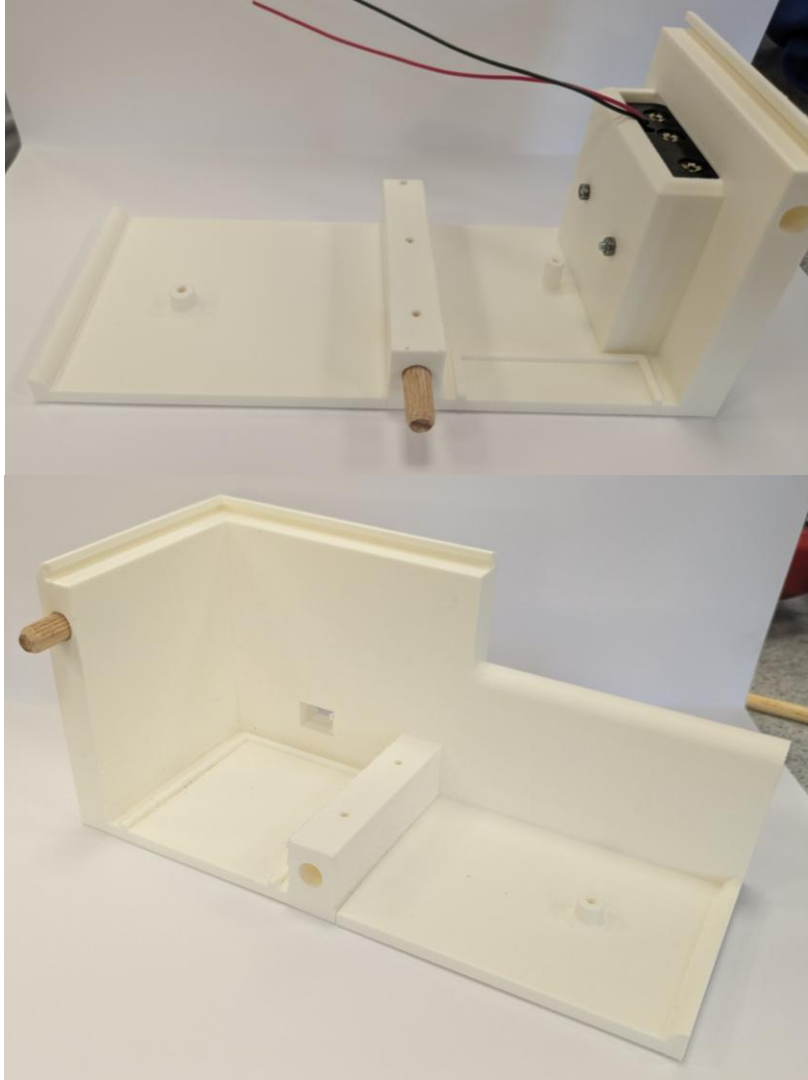


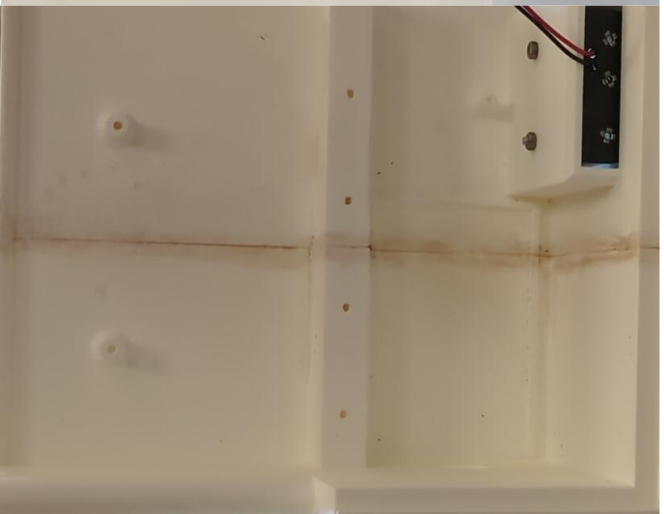
I added a small ridged area to securely hold the breadboard in place once stuck, preventing it from shifting over time. For the smaller boards, such as the DAC and AMP, I used double-sided tape, allowing for easy repositioning when managing cables. I also included a small hole on the side of the body to allow the inserting of a micro-USB cable, allowing reprogramming of the microcontroller and providing an option for wall power if the nursery prefers a more permanent setup. However, due to the thickness of the body, inserting the cable requires some hand-eye coordination. Since this isn't something, they'll need to do frequently, it should be manageable. In future iterations, I could chamfer the hole to make insertion easier.

Originally, I planned to use two sections of wooden dowel that would pass through all three segments and be secured with hot glue. However, I found that the diameter of the hole varied too much due to inaccuracies with the 3D printer, which made it difficult for the 8mm dowel to fit properly.

Going down to a smaller size of 6mm was too small and didn't provide a close enough fit. Instead, I decided to use mini pieces of 8mm dowel, commonly found in furniture like IKEA items; Using a reamer to clear wholes enough to hold them securely. Instead of hot glue I used plastic solvent to bond the pieces together, using the dowels only for structural support. After fitting the pieces together with the dowels and applying the solvent between the cracks, I was able to create a strong connection. I then sanded the joints and applied more solvent, using the plastic dust to further fuse the pieces together.

The solvent is supposed to be clear however due to rust in the canister is had a strong brown tint this gave a unappealing look however after sanding it was barely noticeable especially since I only added solvent on the inside of the body leading the exterior to be mark less.

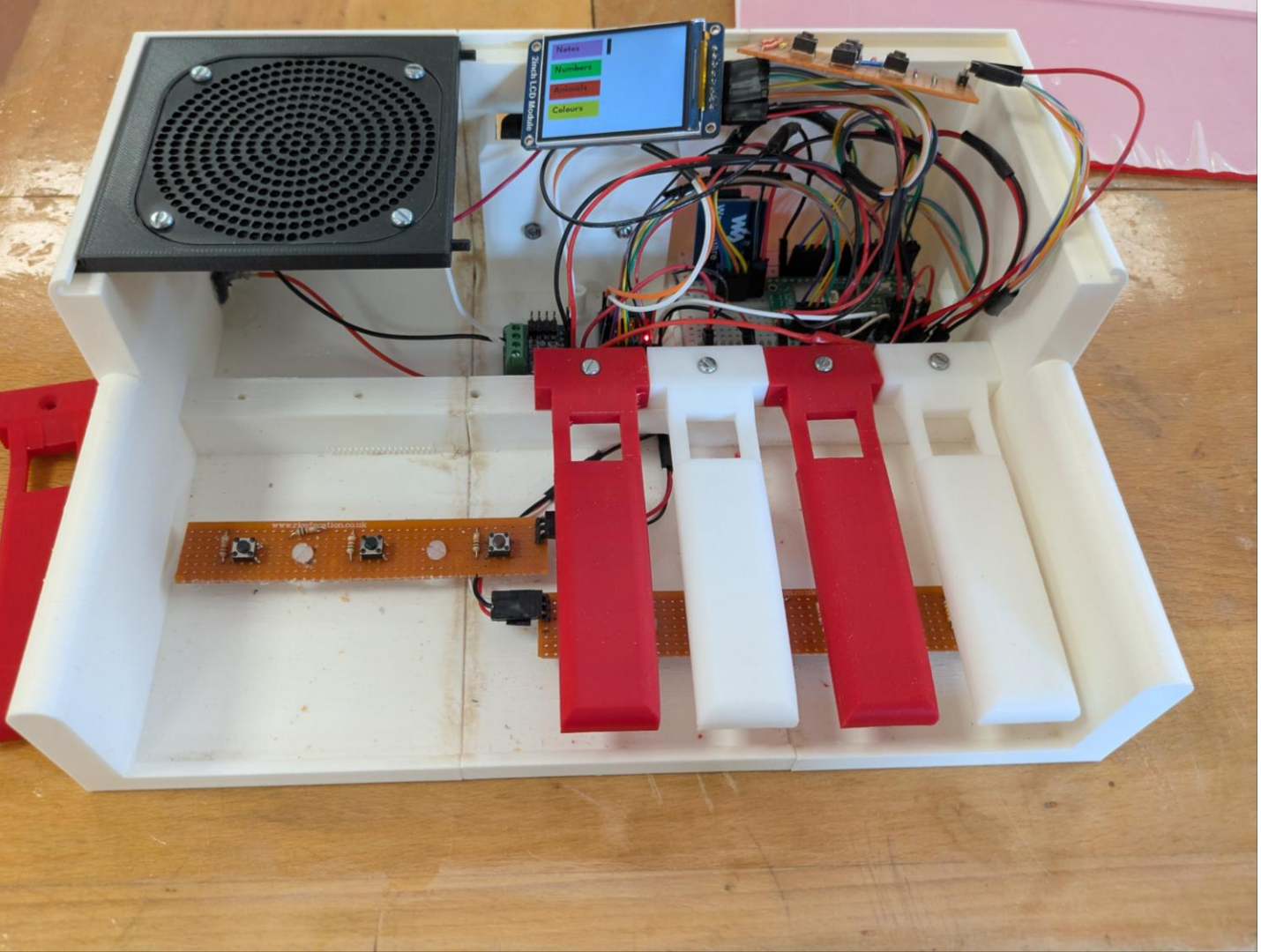




Testing fused plastic durability

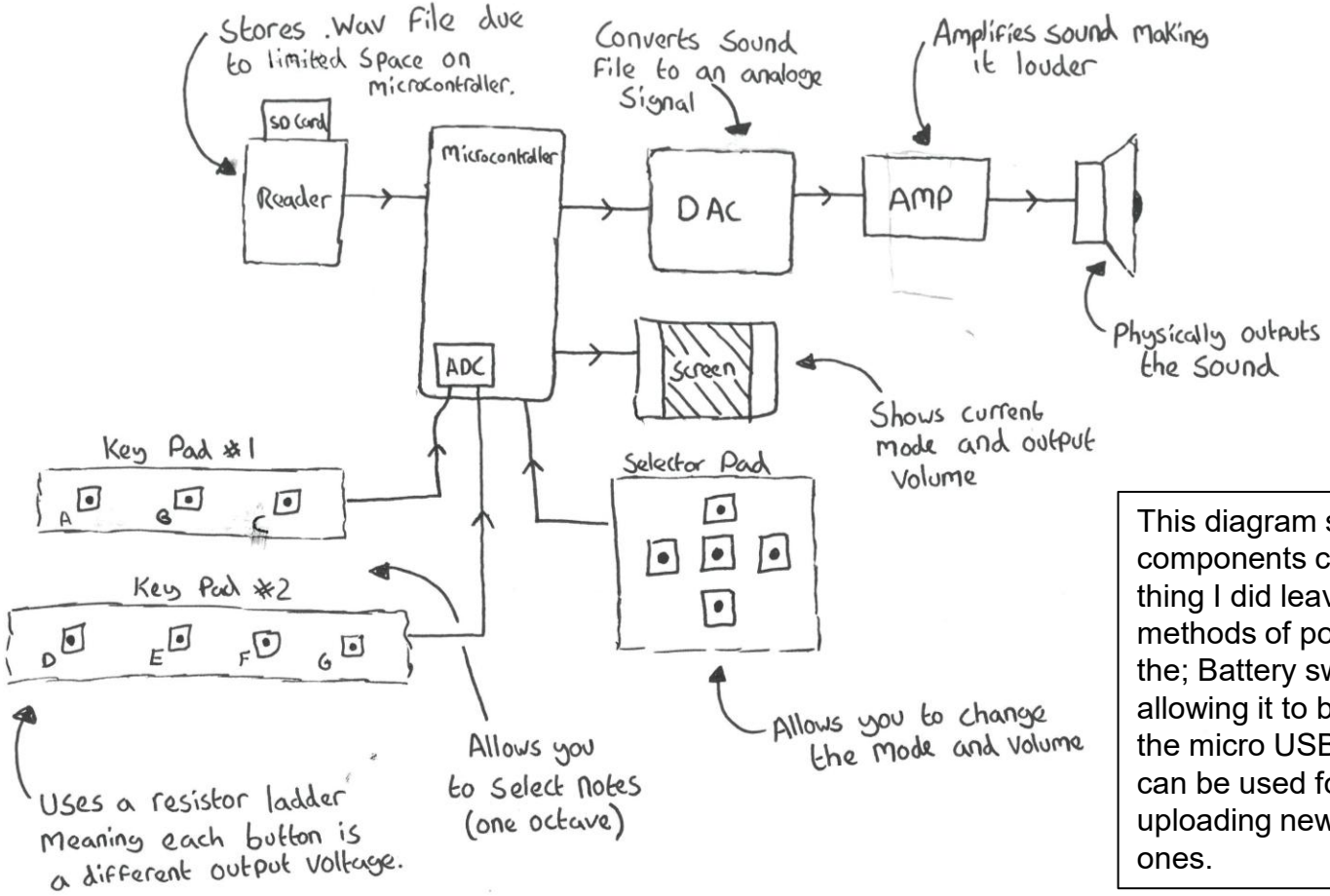
Before using solvent on the final parts, I tested its ability to fuse with the plastic using older prototype body components. I applied several layers of solvent, only on the inside, and found that it held together remarkably well. This was quite impressive since there was no dowel was used. During a bend test, I was able to put a significant amount of force on the joint before it work. The fused area had a slightly rubbery quality, allowing it to bend considerably before giving way. In contrast, the plastic of the body itself was a lot more rigid. This could be due to not enough drying time.

After examining the broken pieces, I could see where the solvent had seeped through the cracks and where it had not. I found that areas without masking tape held together better. This may be because there wasn't a large enough gap for the solvent to seep through and properly fuse the pieces.



This was the first time I put all the electronics into the body, and overall, it went well. All the parts fit, with the only issue being that the key stripboards required slightly larger screw holes. While not all the keys have been added yet, and the control panel hasn't been fitted, the wires were long enough to allow me to slide the part off without disconnecting any cables from the breadboard.

Mini Piano – Electrical Diagram (13/03/25)

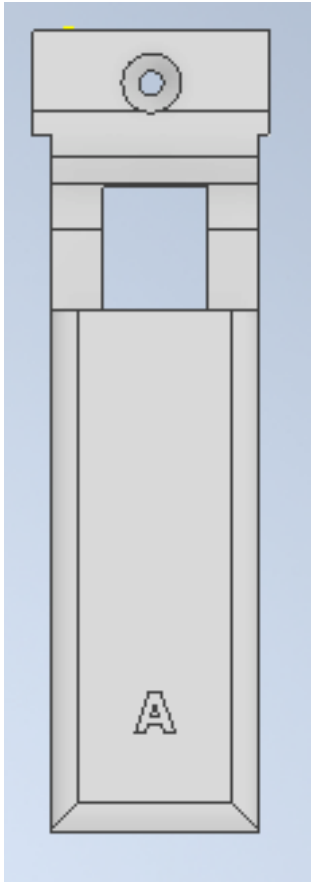


This diagram shows all the different electronic components connected to the board. One thing I did leave out, however, is the two methods of powering the board either using the; Battery switch, which has a rocker switch allowing it to be turned on and off, or through the micro USB port on the controller, which can be used for both powering the board and uploading new programs or editing current ones.

Early Feedback and Improvements

As my final product nears completion, I decided to show it to a few friends who are music students. They provided the following feedback:

- The gap between the control panel and the keys is still wide enough to allow fingers to slip in. It would be better to lower it slightly to prevent this and improve ergonomics.
- Adding some form of visual indication of the note on each key would be a helpful feature
- The keys could be made slightly wider, and the gap between them reduced. This would provide more space for pressing the keys, especially since actual piano keys are placed very close together, with barely any gaps. It would also reduce the visibility of the board underneath, improving aesthetics.

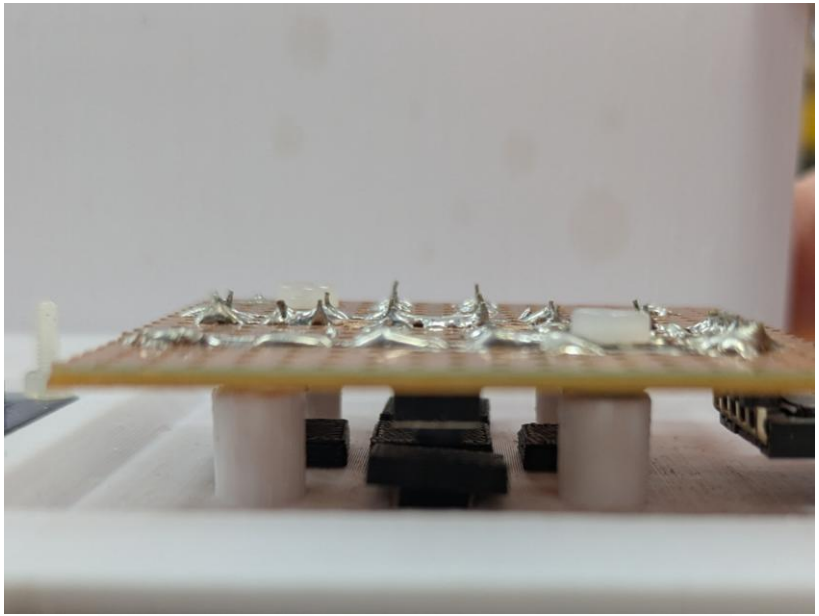


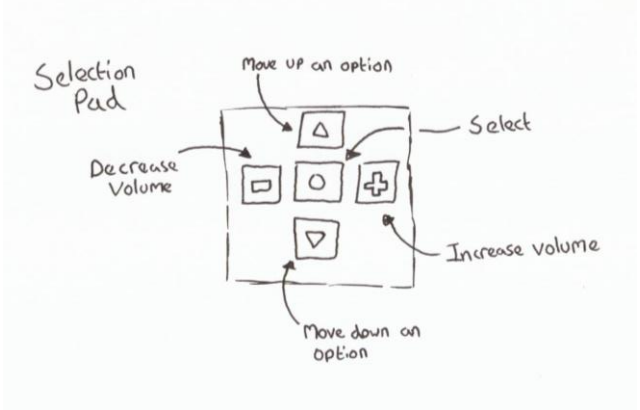
The new key design now includes an indented letter at the bottom, allowing the user to easily identify which note they are pressing; The key width has also been increased to 30mm from the previous 25mm.

The control panel and speaker grill now are also extruded lower meaning you cant easily access the electronics as the gap is much smaller

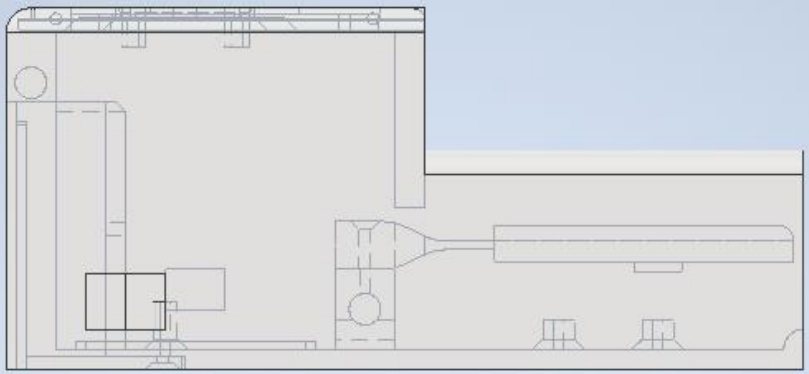
Now that I have the selection pad, I need to add keys so they can be pressed, as I'm currently using a screwdriver. However, I need to make sure that the keys don't fall out and are easily identifiable to their function. I used ridges on the bottom to keep them secure, and I included small extruded icons to indicate the function of each button e.g. Select, Volume Up, Volume Down

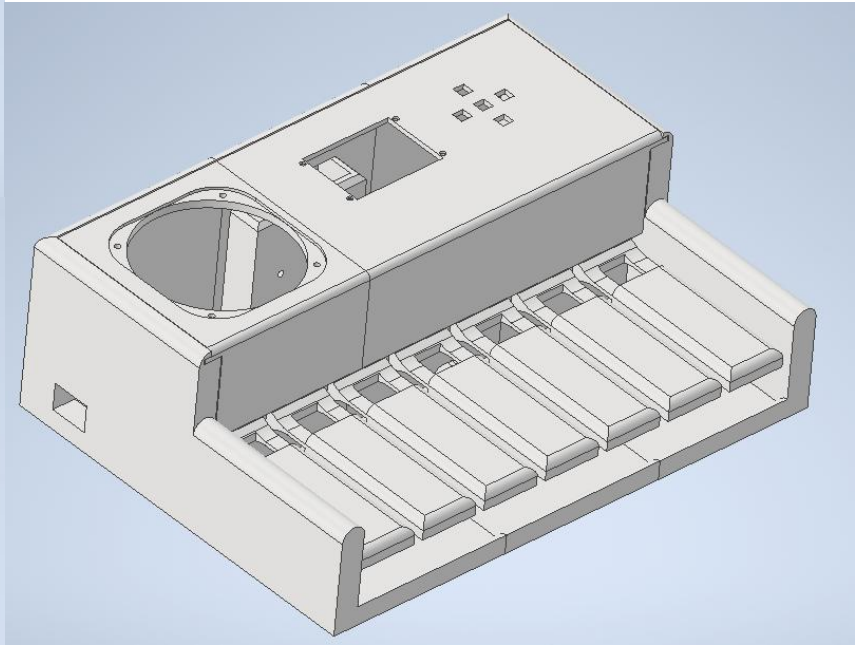
To make sure they can be pressed without grinding against the body, I had to make sure there was enough tolerance with the buttonholes. I also had to make sure the bottom ridge is not too large, so the buttons aren't permanently pressed down. I made this mistake in my original design, but I corrected it by adding one bolt to each screw to slightly lower the buttons and the board, fixing the issue.



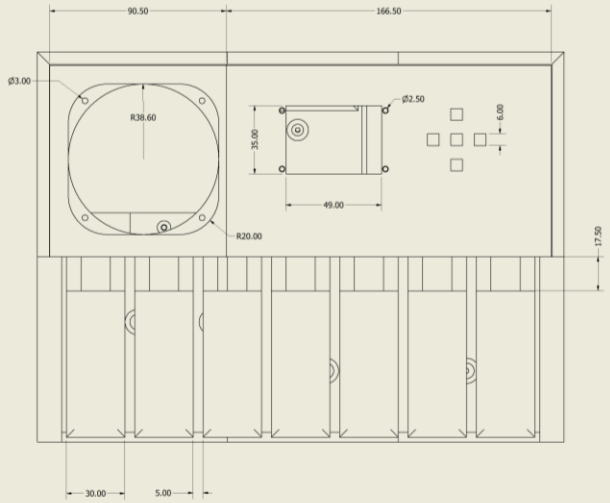


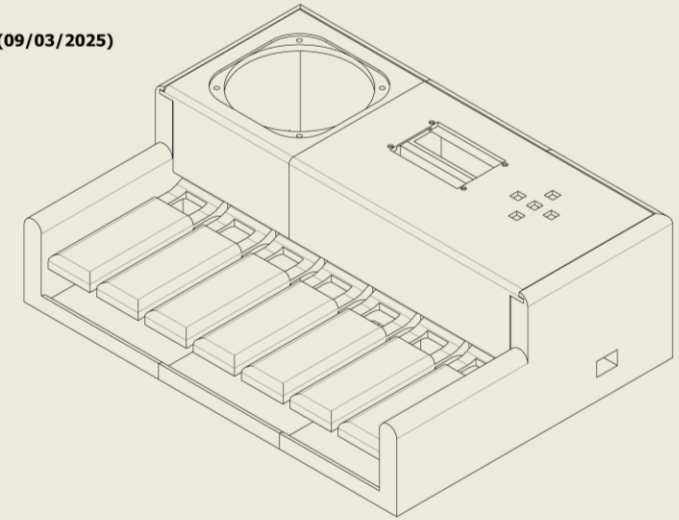
In Inventor I put all the parts into an assembly allowing me to check the control panel and the keys fit correctly into the body; The lack of electronics was due to me individually testing each component. I used the assembly to then create an autographic drawing which showed the overall dimensions of the product when put together, along with some individual measurements of single parts. All parts fit together in the assembly without an issue however 3D printing inaccuracies could still mean some sanding it required even with tolerance already added to both the keys and control panel



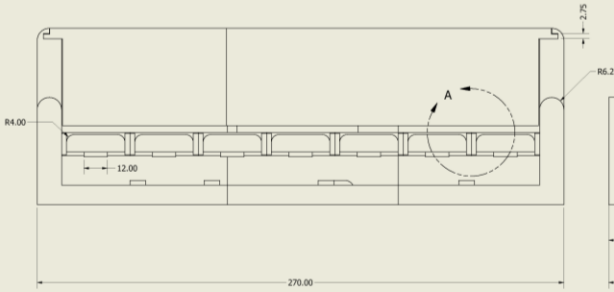


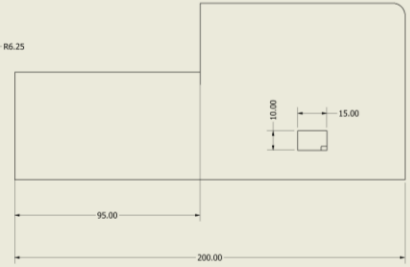
Mini Toy Piano - James Dillon (09/03/2025)

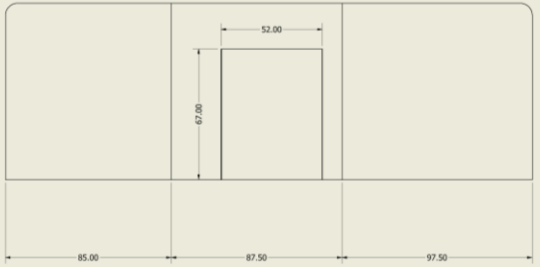




DETAIL A
SCALE 2 : 1

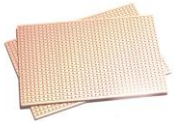






Electronics Parts List

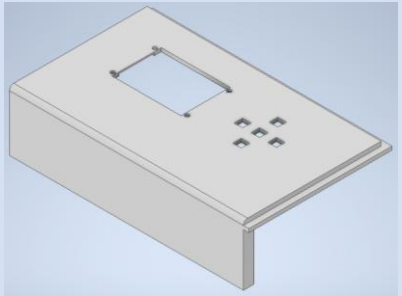
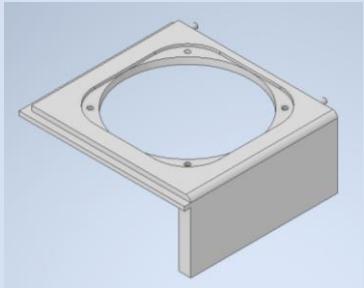
Item	Cost	Quantity	Description
 Waveshare 2 Inch LCD Module	£11.99 (Waveshare)	1	Used for displaying different modes and volume
 Raspberry Pi Pico W	£5.80 (PiHut)	1	The brain of the board controls all the electronics
 Half Sized Breadboard	£1.53 (Switch Electronics)	1	Used to connect all the components to the microcontroller.
 3xAA Battery Holder	£1.07 (RS)	1	Provides power to the controller so it doesn't need to be plugged in
 Rectangle On/Off Rocker Switch	£0.19 (Amazon)	1	Used to control whether the pianos electronics are on or off
 Tactile Switch	£3.48 **£0.29 each** (Mouser)	12	Used to detect presses below the piano keys and for the selector pad.

 Fixed Value Resistor	£0.56 **£0.08 each** (Mouser)	9	Used in the voltage divider for the piano keys
 3” Speaker – 4Ohm 3Watt	£1.90 (DigiKey UK)	1	Outputs the sound.
 Class D Audio Amplifier - MAX98306	£8.90 (PiHut)	1	Used to amplify the sound wave from the DAC to increase its volume before it enters the speaker.
 PCM5102 I2S – DAC	£2.79 (Amazon)	1	Decodes the sound file and plays it.
 Vero Strip Boards (2 boards)	£3.99 **£1.99 each** (Amazon)	2	Used to connect the button control panels together for both the selector pad and piano keys

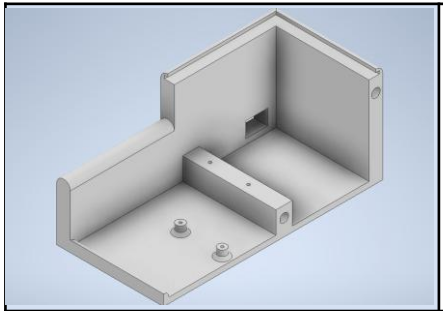
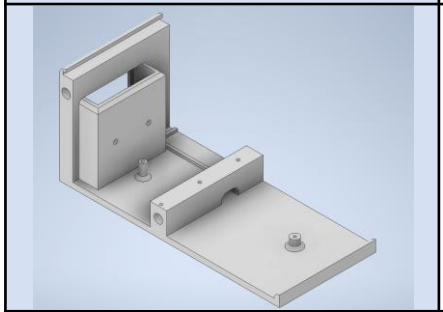
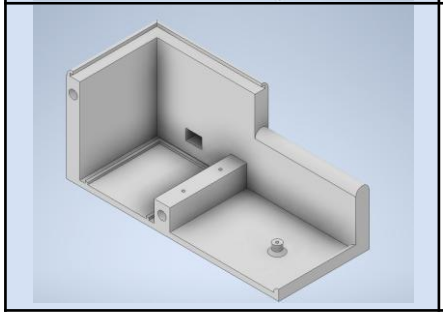
 Jumper Cables (20 pack)	£3.40 **£1.70 each** (PiHut)	2	Used to connect different electronic components together.
 Waveshare Micro SD Card Reader	$3.99 (Waveshare)	1	Used to connect the SD Card to the microcontroller
 8GB Micro SD Card	£2.50 (eBay)	1	
Total	**£52.09**	N/A	

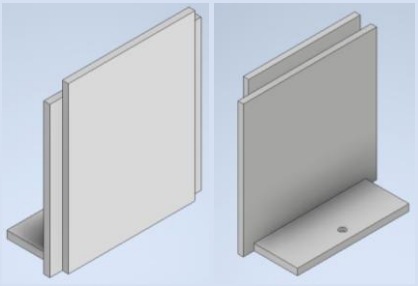
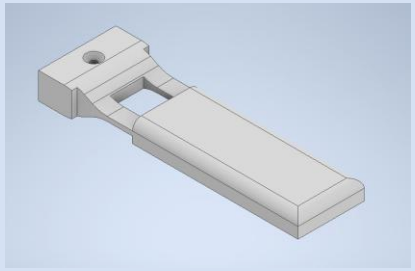
The electronics cost a lot more than I expected, however if I was to mass produce my product, I would be able to order parts in larger quantities getting a discount from suppliers for buying items in bulk. I would also be able research better suppliers who sell parts for cheaper, but I would need to make sure that the quality was still the same or better.

3D Printed Parts List

CAD	Name	Quantity	Description
	**Control Panel**	1	Holds the screen and selector pad.
	**Speaker Housing**	1	Holds the speaker and provides an indent for the speaker grill to sit in.

All the parts are printed in ABS this is due to its high impact resistance and relative flexibility not being as rigid as other plastics like PLA; Its also moderately cheap. It has presented some issues with warping (as noted before) due to inconsistent heating in the printer however not to a drastic extent and something I have mitigated through setting changes.

	**Left Body Section**	1	Allows the speaker grill to be slotted in and has the screw brackets for one of the input boards of the key
	**Middle Body Section**	1	Holds the battery compartment and the hole for wires to enter the internals. It also had one of the screw mounts for the second input board and is where the smaller boards e.g. AMP and DAC are stuck.
	**Right Body Section**	1	Holds the main section of the breadboard and allows access to the micro-USB port on the micro controller It has the other screw for the second input board.

	**Battery Holder**	1	Prevents children from being able to tamper with the batterys.
	**Piano Key**	7	Each key does have the note extruded into it; this is the overall base design.
N/A	**Selector Keys**	5	Allows the user to press the buttons of the selector pad.

Software Test Plan

To ensure the software cannot be broken, especially by children who will push it to its limits, I need to test both the electronics and more specifically the software powering. Since there will be no way to update the product once it is in the field, it's important to find and fix any bugs beforehand; I also need to make sure that the software meets the design requirements and that all the features work as intended.

The main objectives of the tests are:

- Verifying that the correct sounds are output for each key.
- Ensuring that UI elements function as expected.
- Testing the responsiveness of inputs.
- Making sure that if an error occurs, it is properly communicated to the user.

The project will also have the ability of being battery powered or if required plugged into a wall in both circumstances the product should work exactly the same.

	Work
	Partially works
	Doesn't work

Description	Expected Outcome	Status	Feedback
Startup splash screen displays	Shows immediately after startup and no inputs work until the screen has fully loaded		No inputs work until the screen has fully loaded however each box has to load beforehand which takes a while.
Pressing keys produces correct sounds	Correct sound plays		All modes tested
Selection buttons update UI correctly	Buttons correctly update UI when pressed with limited latency		Both volume and selected item update instantly
Mode selection buttons change mode to the correct one.	On selection of a mode the new audio should play on the next key press after.		All keys immediately change after a mode is changed
Volume buttons adjust sound levels	Audio file should be louder or quieter depending on the change.		Works correctly however sounds on wall power were slightly louder likely due to greater available current.

Minimal delay between key press & sound output	The delay between a press and a sound playing should be less than a second.		The time taken it not noticeable and is almost instantaneous
Simultaneous key presses handled correctly	If multiple keys are pressed the higher key takes priority e.g. A over C		If keys from the same resistor ladder is pressed a key wont, make a sound till only one is pressed as otherwise its an invalid voltage that doesn't correspond to any key since the resistance is added together
No SD Card message	Next time a file is accessed or its not found on startup a "No SD Card" message is shown		Currently if an SD card is inserted the screen stays black and nothing works if its reinserted and rebooted it works

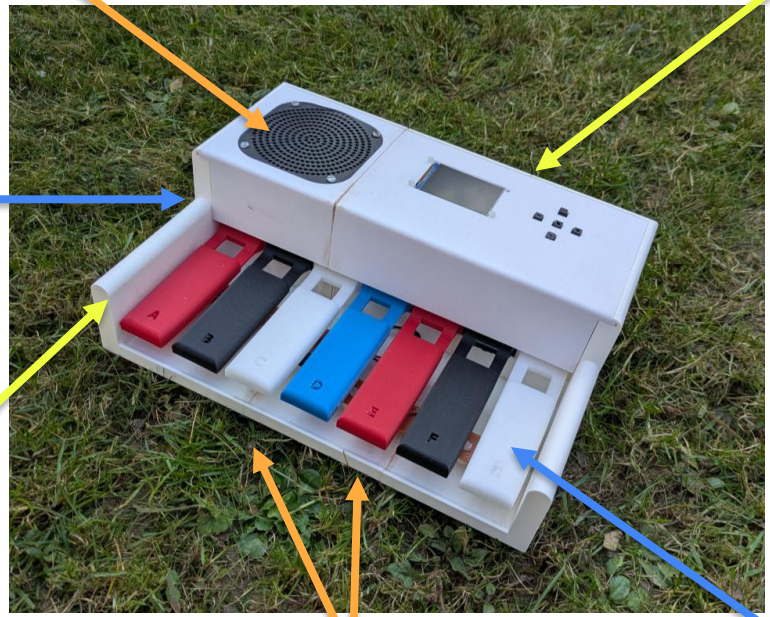
Overall testing found it to be very consistent between the two different power modes other than the slight change in volume one issue that was found was the slow loading of the UI on startup and the lack of an SD card message which could make it confusing to the user.

Final Product

Outputs the sound, the grill on top to provide protection and to improve the visual look

The control panel allows the user to change between the different modes and adjust the audio giving a visual indication

Houses all the electronic components providing screw and stick points to keep them secure



Rounded edges prevents sharp edges would could be uncomfortable to hold

Body split into three pieces with solvent used to fuse them together at two points

Triggers the playing of the note makes use of a compliant mechanism which springs back to its original position

Testing – Outside in the Garden

I decided to test the product outside in my garden. There was a slight amount of washing out on the screen in direct sunlight however overall, it remained very readable. This was surprising, since the backlight was not enabled.
The rubber feet did not perform well on grass but worked well on the concrete and other flat surfaces. I also noticed a few small mud marks, but these wiped off easily with a wet wipe.

Despite the slightly windy conditions, the sound carried well. However, after asking my dad to stand in the neighbor's garden (which has shared access) he said he couldn't hear it. Showing that the volume is not loud enough to cause a public disturbance. Additionally, the white color makes it easy to spot. If a child accidentally leaves it outside, workers should be able to find it easily.

Testing – Indoors in the Kitchin

I tried testing it using on wall power, the cables position keeps it out of the way of the child however there is no form of lock on it meaning if they do try to remove it, they can easily. The connection to the piano looks quite seamless especially with the use of a similar colored cable. When next to the walls it doesn't stand out as much however it should be relatively safe indoors so there isn't as much of a need to be very apparent. The power from the wall is a much more consistent power source meaning the very minor flickering of the LCD when on battery power can't be seen the sound also sounds a little clearer but not by much.

Client Feedback

After showing my product to my mother (client) here was some of her feedback:

Main Body

My client was not fond of the white as the primary color, as lighter surfaces tend to show marks and drawings by children more easily even after cleaning. Instead, she suggested darker or more vibrant color that can camouflage it better. However, it does make it easier to check if its clean.

She appreciates the product's solid feel, saying that its weight gives the feeling its more well-built. The addition of rubber feet on the bottom is also a well-received feature, as it prevents scratches on the bottom, which is common from kids dragging around. The overall size of the product is liked, as it feels comfortable to hold.

Portability

My mother likes the ability for it to run on both battery power and being able to plug it into the mains. As it allows for the child to move around with the toy which they often do. She appreciated the secureness of the battery compartment as a crucial safety feature, as unsecured compartments can pose a significant risk to children.

Accessibility

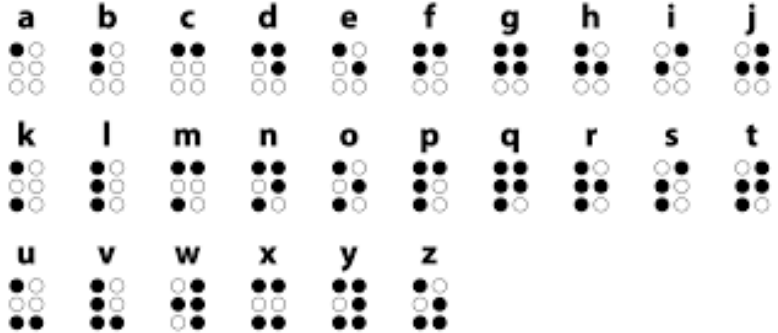
My client likes the ability to change volume, making the product more accessible for children with hearing impairments or those who are sensitive to loud noises due to special needs e.g. ADHD

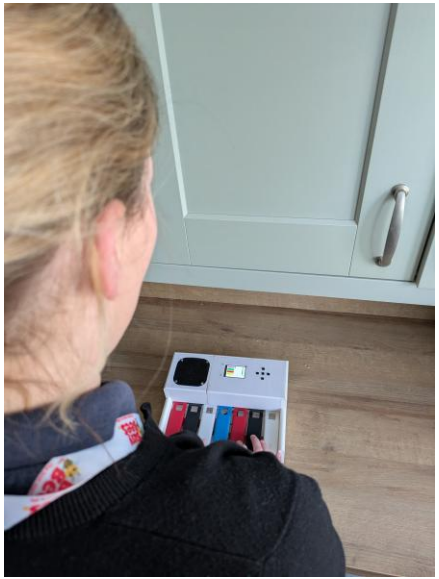
She suggested adding Braille to the keys to improve accessibility for blind children. My client also recommended that as users scroll through the mode selection, the speaker should announce the mode name. This verbal cue would provide confirmation of the current selection, making navigation more intuitive, especially for younger children who maybe are still learning to read or those with visual impairments.

Learning Aspects

She likes the visible speaker on top, as it allows for explanations for how it works improving the learning experience for children. The variety of modes is a highlight for my client, as it prevents children from becoming bored with just musical notes. The inclusion of both educational and fun ones is appreciated.

The ability to support both worker-led and child-led playing is also liked. This means she does not always need to supervise the child while they use it, allowing her to focus on other children.





Moderation

One feature my client would like to see added is remote management, allowing workers to monitor the current mode and volume or change/disable settings via their phone or computer.

Key Design

My client liked the idea of using stickers or recessed pieces with pictures or icons for all the different sound modes directly on the keys, rather than just for the letter for note's. This would make it easier for children to identify the meaning of all sounds.

As for the current letters a larger font size could would be good to improve readability. The bold and vibrant key colors are appreciated for their visibility from a distance, making the product more eye-catching for children.

Additional Modes

She also likes the idea of incorporating images on the screen of popular characters from well-known children's shows such as Disney and Peppa Pig with accompanying sounds, making the product more engaging for kids by featuring familiar characters they love.

Individuals Feedback

I also showed my product to a classmates, family and other people to get their options on my finished product to give a wide variety of opinions

Freddie Simons (Student)

I think your product overall is lovely you have taken a great idea and developed it into a functional product. For me, it could be improved by adding sharps, although I am unsure how practical this would be when it comes to the electronics and your target age group Possibly starting with C rather than A because that's how music normally works. You could also place an LED under the keys to light up when pressed to make it more interesting. maybe a different color for each one?

By adding a led before the on the stripboard it could allow for a cool effect however it could provide resistance to the resistor ladder but assuming all the LEDs have the same amount of resistance it should be ok

Theo Baker (Student)

There are some sharp edges on the box that could be removed however the electronic system inside is incredibly clever. The product could be improved with a bit more musical knowledge which could make it a fantastic mass-produced product

Minor amount of sanding to the edges could resolve this but adding curves in the CAD before printing would be better.

Sam Atkinson (Student)

The current voice for the different modes sounds very “submissive”, maybe voice audio files yourself or find a better one online. I also like the idea of adding a mode of a single animal. e.g. Cats with each note being a different meow.

Mike (Neighbor)

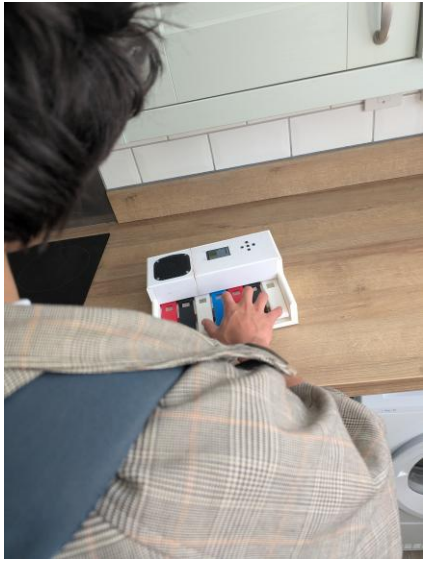
He liked the product and thought it was “very clever” but suggested for the more educational modes that plastic covers could be included that could be put on the keys so for that for example for the days of the week children could learn how to spell or recognize them.

Dax Tekchandani

An intricately designed keyboard with a very creative electronic design. It offers a nice variety of modes. The voice in some modes could be improved maybe by recording custom samples. The animal noises are well done, but the 'lion' sound effect could be changed, as it currently sounds more like a car engine."

Dad

The product is very good overall. However, I have some concerns about water resistance—for example, what happens if water gets into the speaker, which seems to be made of paper. Or what happens if a child tries puncturing it with an object between the holes on the grill? Multiple notes (chords) cannot be played, which would be a nice feature to add. The icons on the keys are nice but could be made more apparent—perhaps by adding white highlights to the icons.



£9.03 (£10.84 Inc. VAT)

Price for: **Each**

Multiple: **1** Minimum: **1**

Quantity	Price
1+	£9.03 (£10.84)
5+	£7.74 (£9.29)

I could use a speaker with a plastic diaphragm this would be more impact resistant and waterproof. However, it does cost slightly more.

In class we did some small focus groups with some randomly assigned classmates. Below is their feedback some was discussed as group leading to some overall group feedback as well

Mason Williams

Looks colourful, its very educational and simple to use, very clean design overall. I like that is had feet on the bottom which is good for keeping it off dirty surfaces. The colour scheme is very nice with the main body being white and the keys being colourful providing a nice contrast.

Maybe cleaning up some parts so the glueing is less apparent and adding rechargeable battery's as you said its charge only lasts about two weeks of constant use. Adding some more keys would also be cool.

Kirian Thode

I like the fact is has four different modes and that some are educational. The colours for the keys are attractive/engaging. Overall, I think its innovative I've never seen a product like this before. The ability to change between with the different modes with the screen is amazing.

Adding even more colour would be good and making the keys a bit bigger so you can't see the circuitry. The material finish is a bit inconsistent (gaps between panels). Also adding a rechargeable battery so its lasts longer.

Joseph Hurst

Good finish on the corners with no issues or flaws with the electronics. Like the different options (days + numbers) as it allows for better learning. The buttons work well and feel nice. The colours are a bit inconsistent and I'm not very fond of the screws not being flush. The heavy use of plastic and use of AA battery's for power is not very environmentally friendly. Small amount of glue seepage on the body and the key colours seem a little random. More volume options (only 100%, 50% and Mute) and more modes would be nice

Title: Volume controlled by speed of key depress

Improvement:

Add volume control to keys i.e. if depressed slowly then sound is quiet but if depressed at speed, the sound is loud.

Add intermediate levels of quiet and loud depending upon speed of key depression.

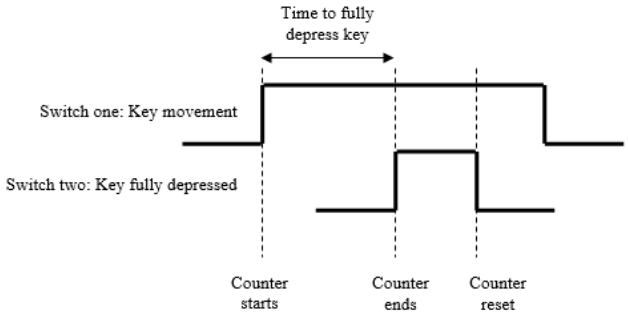
How it could work:

Two switches detect initial key movement and when fully depressed.

The control system starts a counter upon initial key movement and stops the timer when the key is fully depressed.

The time to depress a key is reflected in the count and the loudness adjusted accordingly.

The counter is reset when the key is no longer fully depressed.



Advantages:

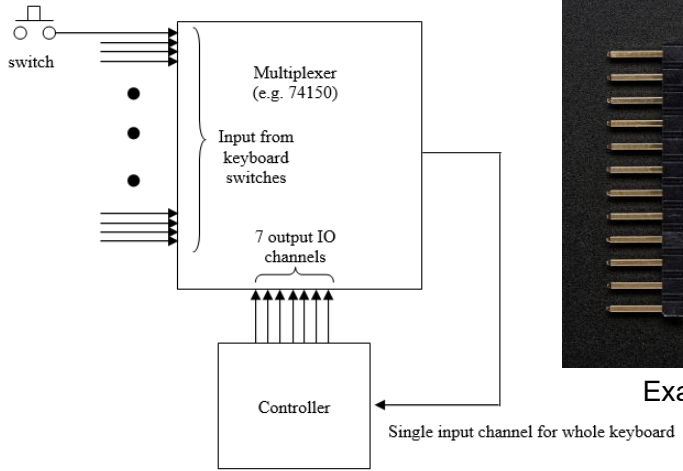
Digital so does not require to be calibrated
Small switches
Inexpensive components
Robust / reliable

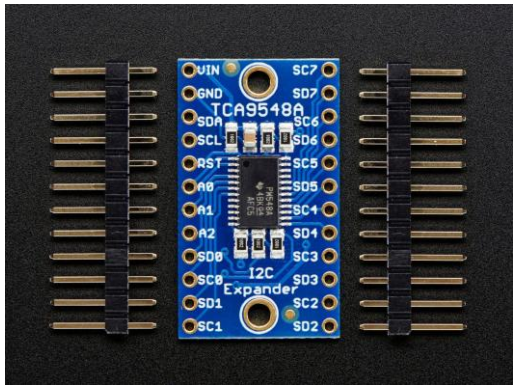
Disadvantages:

Requires double the input channels per key

My **Grandad** whose an electrical engineer offered some more technical suggestions for different ways I could have designed the electronics using a multiplexer instead of using a resistor ladder and direct digital signals to the controller. On the left is a document of ideas he made for me.

While small and inexpensive, multiplexer chips might be quite hard to solder to stripboard instead I would have to design a custom PCB for the buttons and the chip. It would also mean more processing power would have to be dedicated to key detection as the signal is being read at a much faster rate. It would also make it harder to debug.





Example multiplexer board

Specification Review

	Doesn’t meet requirements
	Partially meets requirements
	Meets requirements

From the feedback and my own knowledge, I compared it against my original design specification to how much I had met

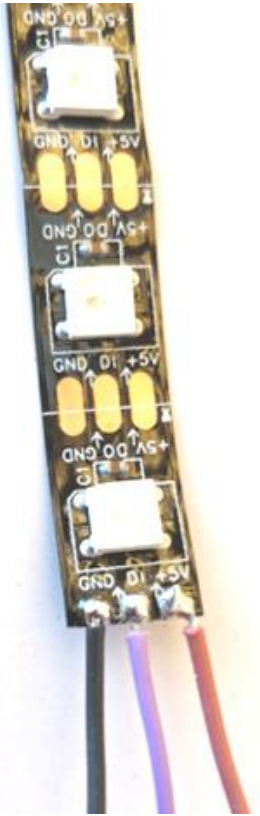
Specification Point	Explanation
The product should be durable against daily use by children	The use of both dowl and solvent in the fusing of the body should make it strong enough for most impacts or bends time, a young child could throw at it. However, drops against hard surfaces like concrete could lead to cracks that could compromise structure over time but my client's workspace is an all-carpet environment in the rooms.
Product should be capable in surviving harsh weather such as rain.	The nature of electronics means that its very hard to make it waterproof while the small margins on the body mean that small splashes and spills might be ok full-on rain would be too much.
Product should be able to be carried with ease by the child with limited effort.	The piano weighs a reasonable amount that makes it feel substantial however its still light enough to not feel stramineous. The large flat base gives lots of hand room however more efforts could have been made to curve edges
Toys should have a limited focus on Phonics and Maths	The product has multiple educational modes which can be used for learning such as numbers and the days of the week.
The product should use non-toxic materials.	ABS is a non-toxic plastic commonly used in food ware all electronics are securely connected or inside where they cant be accessed

The product should have no small parts which a child could choke	All exterior parts fastened securely there is no small parts would could be put in a childs mouth if a child was to gain access to the internals there is risk they could swallow some of the electronic components however all the boards inside are PCBs which often have a coating that makes it unpleasant to taste.
Target age group of product is 4-3 years	The product seems to be found intuitive my both adults and younger children with experimentation being the way most understood how each button works.
Product should be unisex and be friendly for both genders	The use of colours is neutral with no particular focus towards a particular sex this makes its suitable for both boys and girls the modes also reflect this with topics that both can find interesting
Products should strongly encourage problem-solving and collaboration	The product is designed for only a user at a time this limits the collaboration there is limited problem-solving elements with the only one rlly being when the first use it and understanding how to move between modes.
Product should be able to be produced in mass.	The use of 3d printing limits the ability to mass produce due to long printing time and the removal, some parts also need to be soldered together on top of wiring the electronics together the use of circuit boards in the future to make it more manageable and injection moulding the parts
Product should be easy to clean	The body features limited cracks and crevasses leading to less build up of dirt while the removeable nature of the keys and top control pad allows for deep cleaning for example to access the below the keys if a child spilled something.
The product should be priced around £20-30	Just the electronics alone cost that much even with finding different suppliers that are more cost effective it would still most likely cost more than the target price.

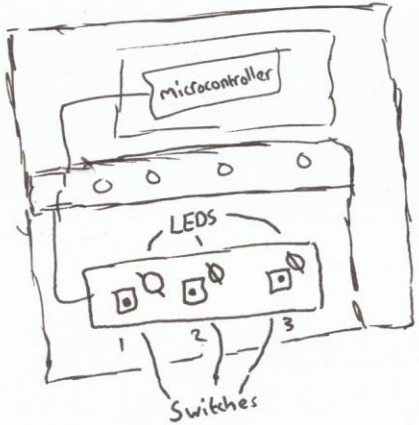
Suggested Improvements

Below is a summary of the suggest improvements and more detailed explanations on how it could be implemented

What could be improved?	How (I could)?
Adding sharp keys making it more like actual pianos reducing the learning curve	Use a second raised portion of stripboard using a resistor ladder again with all the sharp keys using it making use of the final ADC signal line on the controller
Adding LEDs below each key so when one is pressed there is some form indication making it more fun.	Adding a separate LED in the circuit before each button, with different colours or adding an RGB strip which is sent commands by the controller to output different colours.
Playing multiple cords and allowing for different volumes of sound depending on how hard its pressed.	Using a multiplexer which can detect multiple signals simultaneously and work out the amount of time it took to press allowing a speed to be worked out.
Removing sharp edges from the body	Adding curves to all edges on the body giving it a smoother transition
Adding modes based on cirtian shows/movies that children will have watched	Using the blit function for the screen showing images whenever a button is pressed with an accompanying sound e.g. a character's voice



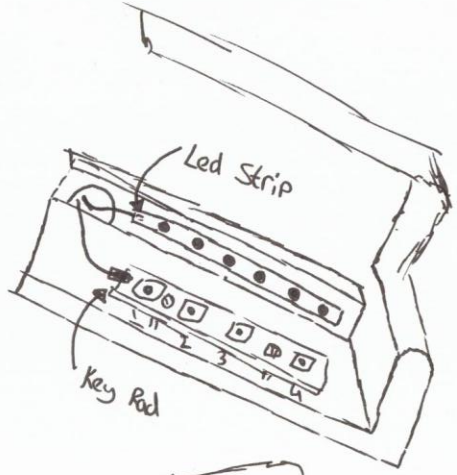
Adding Lights to Keys



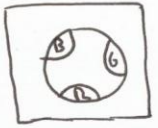
+ No Software with limited circuit changes

– Less Colour variation

VS



Button 1	Red
Button 2	Blue
Button 3	Green
Button 4	Yellow



Neopixel – Consists of 3 smaller LEDS that allow any colour to be made

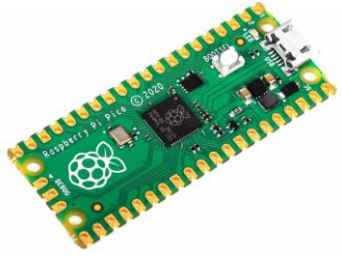
– Requires Software

+ Allows more colour variations

Alternative Microcontrollers

I kept with the Raspberry Pi Pico W mainly due to my past experience developing with it and its use of Python as its coding language which I was more confident with. However there are a number of different boards I was made aware of that could have used instead.

The **ESP32** is another SOC (System on a Chip) which only costs £4.80. It has a much larger storage possibility allowing for audio files to be stored directly however it has fewer input pins with no Analogue inputs; Which are required for the current key input meaning I would have to switch to something like a multiplexer However the lack of an SD card reader would mean less pins are required. It also has Bluetooth and Wi-Fi which could make it easier for a worker to connect to it with their phone, as they wont need to set it up on the nurseys network instead directly connecting with Bluetooth.



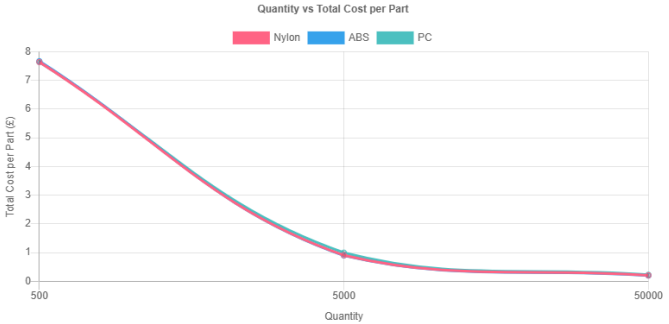
The **Raspberry Pi Pico** is very similar to the W variant however it has no wireless capabilities reducing the price to only £3.80 It .has a range of inputs with a built in ADC (Analog Digital Converter) allowing for the voltage divider to still be used. However it has an even smaller storage capacity and a much smaller processing power to the ESP32; The lower price would reduce the overall cost of the product making it more appealing for the nursery.

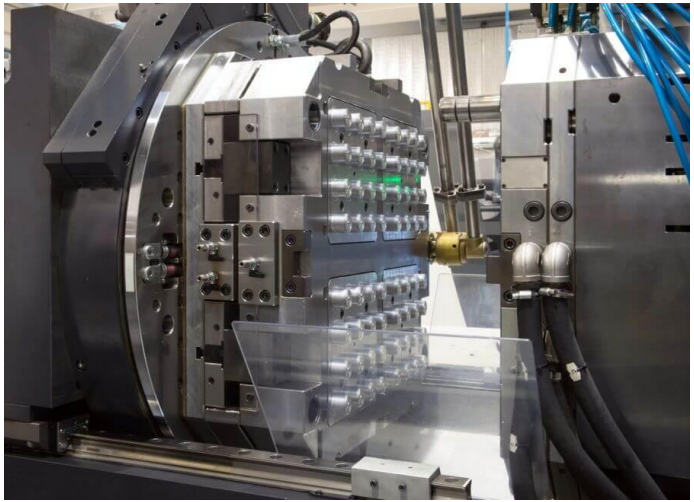
Injection-moulding the Body

While 3D printing is highly effective for rapid prototyping, the need for supports and cleaning up of parts makes it difficult to scale for mass production. If I were to manufacture this product at a larger scale, I would use injection molding. This is when plastic is injected into a mold, which significantly reduces the cost per unit and allows for larger parts to be produced as a single piece e.g. the main body of the piano.

However, the main expense is the initial cost of the mold, as any design changes would require a new one. The large, flat base of the part provides a good contact area, making it easier to press out of the mold once formed. Multiple parts could be connected and molded together, either to form all the components of a single piano at once or to produce multiple identical parts in a single run. Since the current material, ABS, also works with it, no material change would be needed. The design also does not include intricate angles that could obstructed by the mold when part is realized.

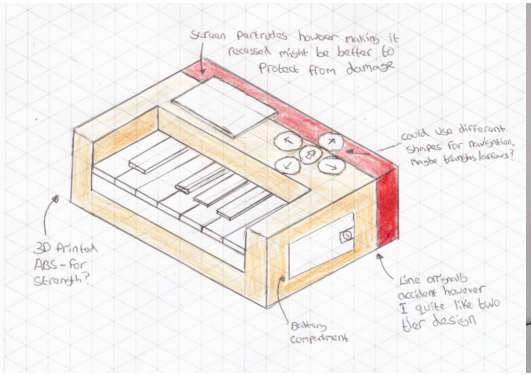
According to *Get It Made* (get-it-made.co.uk), the cost of machining molds for a medium-sized part, such as the speaker holder, is around £4,000. While this is a large upfront cost especially since each part will need one (which will cost more for some) when divided across all units, the cost per unit becomes much more manageable.





Final Thoughts

Overall, I am happy with my final product. My progress has been consistent and constantly evolving. While I have sacrificed some features, the original idea has remained. The use of electronics, especially with sound playback is something I had never done before making it an exciting challenge. The heavy use of 3D printing has also improved my CAD skills. In the future, I would like to better document my project by taking more photos throughout. My client is happy with the final product and has been supportive throughout in suggestions and ideas.



Progression