ENGINEERING

McMaster University

Project Four – Power in Community

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial T03

Team Mon-36

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Submitted: April 14, 2021

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Academic Integrity Statement

The student is responsible for performing the required work in an honest manner, without plagiarism and cheating. Submitting this work with my name and student number is a statement and understanding that this work is my own and adheres to the Academic Integrity Policy of McMaster University.

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Executive Summary

Project 4 was a client-based project that allowed us to interact with a client who struggles with some everyday tasks. This gave us the opportunity to use our skills learned in class to solve a real-world problem. The problem we chose to tackle was the client's difficulty with holding smaller objects and reduced finger dexterity due to her physical impairments. This affected her ability to paint, which is a hobby that she loves and uses as an outlet to voice her thoughts and feelings.

To solve this problem, we designed the *Canvas Wand* (***Figure 1***). The *Canvas Wand* is an ergonomic paint brush adapter that uses a triangular groove with a high friction rubber and a foam lid to clamp the brushes firmly into place. A ratcheting strap is used to keep the lid locked in place, which functions similarly to a zip tie, except that it can be released with the press of a large button on the top of the lid. The button was made large to account for our client's reduced finger dexterity. The *Canvas Wand* can also be used for other cylindrical objects such as pens and pencils due to the firm grip of the lid, allowing one to write comfortably and with stability. We also implemented an adjustable handle so that the user can customize their experience and use multiple styles to hold the *Canvas Wand* in the optimum position. Another feature of the device is that it can be completely disassembled for cleaning or replacing any parts (excluding the rubber and foam on the brush holder and clamp which are adhered on and should not be removed).

***Figure 1**: The final prototype of the Canvas Wand*

We believe the *Canvas Wand* is the best solution to Alanna's problem because it provides her with the means to hold various sizes of paint brushes without sacrificing much accuracy and detail. Our device also gives Alanna multiple options when deciding how to use the device thanks to the adjustable handle which has 7 different positions to choose from. The device is

very lightweight and portable, allowing Alanna to use it wherever and whenever she wants to without any limitations. Allowing the device to be disassembled and cleaned also increases the product lifetime and the method of disassembly requires little to no force.

However, as with all things, our device is not perfect and there are some minor improvements that can be made with more time, money, and resources. To start, we were not able to physically test the mechanism that allows the handle to be adjustable. Had we been able to do this with access to a 3D printer, we would have been able to make changes that provide the perfect balance of stability and ease of use. A second improvement would be to add another loop for the ratchet strap to go into on the other side so that it is not sticking out of the top.

Introduction

Our task for Project 4 was to use the engineering design process to create a device to aid the client in everyday tasks. Alanna, the client, suffers from many autoimmune diseases including Lymphedema and Ankylosing Spondylitis. When someone has undergone lymph node removal as a cancer treatment, they are at risk of developing lymphedema. Alanna, unfortunately, was one of the people that would develop the symptoms of swelling in her upper body due to this. Ankylosing spondylitis is an inflammatory disease that, over time, can cause some of the small bones in the spine to fuse [1]. Alanna's actions are limited due to the effects and unpredictability of her conditions, which at times can completely determine her schedule, lifestyle, and mental health. She experiences symptoms of spontaneous swelling and pain which can cause a great amount of strain on her joints and muscles. Alanna spends a lot of time painting as it is an important aspect during her healing process. She has recently encountered a growing number of problems when she paints due to her developing health conditions, such as difficulty with gripping paintbrushes, painting fine detail, and many other challenges. She says "I desperately in my heart want to keep painting but I can't hold my body up anymore" [2]. Allana's view on painting is that the activity could allow her to express herself in ways that she can no longer do physically [3]. Seeing that painting is Alanna's passion, and yet it was slipping from her fingers because of uncontrollable circumstances, we found the motivation to base our design around this.

Our goal as engineering students was to design a device that assists Alanna in using various paintbrushes to create detailed art pieces in her art studio. This is needed because her health conditions prevent her from gripping them comfortably and for extended periods of time. The device should be lightweight, durable, and comfortable. The main objective of our design was to make it as easy as possible to use, which can be broken down into minimizing weight and maximizing durability and comfort. Another goal for the design process is to construct a solution simple enough that it would be desirable for everyday use. This would mean minimizing the amount of components and need for dexterity. She must be able to use the device for prolonged periods of time, and it must be able to withstand repeated uses and getting splattered with paint. Due to Alanna's physical impairments, our design must be under five pounds so that she can lift it, and it must also be comfortable enough on her skin to accommodate her fibromyalgia and lymphedema.

Current commercial products such as the *Blick Egg Handled Brushes* are subpar at best for accommodating individuals such as Alanna. According to *Dick Blick*, "The hairs are set in an ergonomic handle that makes painting a pleasure for any artist" [4]. In theory, the *Blick Egg Handled Brushes* are a good solution to people that have trouble painting with traditionally shaped paint brushes. In practice, Alanna would have to buy an incredible amount of different sized brushes for every application while paying approximately $10 - $20 for each. An additional goal that needed to be focused on was making a universal design so the device could be used with any brush. Another concept we found was the paint brush with detachable heads found in (Figure 5)[5]. It features a similar "pistol-grip" handle to allow for a comfortable hold, but the main problem found with it was its proprietary brush tips. This requires Alanna to buy specialty parts just to use the paint brush. Our design addresses this problem by using a universally fitting attachment mechanism that allows Alanna to use standard shaped brushes.

Alanna has stated that she has attempted various products and homemade solutions to her struggles as an aspiring artist dealing with the challenges she faces, but nothing has fully allowed her to get close to the ways she painted in the past. The purpose of the *Canvas Wand* is to allow Alanna to continue to express herself through painting in a comfortable manner.

Conceptual Design

The main goals of the design are to create a device that would allow Alanna to hold paint brushes more easily. We started brainstorming ideas with a how/why ladder to decide what our main objectives would be, as can be seen in (Figure 3). This led us to the conclusion that our design needed to be lightweight, easy to use, have an ergonomic shape, and have a surface made from a comfortable material. We then made a morph chart to devise numerous ideas as to how to complete the main functions of our device as can be seen in (Figure 20). We then created preliminary designs for each of the concepts we thought to be viable models such as a slide on pencil grip, a large flat handled palm grip, and a palm mounted strap among others that can all be seen in (Figures 22-35). From these we picked our top 2 designs at that point, being the pencil grip and the drill chuck designs (Figures 36-37). We then got feedback on these designs that can be seen in (Figure 44). This feedback included feedback on general material choice, as well as logistical problems. The drill chuck design would require brushes with much shorter handles than normal so current ones could not be adapted, and a drill chuck mechanism would be heavy. The pencil grip design although very light would still require a finger grip so it would be uncomfortable over time, and the small simplistic design could lead to it getting lost as well as make it difficult to take on and off. With this feedback in mind, we created a new design that would take these problems into account which resulted in the pistol grip design which would be the final concept for the *Canvas Wand* (Figures 38-39). The pistol grip design would allow for a more natural grip and could fit brushes of many different sizes and shapes into the device without the aid of a complex mechanism, by using a simple clamp or strap. We would refine this over time into our final design with the aid of more feedback from (Figure 45). The last iteration before the final design can be seen in (Figures 40-43). In this design there is a dimple and hole on the handle to adjust the angle, a foam cover for a more comfortable grip, and a clamp with a foam base and ratcheting mechanism to hold the brush in place.

Final Proposed Design

Description of Final Design:

Our final design, dubbed the *Canvas Wand* works by adapting any thin paint brush handle, or any other thin cylindrical object, to one standard and comfortable grip. The device takes advantage of a high friction surface for the brush to stay still and a compliant extrusion to apply pressure on the brush handle evenly. The compliant extrusion is attached to a hard plastic lid that has a ratchet buckle with a large button for ease of use. The lid is attached to the brush holder with a long steel hinge and is strapped down with a ratchetting strap. The brush holder is connected to the handle by a hinge with a dimple that can lock into seven different positions to give the user a range of usable angles. The handle is also made of a hollow stiff plastic with a memory foam coating for comfort. Finally, the entire device is easily disassembled for cleaning since it will likely be covered in paint and that paint may get in the way of it functioning correctly. Also, in the case a part is damaged, the easy disassembly allows for replacement parts to be easily installed.

Specifications:

The *Canvas Wand* was designed to minimize the weight so that Alanna can hold it for extended periods of time. Due to this optimization the device is made relatively small, with its maximum length being just under 25cm, with all the parts in the open position, and just over 100cm in width in the maximum position. With these small measurements we were able to lower the mass of the device to roughly 300 grams. This mass was generated using *Autodesk Inventor's* built-in material selection options, meaning the mass is a rough estimate but since it is well below our limit of 5 pounds, this device should be very easy to use for extended periods of time.

Final Images:

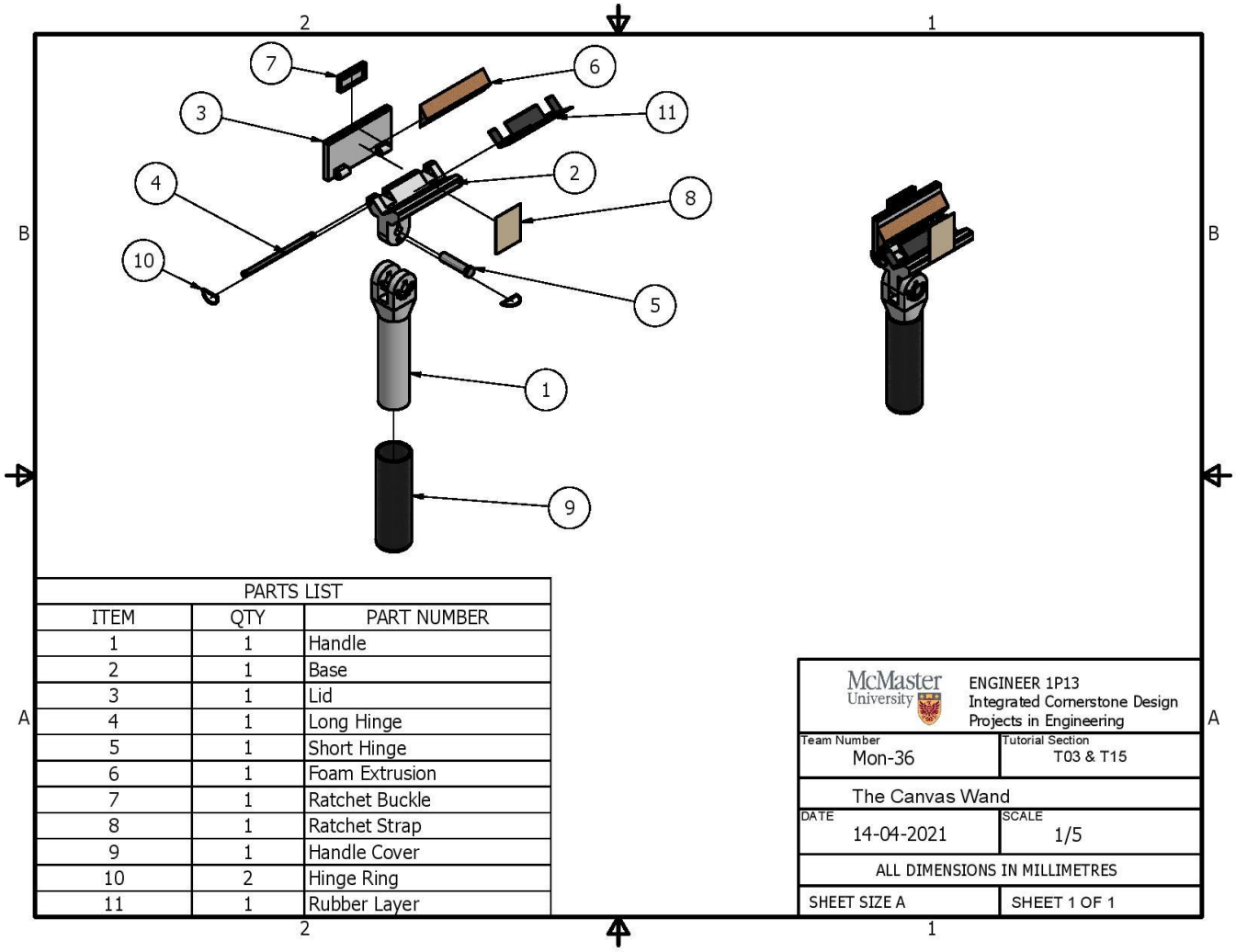


***Figure 2**: Exploded assembly drawing*

Each entry in Table 1 is a link to the corresponding engineering drawing in the appendix and a video demo of the design in motion can be viewed on YouTube at: https://youtu.be/cKP3WryXJHc.

Table 1 List of Parts:

Handle	Short Hinge	Handle Cover
Base	Foam Extrusion	Hinge Ring
Lid	Ratchet Buckle	Rubber Layer
Long Hinge	Ratchet Strap	

Discussion of Objectives/Constraints:

Our design meets all our objectives and constraints by being comfortable, lightweight, and easy to use. The entire device weighs less than one pound making it well below the five to ten limit Alanna gave us, meaning it will likely be easy to hold for extended periods of time. The device has a large memory foam grip that can be adjusted to a variety of angles for a very comfortable experience. Lastly, the device has few moving parts and allows for a quick adaptation period to using it. To further validate our device, we would need to create a physical prototype since two of our objectives are ranked on a subjective scale it is hard to qualify these objectives with a digital prototype. Although our objectives have limitations, from our analysis of the digital prototype we are happy with our design and are confident that it is the best design for the problem we chose to tackle.

Construction and Development:

The *Canvas Wand* is made of various materials which are all very easily worked with. The main material used is ABS plastic which is often used in 3D-printing and costs roughly $\$0.04/cm^3$ [6]. The handle, base, lid, and ratchet buckle are all made by 3D-printing using ABS plastic. The next most used material is stainless steel that was picked for its rigidity and corrosion resistance. Stainless steel is manufactured using milling and has an average cost of $\$0.15/cm^3$[7]. Stainless steel is used for both hinges and the hinge rings. The rest of the parts are made of unique materials for their specific material properties. For instance, the ratchet strap is made of nylon for its flexibility and is manufactured through chemical processes and has an average cost of $\$0.02/cm^3$[7]. The handle cover is designed to be made of memory foam which is a type of polyurethane foam which has an average cost of roughly $\$0.01/cm^3$[7]. Finally, the rubber layer, as the name suggests is made from rubber, because of its high friction, and is manufactured through chemical processes which have an average cost of roughly $\$0.01/cm^3$[7]. A list of the price for each part can be seen in the Appendix as (Table 2).

Conclusion

Overall, the final design of the *Canvas Wand* was chosen to be the most effective in Alanna's specific case due to it achieving the objectives set while satisfying the constraints and giving her the most efficient device to assist in painting. The design features a simple layout with minimal effort for use and allows Alanna to paint without worrying about her unpredictable and uncontrollable symptoms from her autoimmune diseases. In the end, the design could have been simplified even further and expanded upon if given the additional time and resources. We never fully tested out the design physically for a more in-depth look at usability. If given the necessary resources such as a 3D printer to fully construct the model, we could have tested the durability and efficiency of the design. There are also improvements that can be made based on some physical prototyping, such as addressing issues that may or may not exist like the ratchet strap being in the way of Alanna painting.

As we continued throughout the design process, we learned that feedback and refinement is the most crucial part in constructing an efficient and effective design. After going through multiple cycles of refining and reviewing our prototypes, it is evident that feedback was the most important part of creating the *Canvas Wand*. Among all the original prototypes, the final design shares little to no similarities with them. The first chosen prototype was a baseball-type grip attached to a drill chuck see (Figure 29) and after meticulous refinement, we developed the *Canvas Wand*. A key aspect to team dynamics that was learned throughout Project 4 was the importance of diverse ideas. In general, the different ideas contributed in the design process were quintessential to the refinement of the model. If every group member passively agreed to whatever one individual said, the model would still be at the preliminary stage and would not be as successful. The use of thought-process activities such as the How-Why Ladder (Figure 3), Decision Matrix (Figure 21), and other tools aided in visualizing the entire decision process and documenting the unbiased choices made. As we progress as engineering students, we will face various projects and problems that need solutions, so the ability to define a problem, combine ideas, and construct a solution as a team is going to be a key aspect in our accomplishments in the future.

List of Sources

[1] "Ankylosing spondylitis - Symptoms and causes - Mayo Clinic." https://www.mayoclinic.org/diseases-conditions/ankylosing-spondylitis/symptoms-causes/syc-20354808 (accessed Apr. 13, 2021).

[2] "Feb. 24th Client Visit Q&A - ENGINEER 1P13A:Integrated Cornerstone Design Projects in Engineering." https://avenue.cllmcmaster.ca/d2l/le/content/340370/viewContent/3096251/View (accessed Apr. 13, 2021).

[3] "1 - P4 Project Module - ENGINEER 1P13A:Integrated Cornerstone Design Projects in Engineering." https://avenue.cllmcmaster.ca/d2l/le/content/340370/viewContent/3086205/View (accessed Mar. 16, 2021).

[4] "Blick Egg Handled Brushes | BLICK Art Materials." https://www.dickblick.com/products/blick-egg-handled-brushes/ (accessed Apr. 13, 2021).

[5] "US8640295B2 - Paint brush with detachable head - Google Patents." https://patents.google.com/patent/US8640295B2/en?q=paint+brush+handle&oq=paint+brush+handle&page=1 (accessed Apr. 14, 2021).

[6] "Toy Builder Labs." https://www.toybuilderlabs.com/blogs/news/13055597-material-cost-for-printing (accessed Apr. 13, 2021).

[7] "Online conversions, calculations and formulas." https://www.aqua-calc.com/ (Accessed: 13-Apr-2021).

Appendix A

Section 1

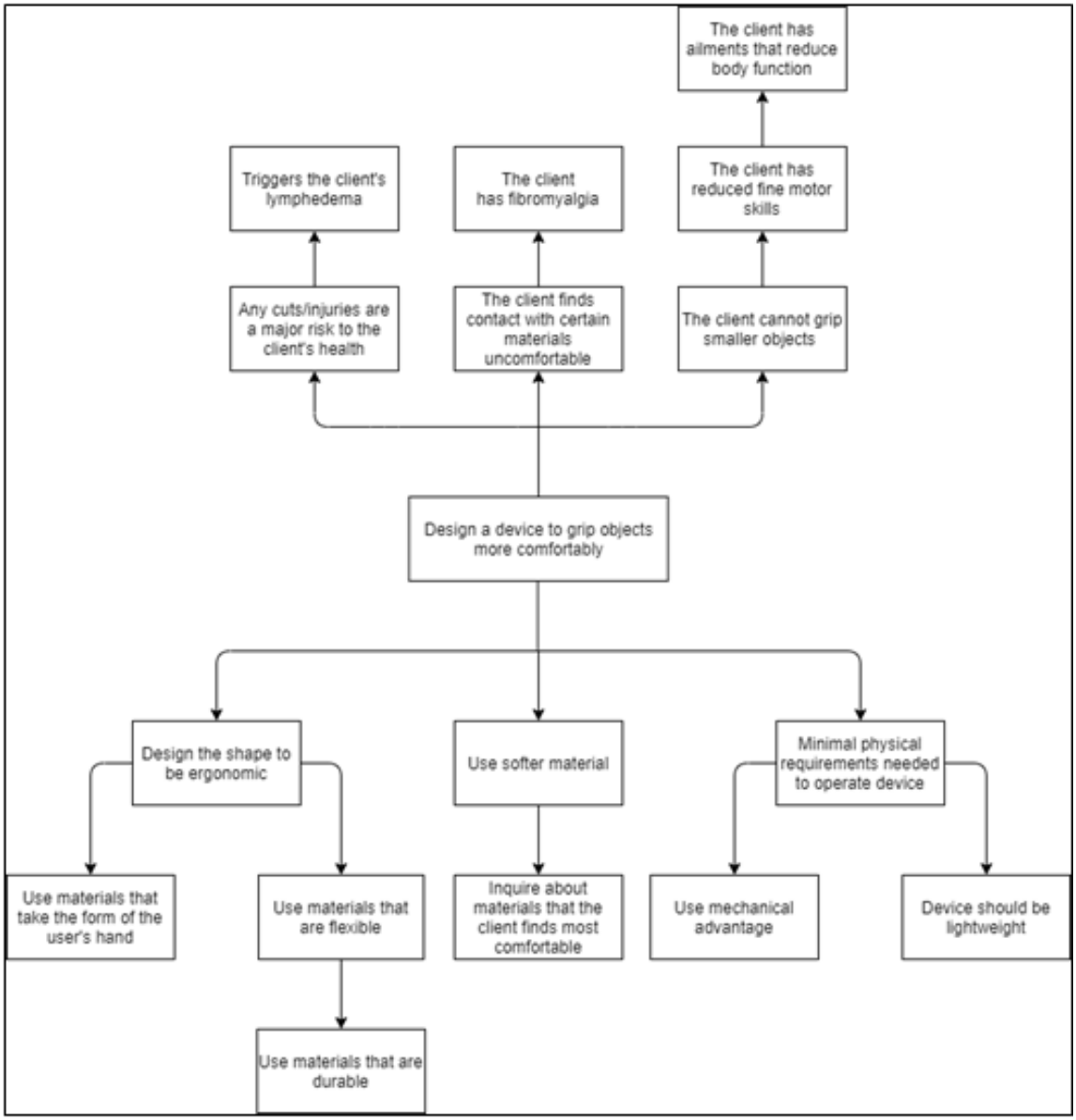


***Figure 3**: How/Why Ladder*

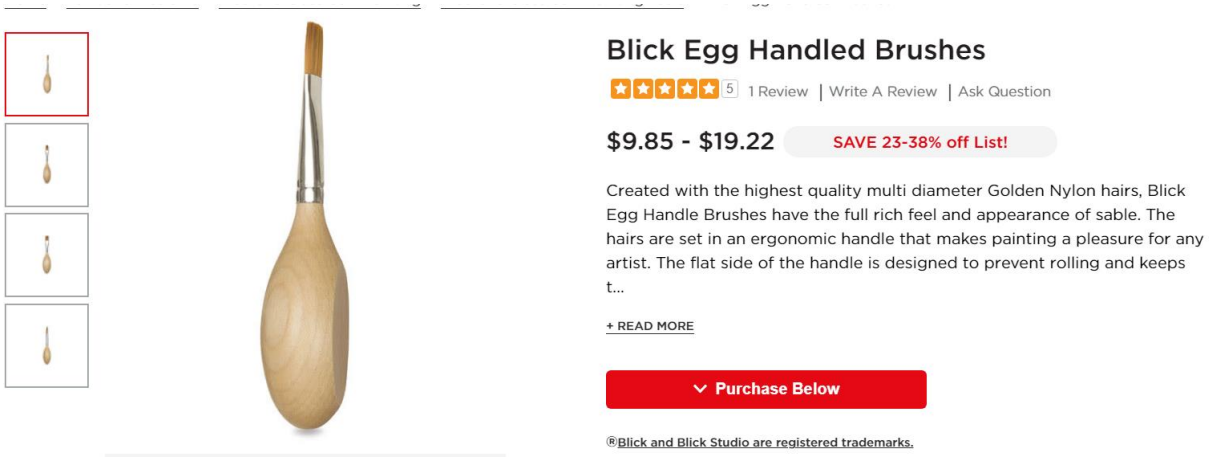


Figure 4: *Blick Egg Handled Brushes*

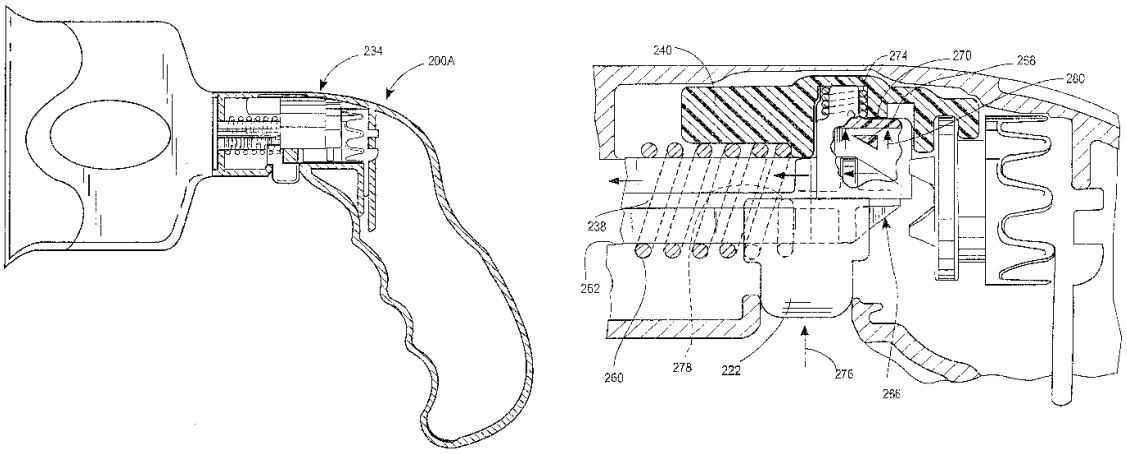


Figure 5: *Paint brush with detachable head*

Client interview notes:

Name: Jonathan Juneau	MacID: juneauj

Client Interview

Alanna

1. Personality
    a. Worked as a midwife 15+ years.
    b. Is an activist. Wants to make the world a better place.
2. Symptoms
    a. Has autoimmune problems.
    b. Was in a car accident that caused injuries.
    c. Was diagnosed with breast cancer and went through treatment.
    d. Painful muscle spasms
        i. Now paints with wider handled brushes.
        ii. Wraps her brushes with soft materials to make them more manageable.
        iii. Cannot work with clay when sculpting due to force required.
        iv. Lack of hand dexterity when sculpting for tasks such as twisting wires.
        v. Lack of dexterity leads to lack of detail in paintings.
    e. Lymphedema
        i. Swelling and infection risk on cuts
        ii. Muscle weakness may lead to needing to support one arm with the other.
        iii. Unpredictable
        iv. Cannot have an IV inserted into the arm
    f. Cannot bend over.
    g. Symptoms seem to be unpredictable.
    h. "Brain Fog" Cognition and memory seem to fade as pain increases.
    i. "Type A personality"
    j. Tasks take a long time to accomplish due to symptoms.
    k. Lack of hand eye coordination
    l. fibromyalgia
        i. Makes things on skin feel uncomfortable.
    m. Has had compression in spine during exercise
    n. Stress causes condition to flare

Figure 6: *Jonathan's First Client Meeting Notes – Part 1*

3. Desires
    a. Wants to paint.
    b. Enjoys sculpting.
        i. Makes sculptures from materials (putting different materials together not clay)
    c. Used to be able to knit and sew. Desires to be able to do so again
    d. Does gardening
        i. Herbalist and makes her own medicine
        ii. Currently does not grow food
    e. Thinks of methods like an exoskeleton that would allow her to use her body properly.
4. Attempted coping mechanisms
    a. Meditation (part of 2 different online groups)
    b. Brazilian jiujitsu
    c. Wears medical comprised compression gauntlets and vests due to lymphedema.
        i. Very helpful but uncomfortable
    d. Has tried a posture necklace but it did not work.
    e. Has tried exercise but it led to a spinal compression.
    f. Has had surgery and chemo for cancer
    g. Did yoga teacher training so she can make her own routines
    h.

Her website

https://inapowerfailure.com/

Figure 7: *Jonathan's First Client Meeting Notes – Part 2*

Name: Viktor Veljanovski	MacID: veljanov

Client: Alanna

I. *Personality / Interests*
- *Interested in Activism and making the world a better place.*
- *Midwifery*
- *Enjoys painting, jiu jitsu, yoga, sculpting.*
- *Very creative.*
- *Allergic to gluten.*
- *Enjoys gardening.*
- *Enjoys sewing.*
- *Likes punk music.*
- *Has two children.*

II. *Symptoms*
- *Accumulates auto immune diseases.*
- *Lymphedema (Swelling due to cuts/bruises)*
- *Fibromyalgia*
- *Very unpredictable signs and symptoms.*
- *Has compression equipment for swelling in arms.*
- *Difficulty bending over.*
- *Difficulty holding the paint brush for extended periods.*
- *Has had cancer and surgery as a result.*
- *Paints with wider handle brushes.*
- *Lessened hand-eye coordination.*
- *Experience's brain-fog.*

Website: https://inapowerfailure.com/

Figure 8: Viktor's First Client Meeting Notes

Name: Peter Khalaf	MacID: khalafp

Interview Notes

Alanna

Interests:

- Likes to paint
- Likes to sculpt
- Gardening
- Yoga
- Has children
- Sewing
- Brazilian Jiujitsu
- Meditation
- Was a midwife previously
- Wants to make a positive impact on the world
- Activist

Ailments:

- Had breast cancer in the past and was treated for it
- Was in a car accident
- Has autoimmune diseases
- Getting sick, injuries or cuts are very dangerous
- Has not left her house since beginning of pandemic
- Brain fog
- Conditions are unpredictable
- Lymphedema
    - Swelling/infections in any injuries
- Fibromyalgia
    - Certain materials are very uncomfortable
    - Skin is sensitive
- Conditions flare due to stress

Figure 9: *Peter's First Client Meeting Notes – Part 1*

Problems:

- Finds it difficult to bend down and pick up objects
- Some days, she is unable to get out of bed due to the pain
- Cannot stand for prolonged periods of time
    - Has to paint while sitting down sometimes
- Cannot hold thin brushes anymore
- Needs to use wider ones in order to be able to paint
- Cannot paint for prolonged periods time
- Sleeps very early in the day
- Loss of finer motor skills
- Unable to schedule her days
- Must listen to her body on a daily basis to decide what she can and cannot do

Figure 10: *Peter's First Client Meeting Notes – Part 2*

Name: Daniel Bamm	MacID: bammd

Copy-and-paste the notes from the introductory client visit for one team member in the space below.

General Problem:

- biggest challenge: no predictability
- can't schedule things ahead of time
- daily tasks are planned in the morning

Ailments and Effects:

- Lymphedema (side effect of breast cancer surgery): causes unpredictable swelling and infection or swelling in any cut or wound
- spondylarthritis: impacts mobility/can't bend at the waist
- pain causes brain fog
- stress causes flare ups
- has sudden muscle spasms in her hands
- has autoimmune diseases and chemotherapy making the pandemic very dangerous for her
- sleep impacts condition

Treatments:

- lymphedema: wears compression sleeves and vest – not comfortable because of fibromyalgia
- spondylarthritis: wears SI brace/belt – uncomfortable
- created a posture necklace but it didn't work well
- treats stress with meditation
- oral chemo causes insomnia

Figure 11: *Daniel's First Client Meeting Notes – Part 1*

Hobbies and Activities:

- Worked as a midwife for 15 years
- enjoys activism
- paints as a means of healing communicating
- meditates and does yoga
- trains in adaptive Brazilian jujitsu
- attempted to work with clay but fount it too difficult
- uses found objects to create sculptures uses wire to hold together (beat up hands while working with wire)
- works with acrylic paint, cold wax/oil paint, collage and found objects
- Preferred to paint in detail but can no longer do so because she can't hold small brushes
- takes very long to paint small detailed art
- loves sowing and quilting but doesn't have enough control over her hands anymore
- misses sowing a lot
- used to grow her own medical herbs – continues to plant a garden but can't do the physical work
- Needs a new way to hold brushes
- feels more stable on the ground
- can't sit for ling time periods
- uses wide handled brushes wrapped with something to make them feel soft

Figure 12: *Daniel's First Client Meeting Notes – Part 2*

Peter Khalaf:

Presentations

Science Perspective

- IMPACT Model- The 'Process'
  - Identify client's needs
  - Ideation & early prototyping
  - Design reviews
  - Refinement of design
  - Showcase event
- **AIM**: To develop and validate concepts using a unique design thinking approach

- Example Questions
  - is the device comfortable to use?
  - is it portable?
  - Why did you select these materials?
  - Are they replaceable?
  - Is the device versatile? Adaptive?
  - Durable?
  - Works under different circumstances?
  - How long did it/will it take to build?
  - How easy is it to recreate
  - What are the limitations of the device?

Figure 13: *Peter's Second Client Meeting Notes – Part 1*

Occupational Therapy Perspective

- "Disability is seen as a collective problem, a problem caused by inadequacies of the environments in which we live, not always ameliorated by changing the individual." - Mary Law
- **Occupation** is anything that occupies our time
- Tied to health & well-being
- Christine Caron, Mother of four
- Re-designing to enable occupational performance and engagement
- Partner with individuals, groups, and organizations to promote functions & achieve their goals
- Not patronizing, super-man like help, but cooperative effort
- "Driving provides the means to do all the things that keep me healthy and active in my community"

- OT is a master's degree
- In 2019, ~1013 applied - did 252 interviews
- Only 63 students in incoming class

- Functional Capacity decreases over time after childhood
- Stay healthy to stay above disability threshold
- Can use person-environment-occupation model to do an occupational analysis of clients

- John is a 25 year old university student who was in a motor vehicle collision and suffered a spinal cord injury that left him paralyzed from the waist down. He has full use of his upper extremities but must use a wheelchair. He is going back to university
- John indicates he wants to be able to drive again
- Think about doing a P-E-O with him to consider what factors might impact his ability to drive again?

- Vehicle adaptations require special licenses
- Also require special training for client to be able to drive them

Video 1: https://youtu.be/Z1A_3eolJJs
Video 2: F-Words: https://vimeo.com/236235559

- OT program is competitive because of workforce analytics and the needs of the workforce based on people retiring
- In top 15 careers of the future

Figure 14: *Peter's Second Client Meeting Notes – Part 2*

Alanna

- If she were to hold paint brushes in different ways, she doesn't know how it would affect fine painting, but could more adaptable to abstract art
- Hands are affect by arthritis, fibromyalgia and nerve damage
- Tasks that require bending are difficult and fine motor skills are difficult
- Struggles lifting heavy objects
- The largest painting she's done is about 10ft by 10ft
- Maximum load is about 5 to 10 lbs
- Prefers to paint only in her studio
- Has meditation space that can be used for larger pieces
- Wants to buy seeds but buys her plants pre-planted
- Used raised beds in the past but does not have any currently
- Hasn't used them since her body has changed
- Plants growing indoors and has outdoor space that hasn't been used yet
- Previously grown vegetables but doesn't feel like she has the patience for them currently
- Herbs and flowers are what she's looking for
- When she has muscle spasms in hands, they freeze up. Very limited range of motion
- Other pains don't limit range of motion but limit the time she's able to hold a certain position before feeling discomfort and pain
- When painting close to the floor, she uses cushions and a stool to paint
- When painting on the floor, she lies down on the floor and places the canvas on the floor
- Can't work with gluten (paper mache, primed canvases that use flour), cautious with chemical components
- Right wrist size: 5.75 inches
- Left wrist size: 5.75 inches
- Uses variety of brushes and brush sizes on one painting, uses fingers sometimes
- Bearing the weight of own arms can be difficult
- Has lymphedema in both arms and torso, so lats and pecks get fatigued when holding arms up
- Alana is about 5'1.5"

Figure 15: *Peter's Second Client Meeting Notes – Part 3*

- Seams are the main issue with clothing material as opposed to fabric
- Doing things on the floor is an energy saving tactic
- Swelling is mild in hands due to lymphedema
- Length of hand from middle finger to wrist: 6.5 inches
- Width of hand across palm: 3.75 to 4 inches
- Much easier to extend hands than it is to grasp
- Easier to pull arm downwards than it is to pull it up
- Being able to paint without difficulty again would have the biggest impact
- Wants to leave the world a better place than when she arrived
- Demoed how she would hold brushes at 2:06
- Often shakes hands when they are in pain and shakes out whole arm when nerve shocks occur
- Runs hands under warm water when they are in pain
- Massages herbal cream into hands
- Her autoimmune diseases cause temperature instability at times
- Cancer treatment causes "hot flashes"
- Cautious about experimenting with temperature
- Floor space in studio: 7 ft x 4 ft
- Wider brushes are easier to hold
- Painting is intersectional (storytelling, tactile)
- Comfortable fabrics: 100% cotton, silk
- Most uncomfortable: Velcro, latches, hard, rigid areas in medical devices
- No preference between wood, metal, plastic, etc.
- Structurally strong materials help to alleviate nausea
- Writes with fountain pen so she can use a relaxed grip
- Bigger grips are better

Figure 16: *Peter's Second Client Meeting Notes – Part 4*

Interview #2

- Ankylosing spondylitis
- Hand pain is not due to ankylosing spondylitis
- Can lift 5-10lbs of weight depending on lymphedema
- Raises plants as pre planted not seeds
- Muscle spasms causes hand to be unable to maintain a held position.
- Wrist size 5.75 inches
- Hand length = 6.5 inches
- Hand width = 3.25 inches
- Hand shakes tend to relieve pain
- Running hand under warm water relieves pain
- May perceive temperature changes due to symptoms and treatments such as hot flashes from chemo
- Room area available = 4ft x 7ft
- Fingers applying outwards force does not hurt much but inwards force does (gripping hurts extending does not)
- Cotton, silk are comfortable
- Uncomfortable, Velcro, non padded
- No preference over wood and plastic
- Compliant materials make her feel like she may fall over
    - Objects need to fell stable for her to feel stable
- Larger grips are better

Figure 17: *Jonathan's Second Client Meeting Notes*

Daniel Bamm:

- Has not tried holding brushes in any unique ways but is open to it
- Spondylitis - primarily impacts the base of the spine
- Hand pain is not due to spondylitis it is due to nerve damage, fibromyalgia, lymphedema and maybe osteoarthritis
- Hardest things to do are using hands for fine work or bending down
- Maximum lifting load is 5 to 10 pounds
- Can't hold a brush in a single position for long periods of time
- Can't hold a grip for long periods of time
- Finds it difficult to support her own body
- Finds repetitive prolonged movements painful
- Can pick up small objects but finds holding them for long periods of time difficult
- Some art supplies include flour which has gluten which she is allergic to
- Right wrist is 5 and 3/4 inches in circumference
- Left wrist is the same
- Right hand dominant
- Uses lots of different brush sizes to create paintings
- Has used fingers to help make fine adjustments on every painting
- Sometimes when painting the arm is affected by pain first but other times it will be her finger joints
- Sometimes experiences nausea that stops her from standing
- Holding the weight of her own body on her feet is exhausting
- Hand length - 6.5inches
- Hand width - 4 inches
- Finds it easier to extend fingers then grasp
- Number one thing she would like to do with less difficulty is painting because she finds it is a way to leave a lasting impression on the world
- BRUSH DEMO AT 2:08

Figure 18: *Daniel's Second Client Meeting Notes – Part 1*

- Wears 100%cotton and silk when fibromyalgia flares
- Hard edges are very uncomfortable
- The discomfort is so apparent that it takes away from the purpose of the clothing - often makes medical devices too uncomfortable to wear
- Feels more comfortable with structurally strong materials due to nausea
- Relaxed grip on paintbrushes or pens is much easier to hold for long periods of time
- Pen like holds are more painful than large brush handles
- Wants a combination of the big brush handles and the tips of the smaller brushes

Figure 19: *Daniel's Second Client Meeting Notes – Part 2*

Section 2

Function	Mean 1	Mean 2	Mean 3	Mean 4	Mean 5	Mean 6
Easy to Grip	Round doorknob handle	Strap the device to the client's hand	Strap the device to the client's arm	Create a device that uses the extension of the hand instead of the contraction	Large Flat Handle	Memory foam covered Handle
Holds a Paint Brush Securely	Drill Bit Adapter	Magnet	Velcro	Coupling Mechanism	Duct Tape	Super Glue

Figure 20: *Morph Chart*

Criteria	Weight	Pencil Grip		Pistol Grip		Drill Chuck		Palm Strap	
		Score	Total	Score	Total	Score	Total	Score	Total
Weight	1	4	4	2	2	1	1	3	3
Comfort	2	4	8	3	6	2	4	1	2
Ease of Use	3	2	6	4	12	3	9	1	3
Overall Score		18		20		14		8	

Figure 21: *Decision Matrix*

Conceptual designs

Figure 22: *Initial Concept 1 - Part 1*

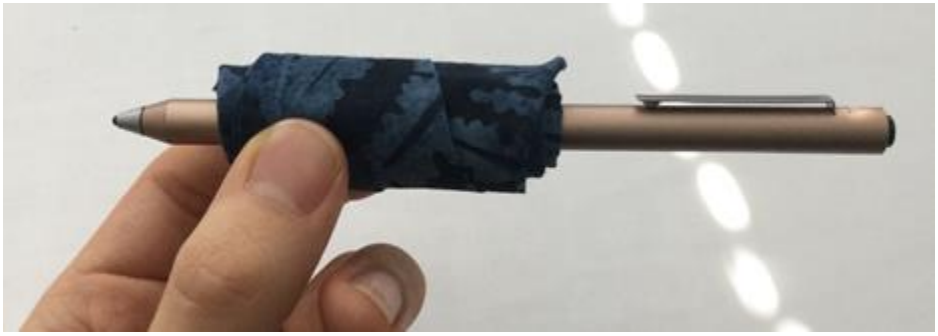


Figure 23: *Initial Concept 1 - Part 2*

Figure 24: *Initial Concept 1 - Part 3*

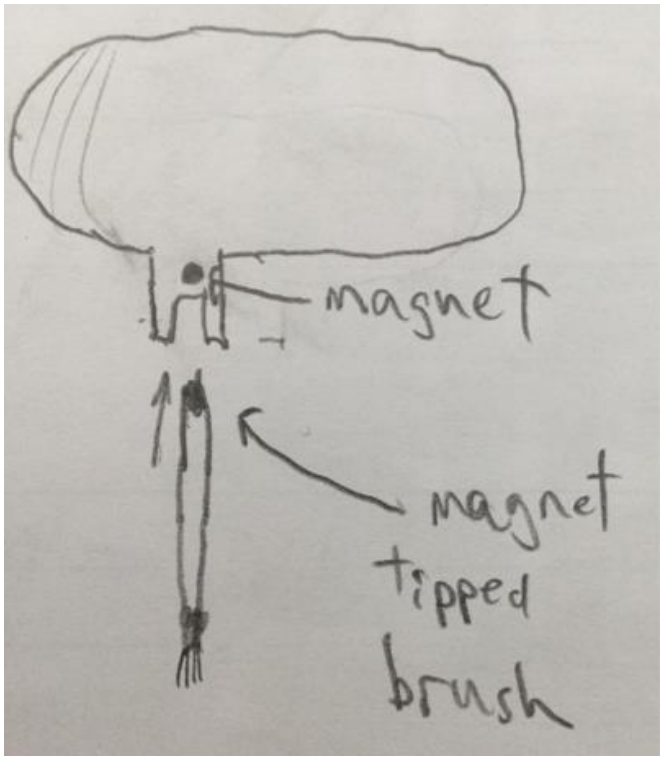


Figure 25: *Initial Concept 2 - Part 1*

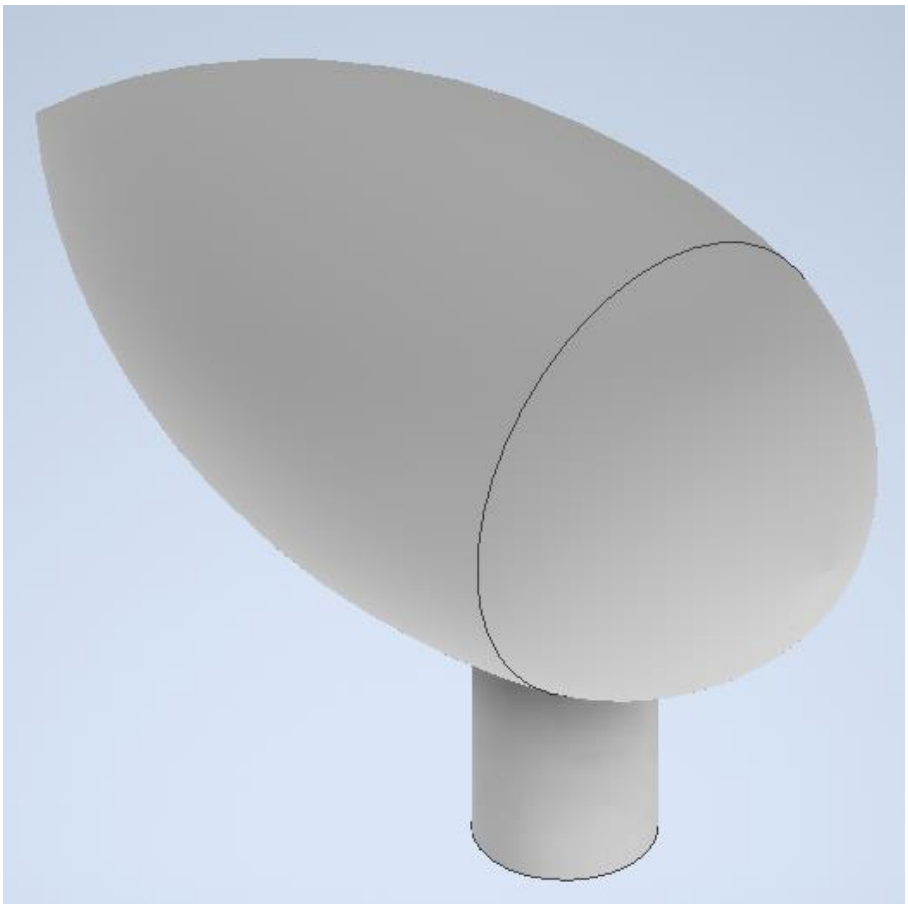


Figure 26: *Initial Concept 2 - Part 2*

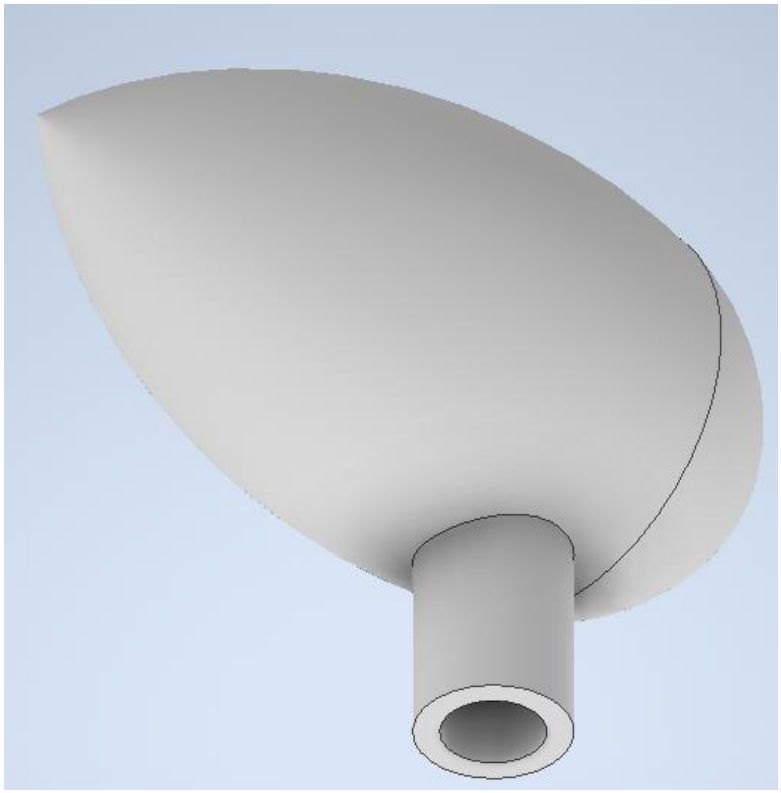


Figure 27: *Initial Concept 2 - Part 3*

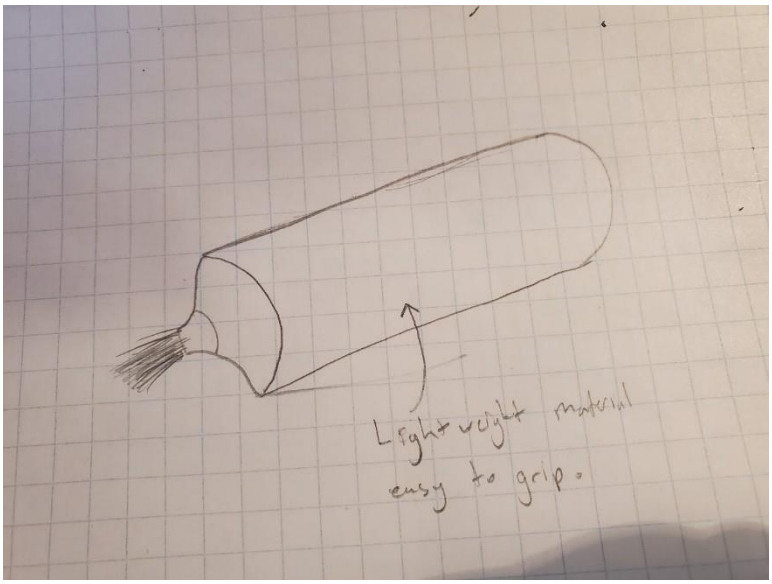


Figure 28: *Initial Concept 3*

col

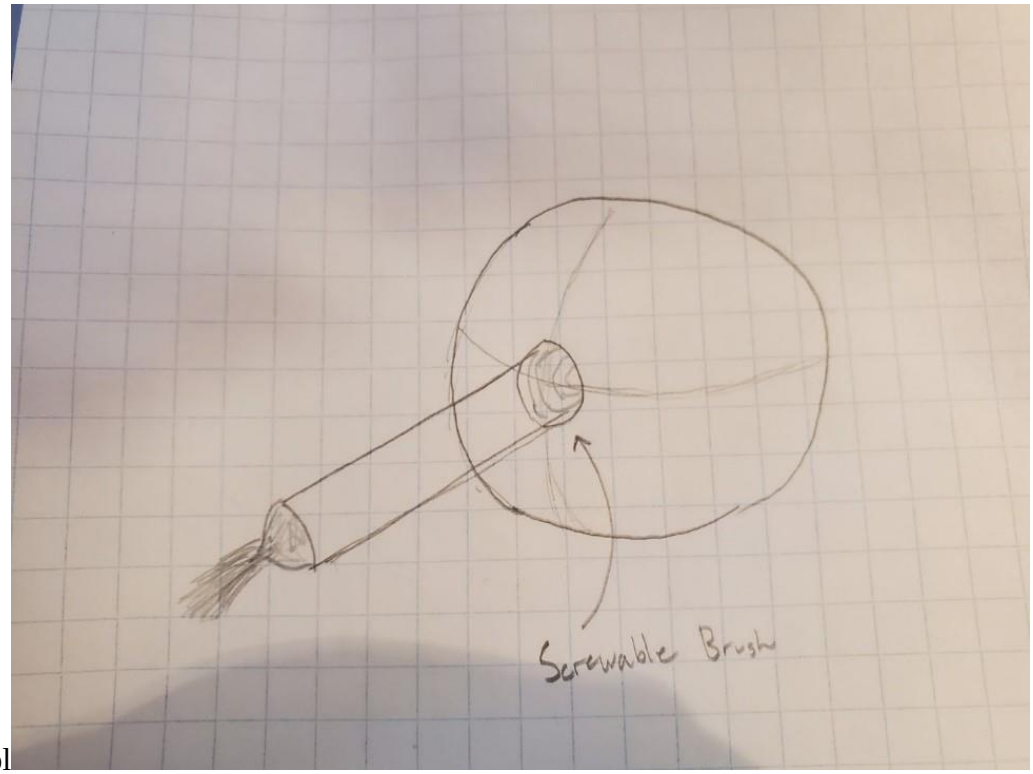


Figure 29: *Initial Concept 4*

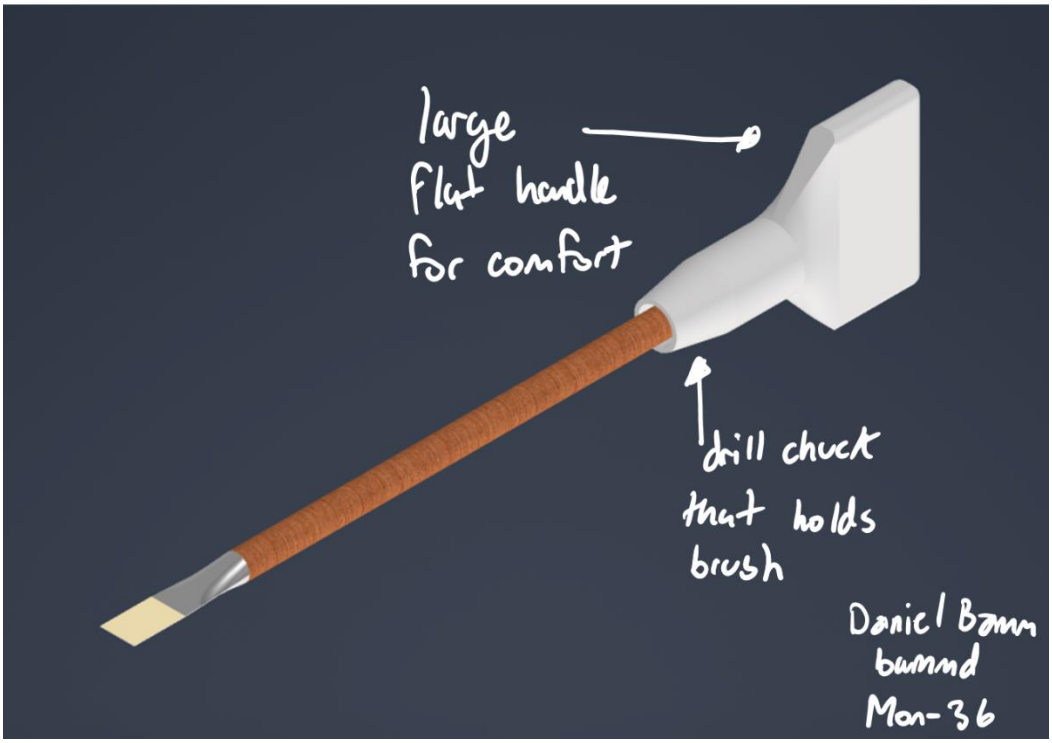


Figure 30: *Initial Concept 5 - Part 1*

Figure 31: *Initial Concept 5 - Part 2*

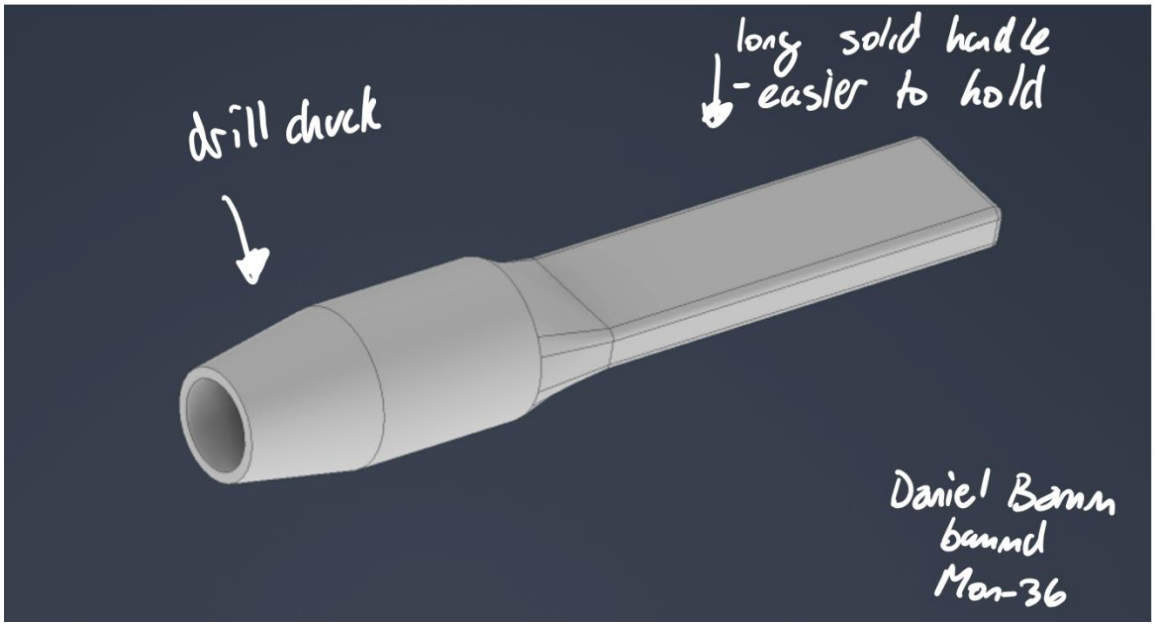


Figure 32: *Initial Concept 6*

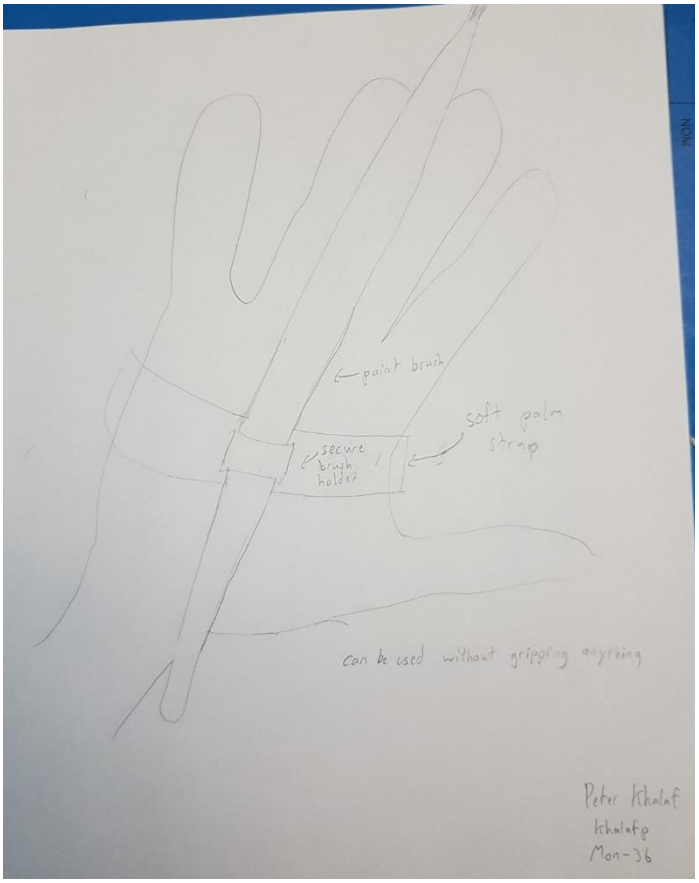


Figure 33: *Initial concept 7 - Part 1*

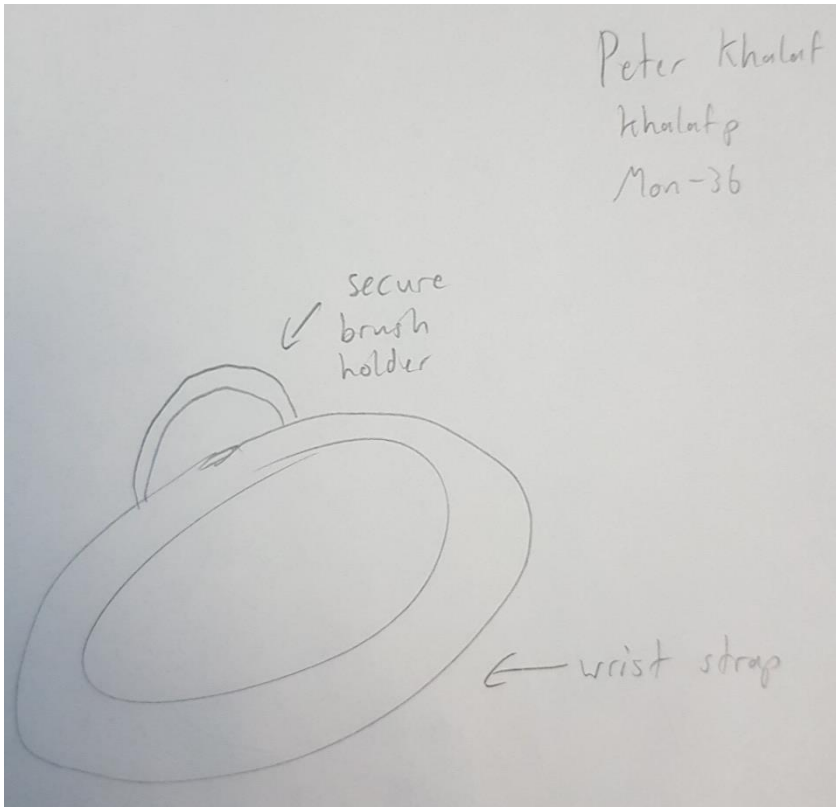


Figure 34: *Initial Concept 7 - Part 2*

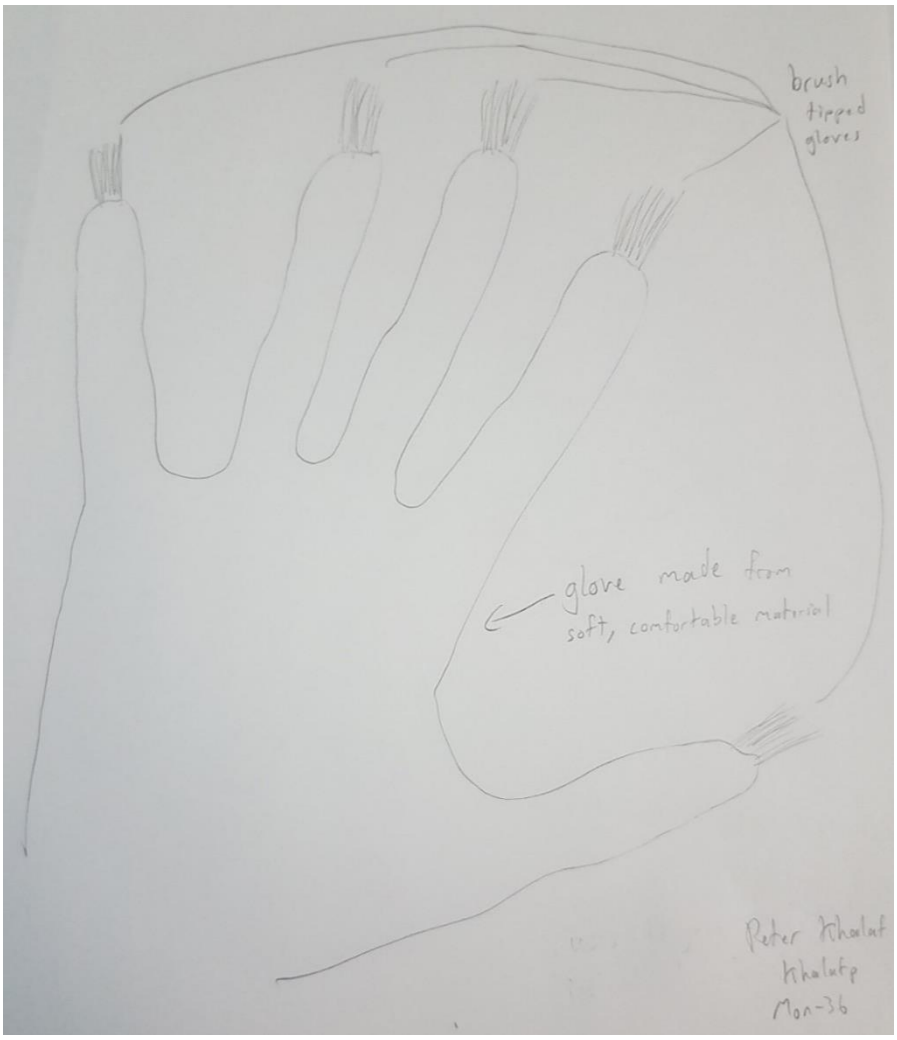


Figure 35: *Initial Concept 8*

Design progress 1

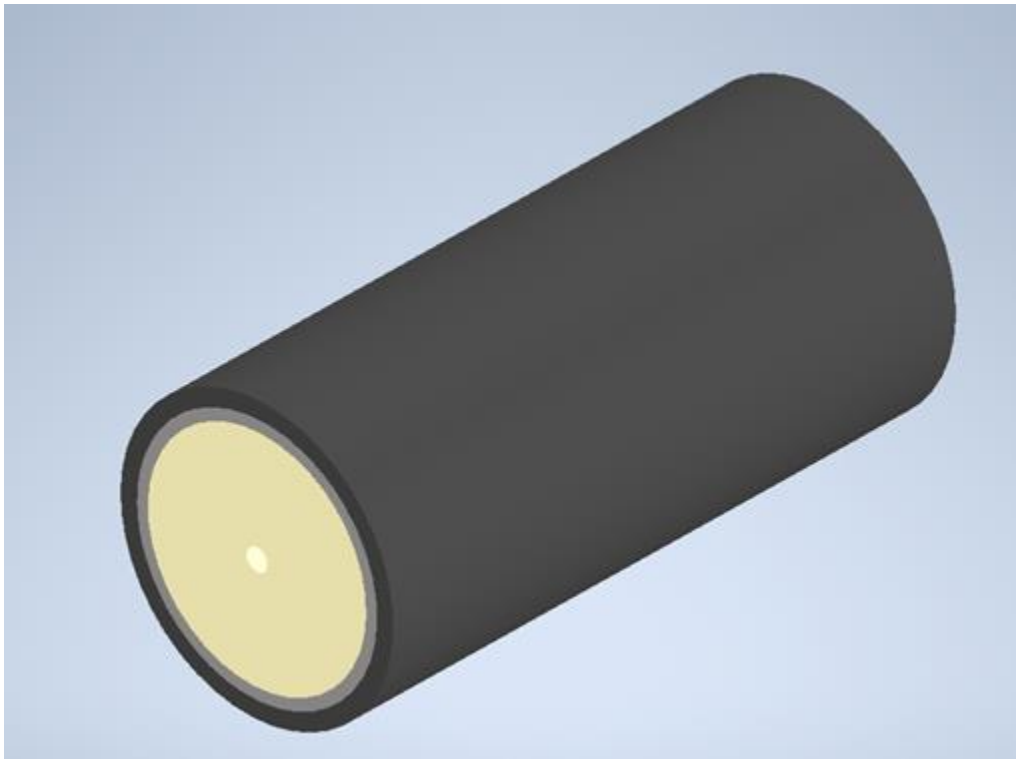


Figure 36: *Initial Prototype 1*

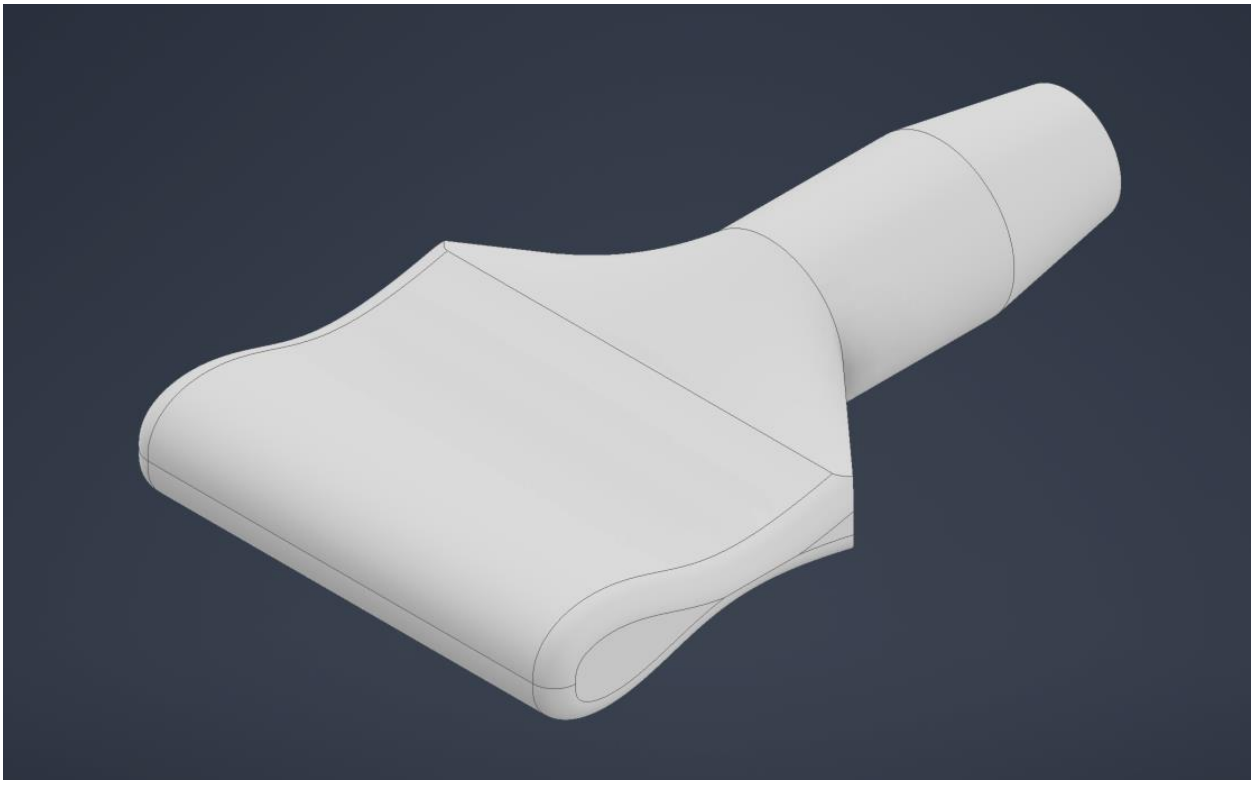


Figure 37: *Initial Prototype 2*

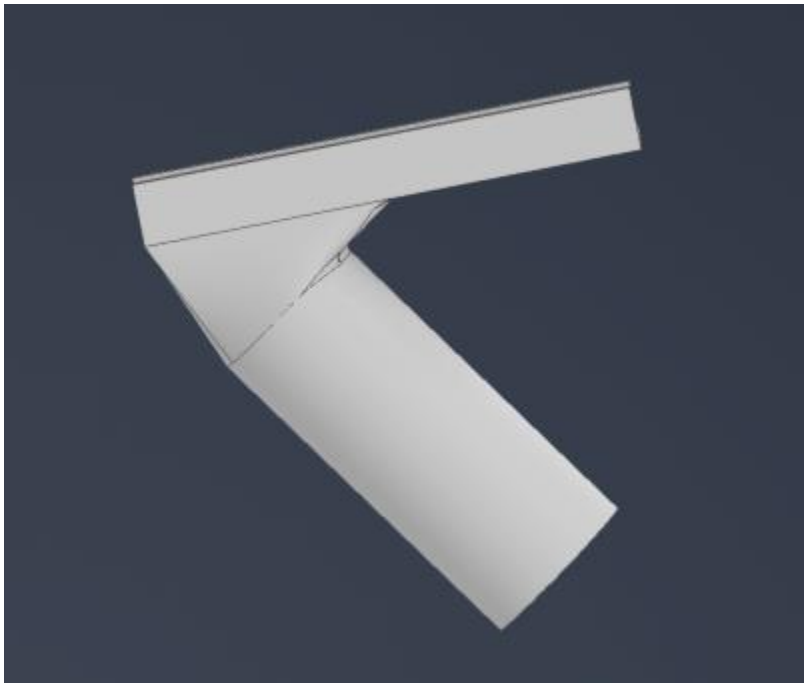


Figure 38: *Initial Prototype 3 - Part 1*

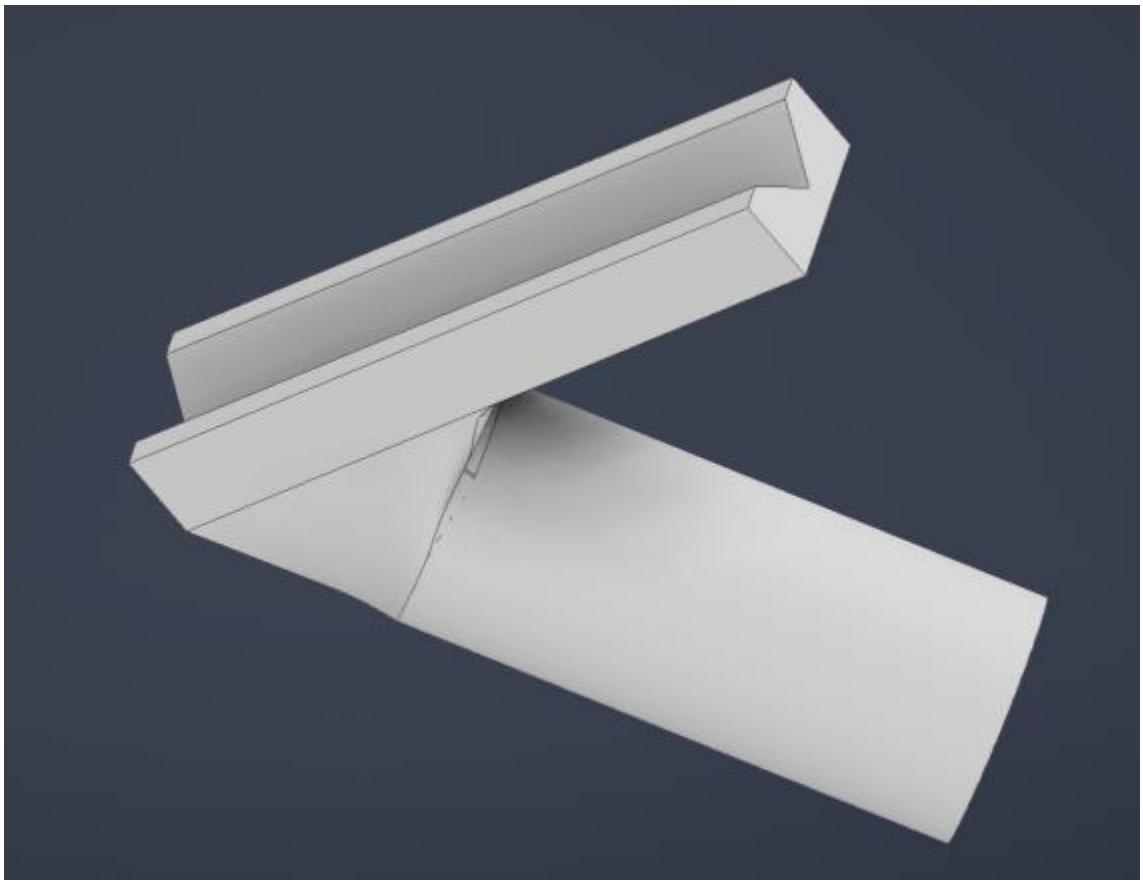


Figure 39: *Initial Prototype 3 - Part 2*

Figure 40: *Refined Prototype - Part 1*

Figure 41: *Refined Prototype - Part 2*

Figure 42: *Refined Prototype - Part 3*

Figure 43: *Refined Prototype - Part 4*

Peer Feedback: Daniel's pistol grip: - Velcro may irritate skin over time - Adjustable angle for grip - Hollow out groove to reduce mass - Slide brush holder forward so it does not come into contact with arm - Fillet edges Daniel's drill chuck design: - Ball handle might provide more options for gripping Jonathan's pencil grip: - Consider extending it to allow for a fist grip
Science Student Feedback: Concept 1: Be careful when using rubber because it can leave undesirable smells. Not much more to say Concept 2: Make sure to keep weight below limit with and without paint brushes. Try to modify brushes similar to hers rather than make her alter her own brushes. Ball handle might be tougher on the hands and joints.

Figure 44: *Initial Prototype Feedback*

Include feedback from peers in this row. - Use only one bump as opposed to one per hole (7) - Increase size overall - Increase cut-out depth and width - Add memory foam surrounded with a polymer onto the handle for increased comfort
Include feedback from science students in this row. - Make handle more ergonomic - Use padding on handle - Make sure bumps fit into holes - Make sure we understand how to manufacture it

Figure 45: *Refined Prototype Feedback*

Section 3

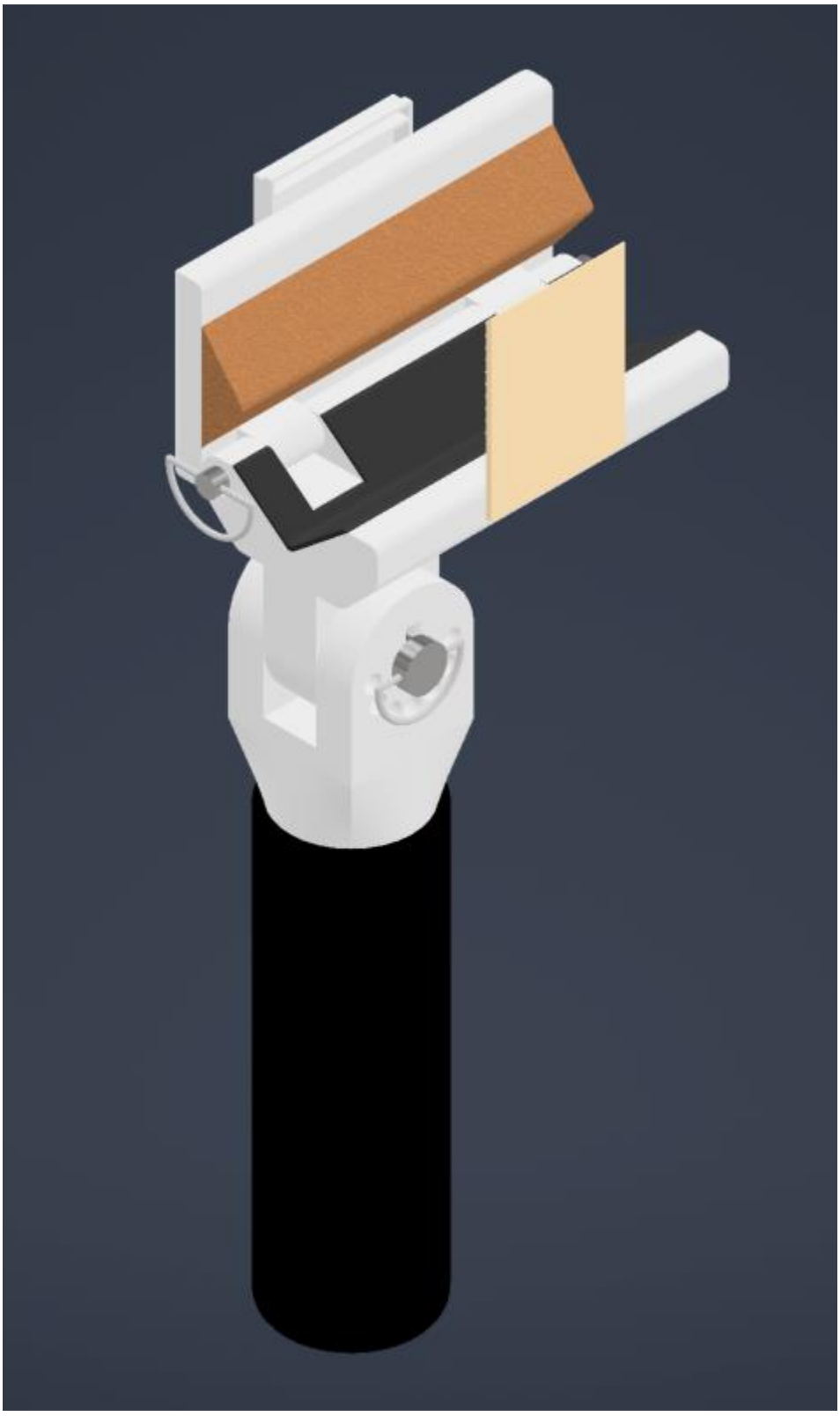


Figure 46: *Final Design - Part 1*

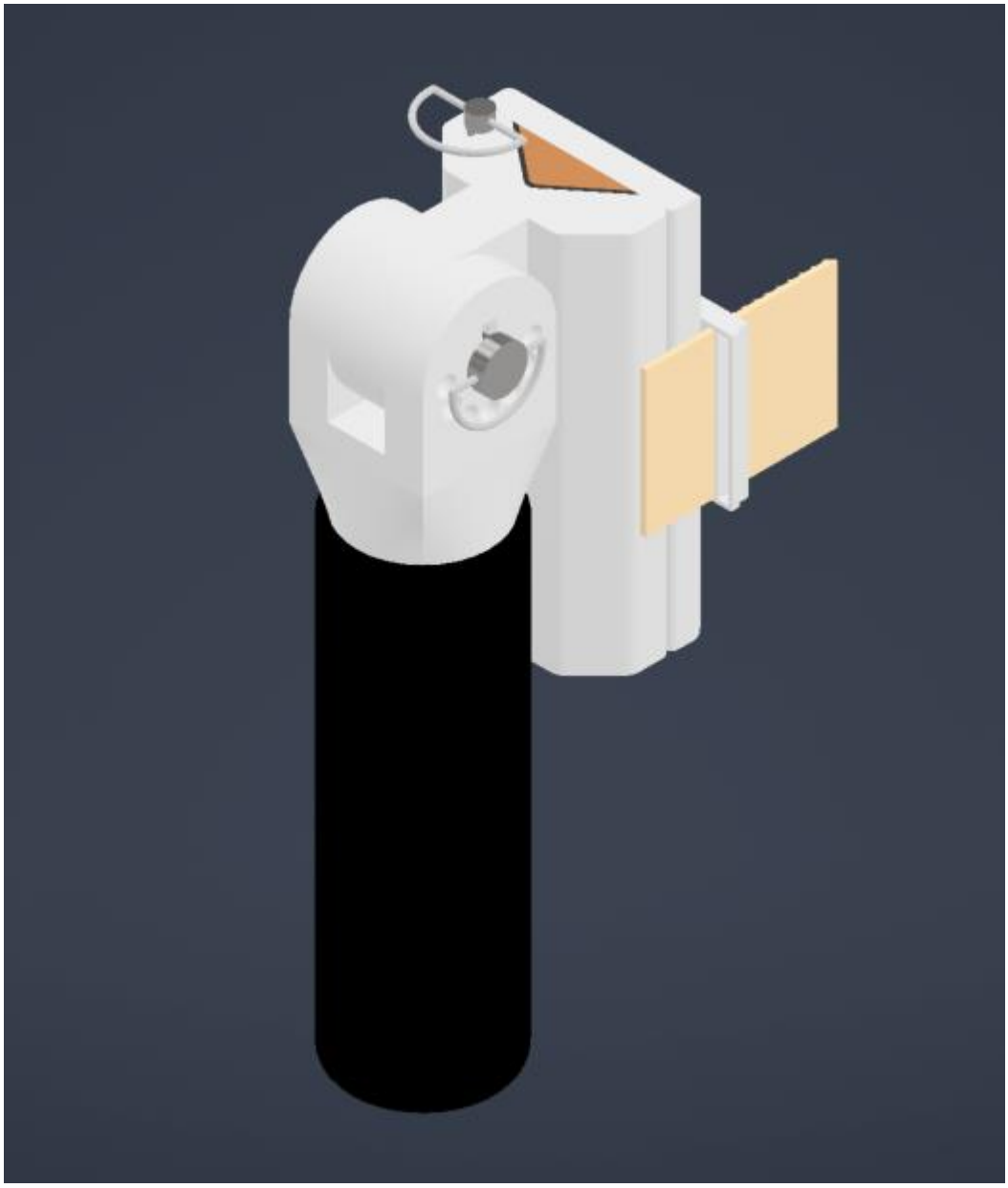


Figure 47: *Final Design - Part 2*

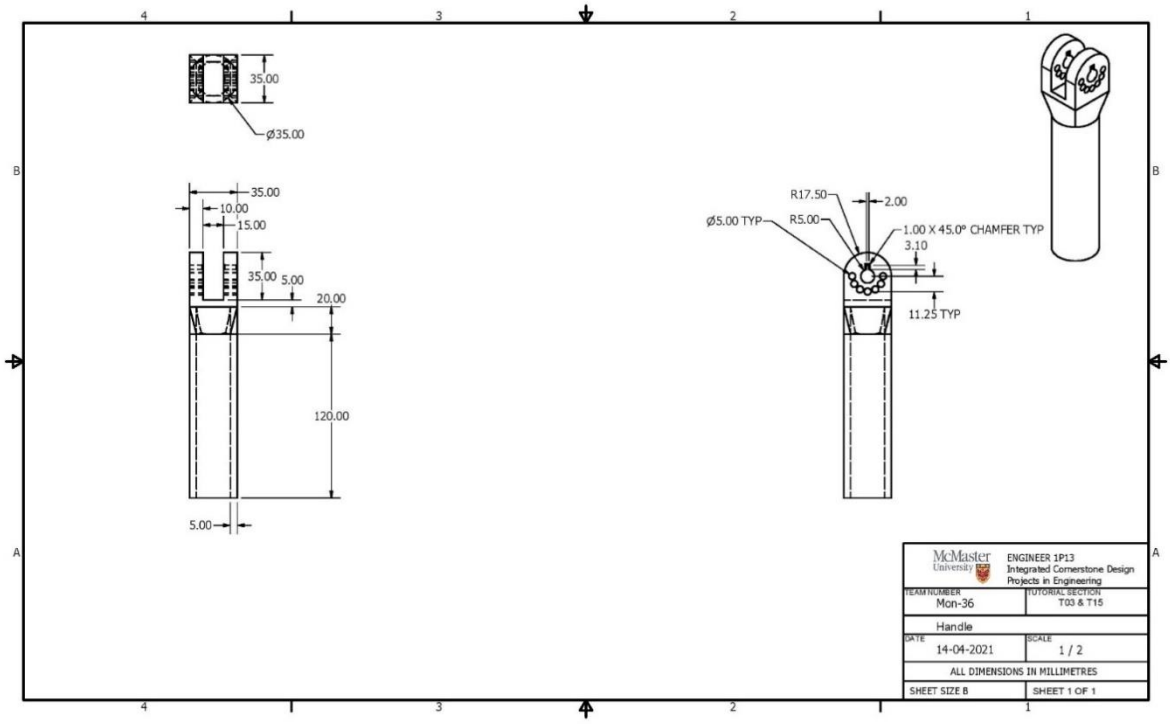


Figure 48: *Engineering Drawing - Handle*

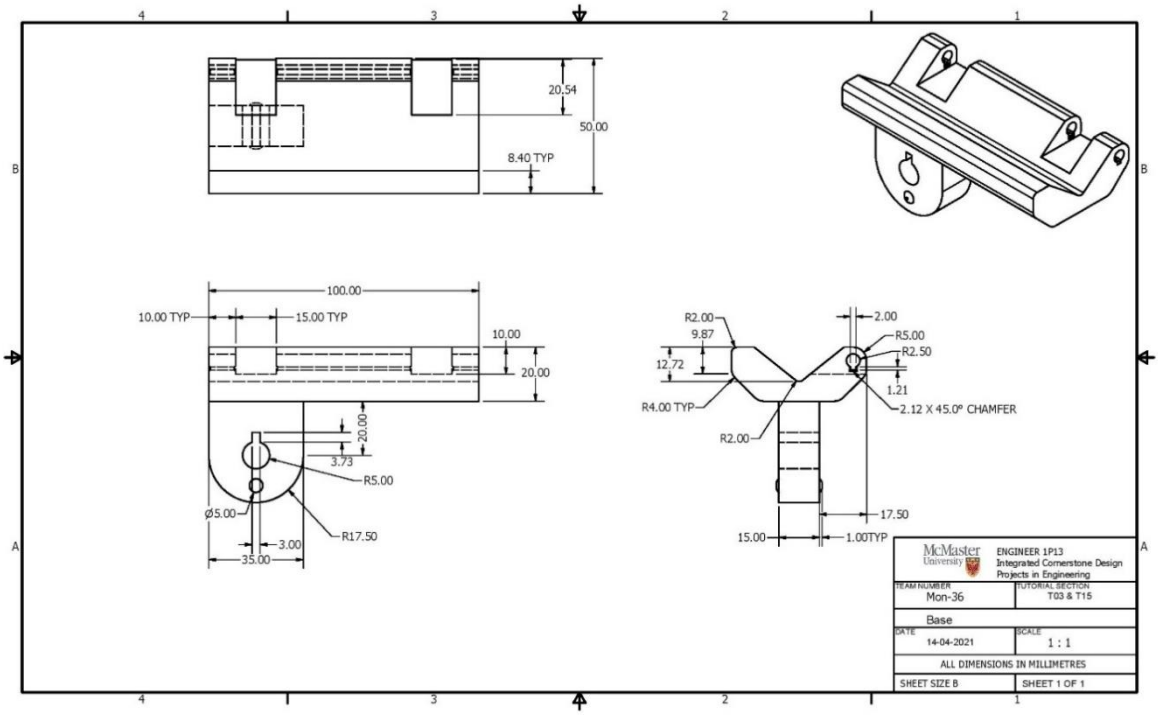


Figure 49: *Engineering Drawing - Base*

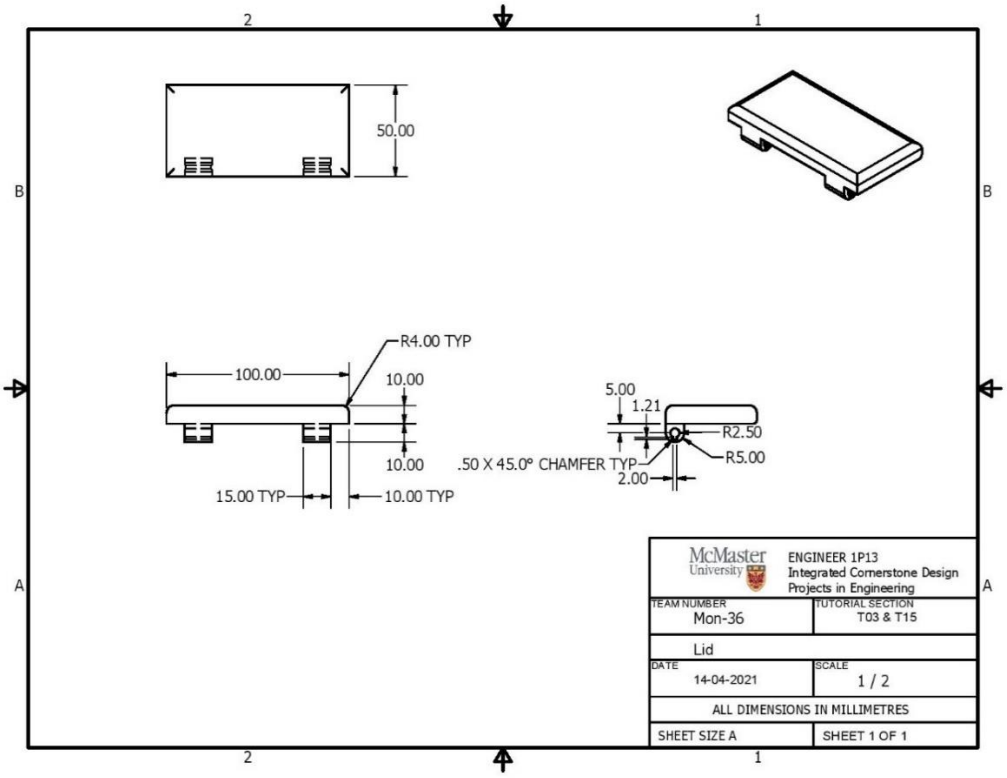


Figure 50: *Engineering Drawing - Lid*

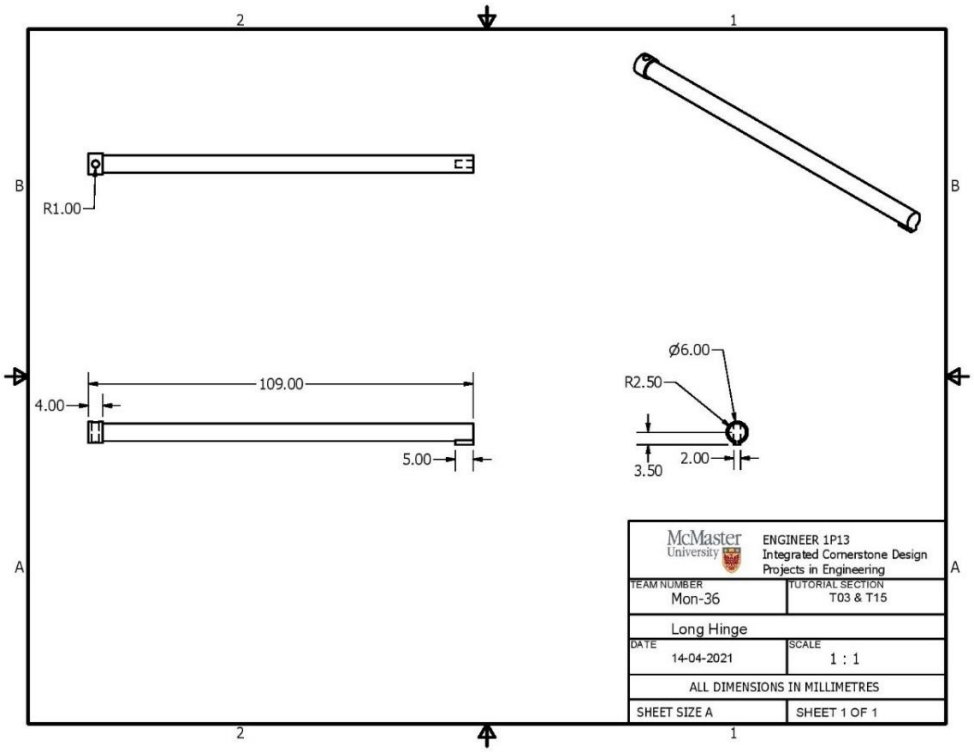


Figure 51: *Engineering Drawing - Long Hinge*

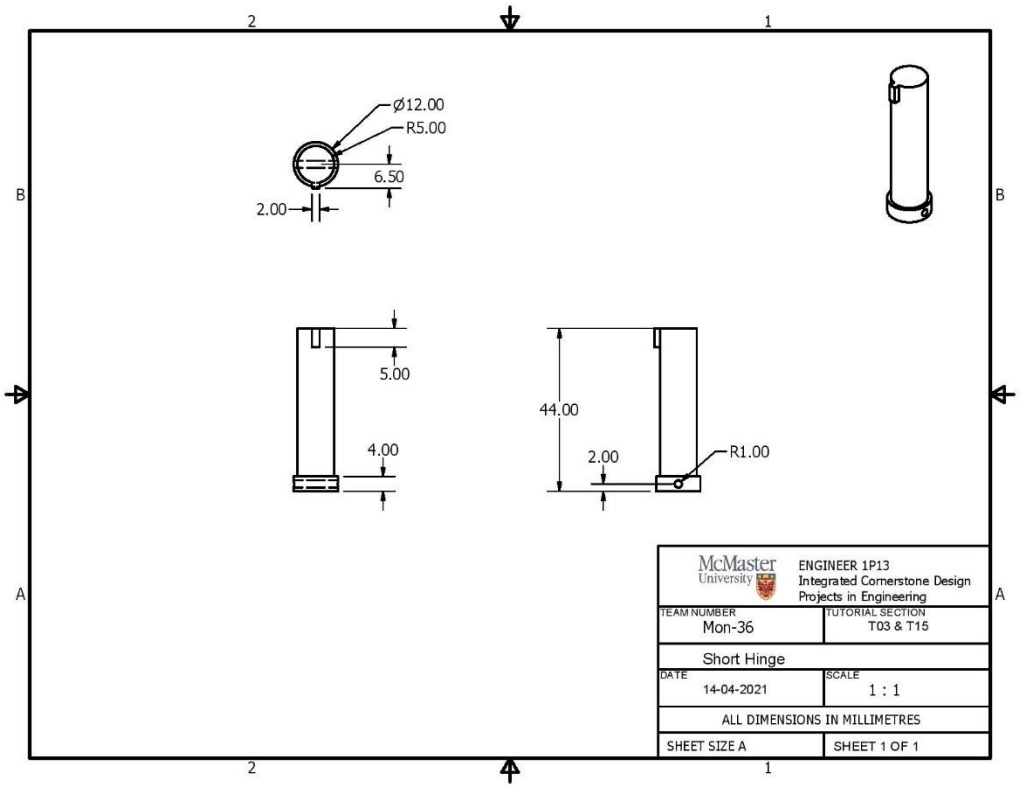


Figure 52: *Engineering Drawing - Short Hinge*

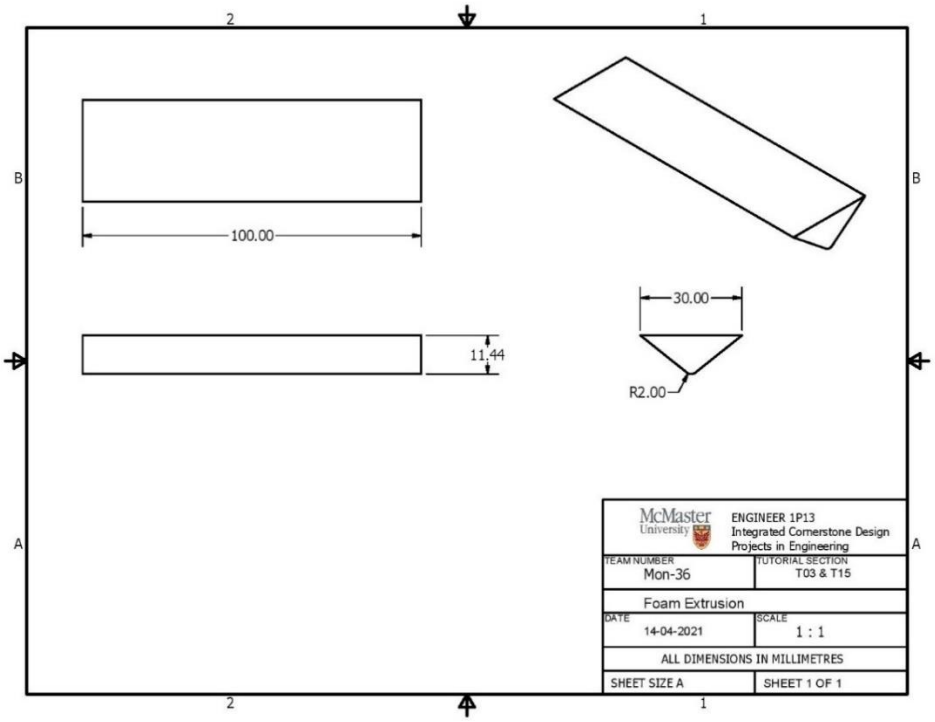


Figure 53: *Engineering Drawing - Foam Extrusion*

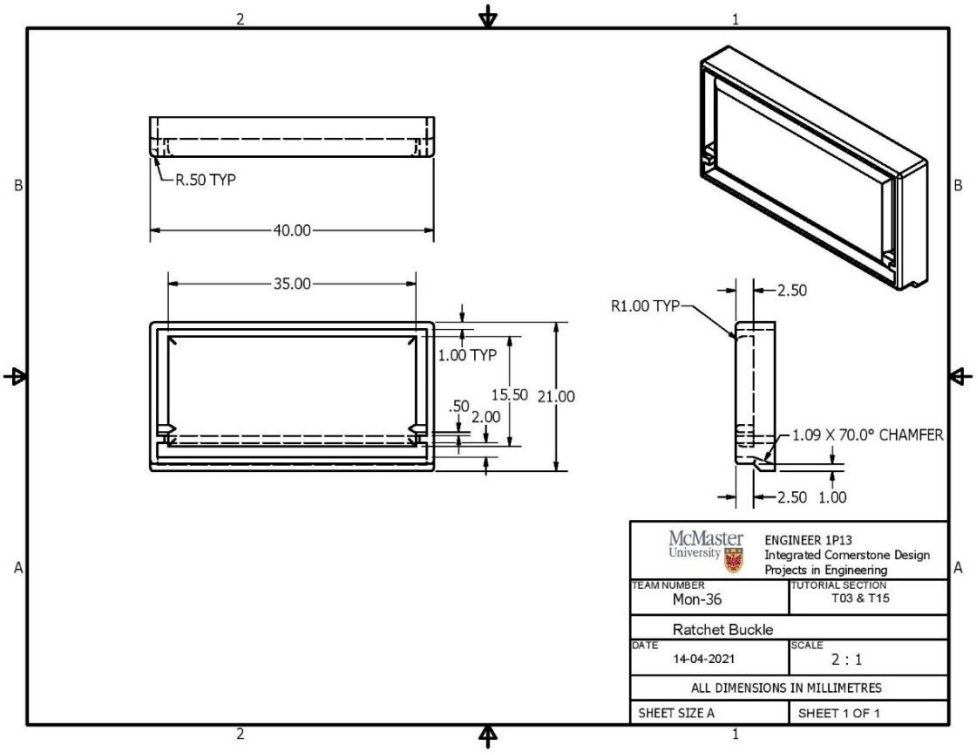


Figure 54: *Engineering Drawing - Ratchet Buckle*

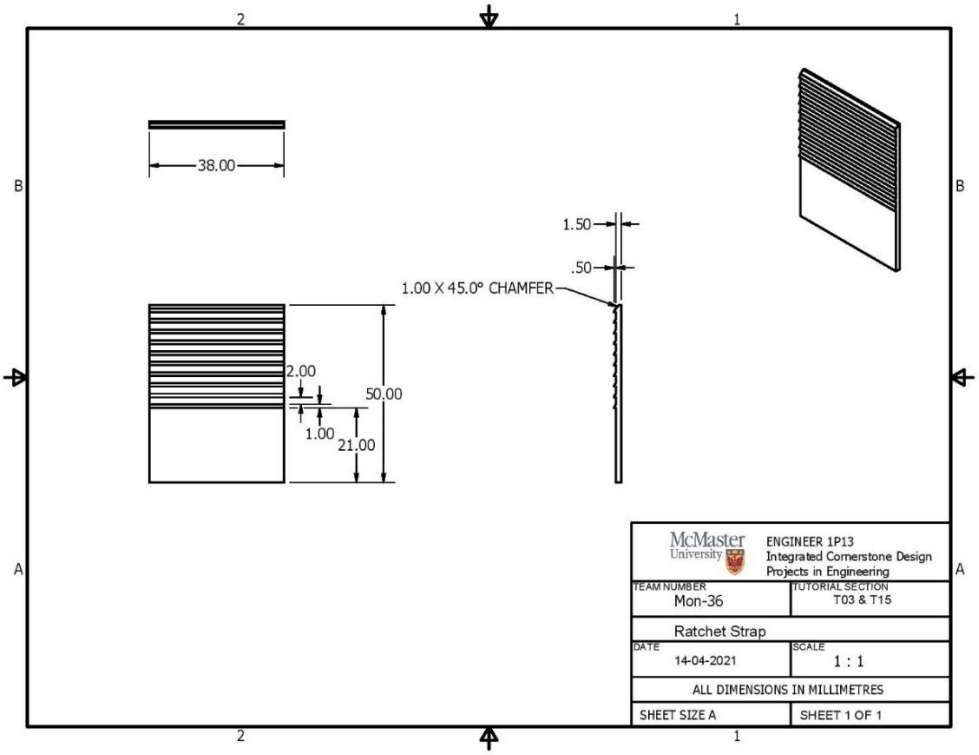


Figure 55: *Engineering Drawing - Ratchet Strap*

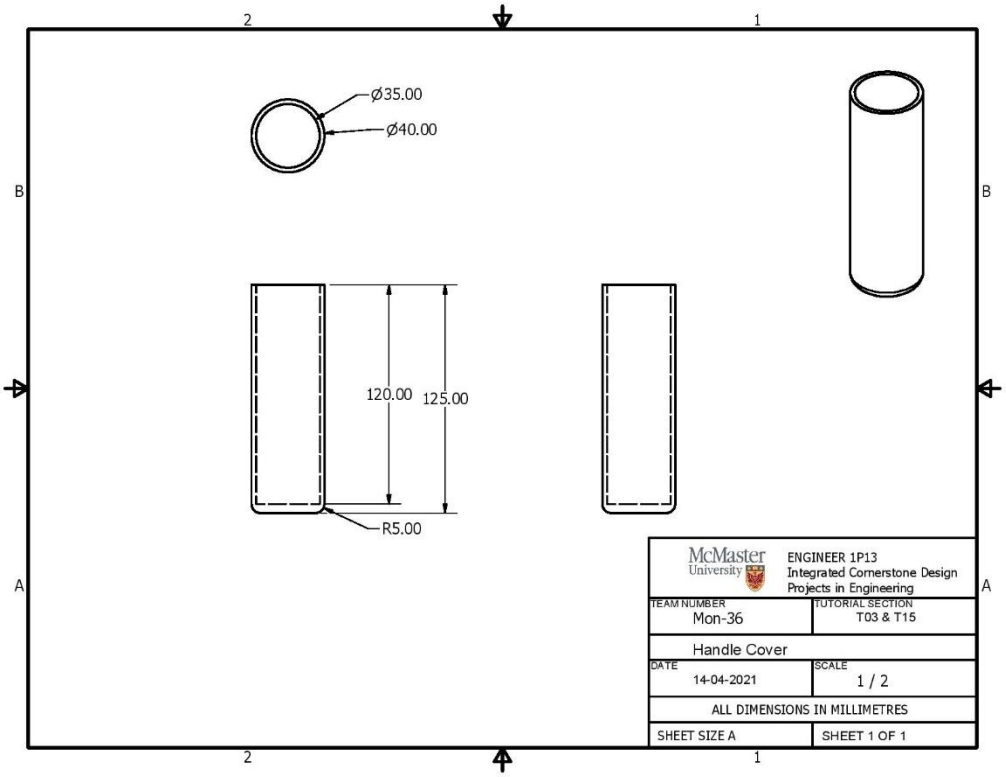


Figure 56: *Engineering Drawing - Handle Cover*

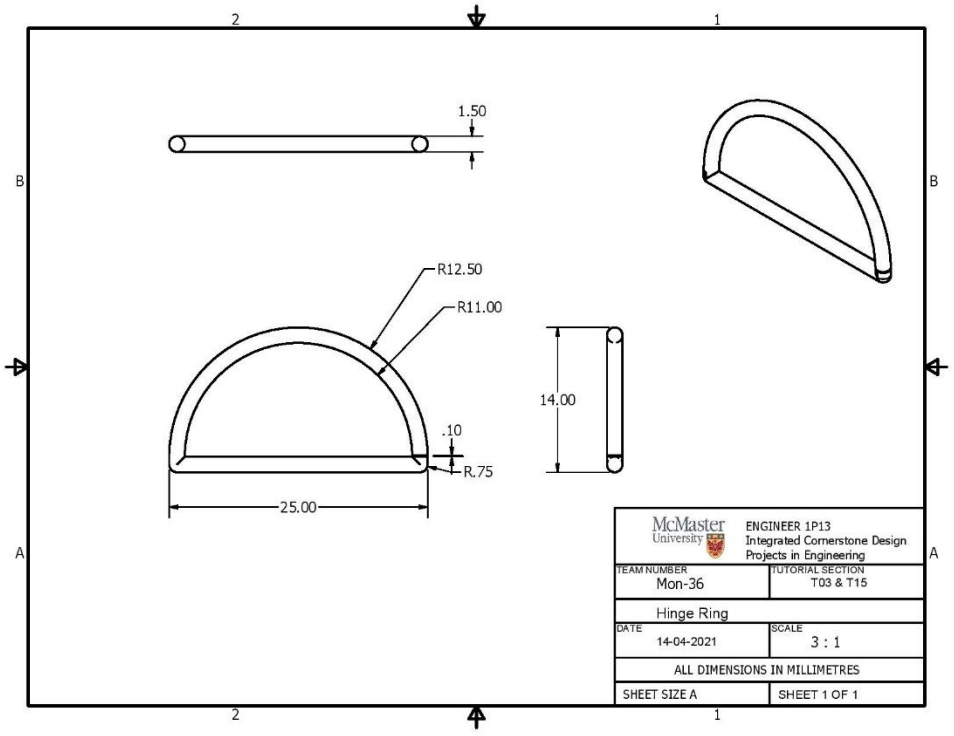


Figure 57*: Engineering Drawing - Hinge Ring*

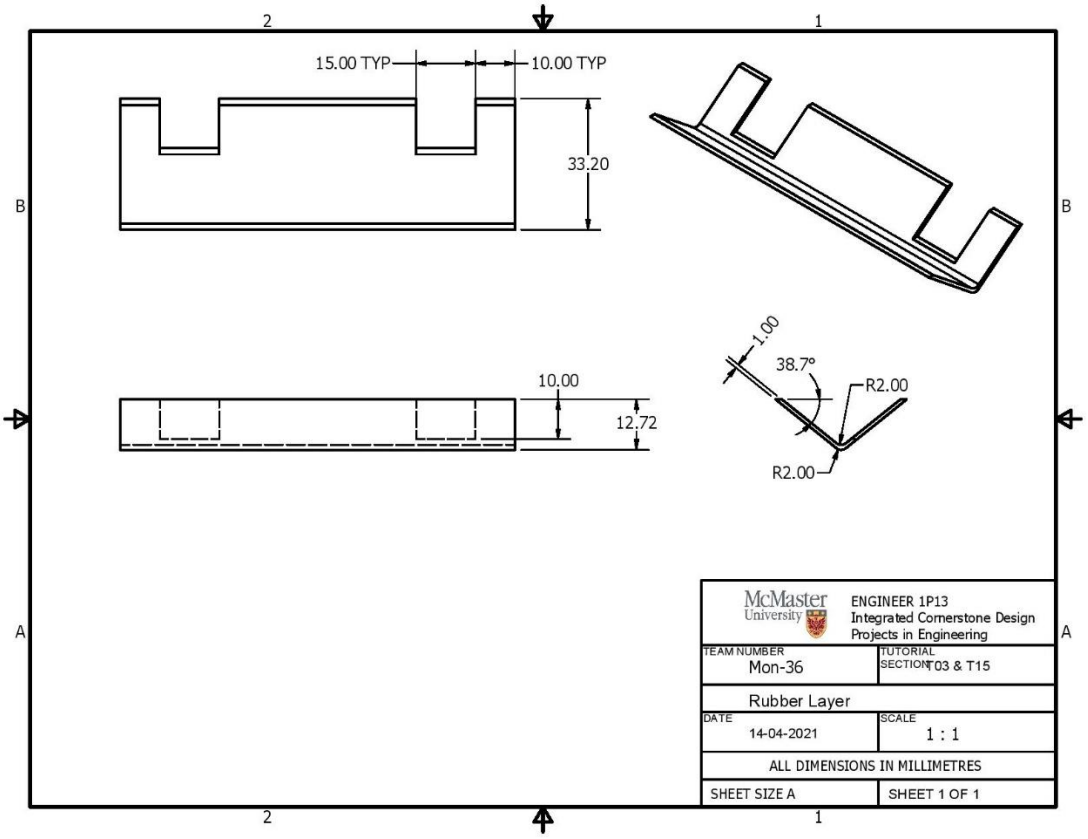


Figure 58: *Engineering Drawing - Rubber Layer*

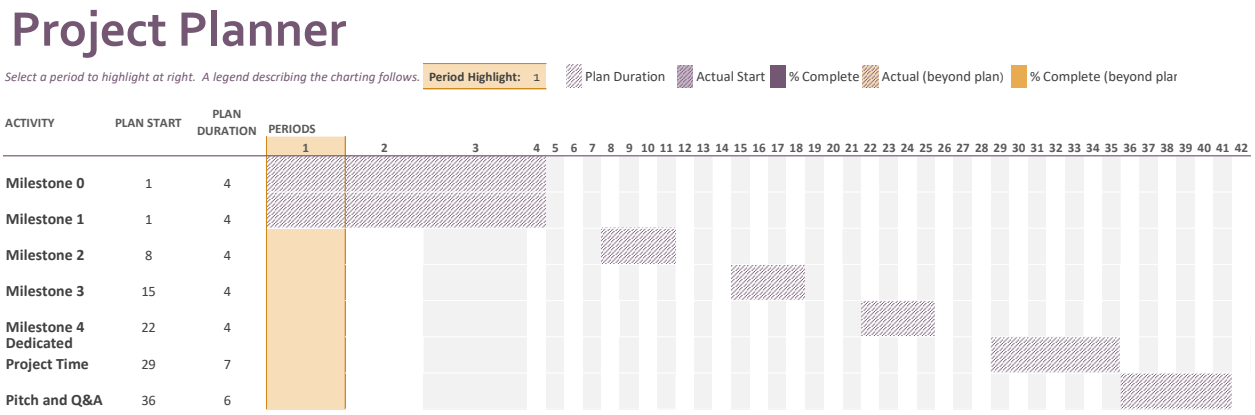
Table 2 Bill of Material:

Parts	**Quantity**	**Price of Each Part ($)**	**Cost of Parts ($)**
Ratchet	1	≈0.08518	≈0.08518
Ratcheting Strap	1	≈0.05852	≈0.05852
Lid	1	≈2.03724	≈2.03724
Foam Extrusion	1	≈0.17950	≈0.17950
Long Hinge	1	≈0.32502	≈0.32502
Short Hinge	1	≈0.53573	≈0.53573
Hinge Ring	2	≈0.01635	≈0.03270
Rubber Surface	1	≈0.07133	≈0.07133
Base	1	≈3.11555	≈3.11555
Handle	1	≈3.62944	≈3.62944
Handle Cover	1	≈0.40990	≈0.40990
		Total Cost:	≈10.48011

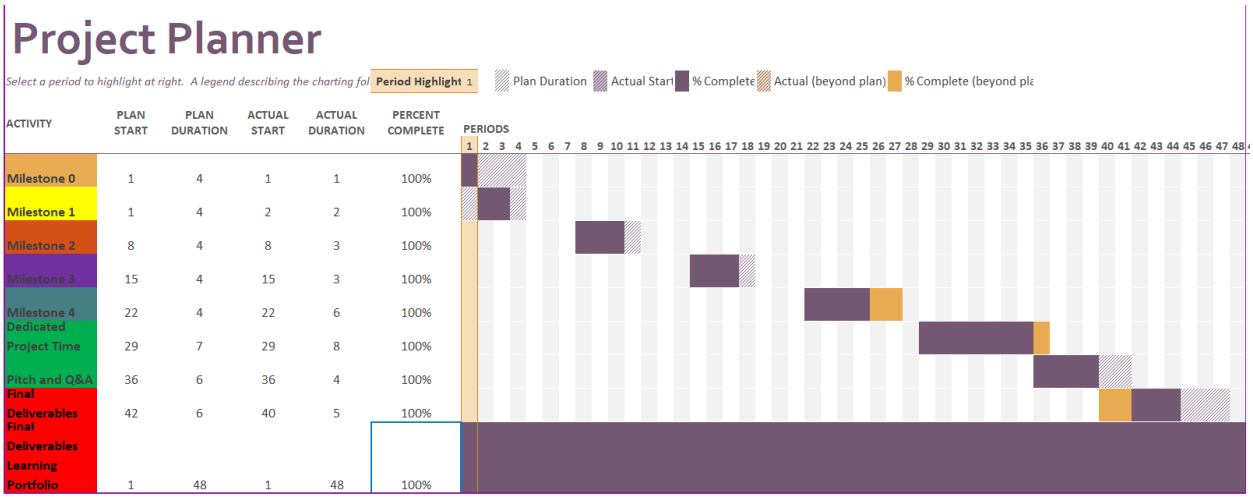
Appendix B

Section 4

Preliminary Gantt Chart



Final Gantt Chart



Logbook of Additional Meetings and Discussions: LINK

Section 5

Source Materials Database

[1] "Triple amputee back behind the wheel - YouTube." https://www.youtube.com/watch?v=Z1A_3eolJJs (accessed Apr. 12, 2021).

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[3] "Drill Chucks Technical Information | MSC Industrial Supply Co." https://www.mscdirect.com/basicsof/drill-chucks (accessed Apr. 12, 2021).

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[5] "10 Pieces Synthetic Hair Paint Brush Set, Blue, for Acrylic, Oil and Watercolor Painting (1 Set): Amazon.ca: Home & Kitchen." https://www.amazon.ca/dp/B0743GKDYM/ref=redir_mobile_desktop?_encoding=UTF8&aaxitk=U9wy4zgKhnE57HR.SlzMpw&hsa_cr_id=9868455200801&pd_rd_plhdr=t&pd_rd_r=a0bf0409-6bd7-475b-a5b9-80149474133d&pd_rd_w=DtqY5&pd_rd_wg=396IW&ref_=sbx_be_s_sparkle_mcd_asin_0_img (accessed Apr. 12, 2021).

[6] "Holzerzeugnisse Deml | Paintbrush handles." http://deml-gmbh.com/cms_eng/index.php?page=alias (accessed Apr. 12, 2021).

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Tools & Home Improvement." https://www.amazon.ca/Mokani-Ceilings-Paintbrush-Professional-Architects/dp/B08DKPZQWH/ref=sr_1_5?dchild=1&keywords=paint+brush&qid=1615823256&sr=8-5 (accessed Apr. 12, 2021).

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