
Project Four – Power in Community

Stabilizing Gauntlet Paintbrush

ENGINEER 1P13 – Integrated Cornerstone Design Projects

Tutorial 17/11

Team Fri-38

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Academic Integrity Statement

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Caleb Garbe

400299054

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Harikashan Thayeswaran

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Ansh Tiwari

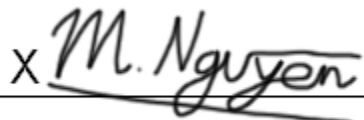
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Handwritten signature of Ansh Tiwari, featuring a stylized 'A' and 'T' intertwined.

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Michael Nguyen

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Executive Summary

In project 4, team Fri-38 was introduced to a client from the community facing various ailments that impaired her ability to function day to day as a creative, and active mother to young children. While the client used to enjoy hobbies like gardening, painting, and Brazilian Jiu-Jitsu, conditions including ankylosing spondylitis, chronic lymphedema, and fibromyalgia had severely limited her range of motion and tolerance for the activities that she held so dear to her heart. Fri-38 was assigned the broad sweeping task of designing a device that would improve the client's quality of life in some way. Upon hearing her speak in several guest lectures, it was clear that the most important ability that the client had lost was her ability to paint comfortably for extended periods. As will be discussed further in far more detail, the final prototype had to be physically comfortable, minimize the effect of any hand tremors on the quality of painting, and encourage movement to counter the client's various muscular conditions. Through the process of conceptual design, the below final prototype for the "Stabilizing Gauntlet Paintbrush" was conceived.

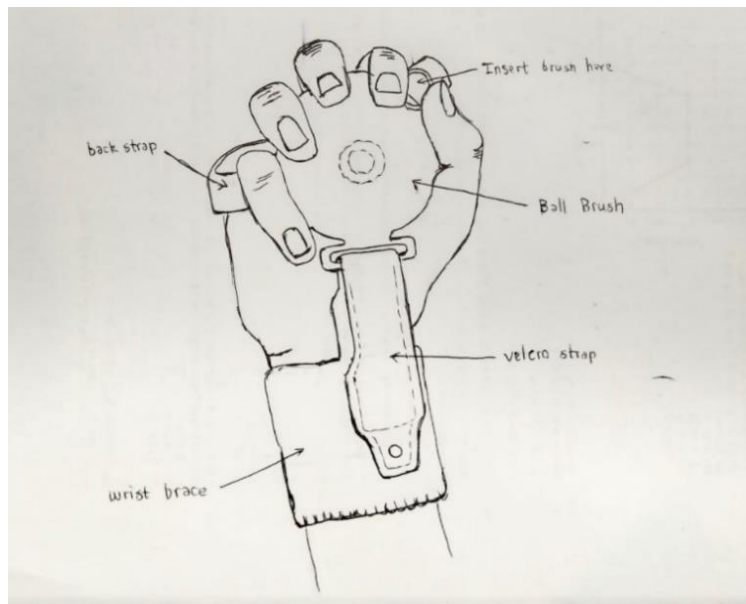


Figure 1. Final prototype sketch

The prototype is comprised of two main parts that accomplish each objective. The first component is a ball made out of thermoplastic; a synthetic rubber material often used in stress balls that allows the structure to "squish" when pressure is applied. The ball is the part of the device that the client holds on to. The shape of the ball allows the user to maintain a natural position while painting and the give of the material allow the user to periodically exercise the muscles that are primarily affected by her ailments. This feature is one of the most unique parts of the device. While most design solutions focus on accommodating the effects of the client's muscular conditions,

the stabilizing gauntlet paintbrush focuses on preventative measures aimed at reducing the frequency and magnitude of debilitating symptoms from the client's ailments. The client's ability to squeeze the device periodically as a preventative measure. The other main component of the device is the wrist/forearm strap. This piece was designed to counter the tremors that the client often experiences in her hands. The idea is that attaching the ball component to the wrist strap, will stabilize the entire lower arm/hand region and greatly reduce the effects of any tremors that the client might experience. This feature allows the client to paint with greater precision and less frustration resulting from involuntary hand movements. The prototype is discussed in further detail in the subsection *Final Proposed Design*. If more time and money were allocated to the development of the stabilizing gauntlet brush, the most effective use of said resources would be actualizing a physical prototype that the client can wear. This would make implementing a testing plan far more effective and would allow for the theory behind the different mechanisms in the design to be evaluated in a tangible way. Ideally, many more prototypes would be made and tested until the perfect design is constricted. Further, the quality of materials can be improved. For example, the ball component was budgeted as a stress ball purchased from Walmart however with more time and resources, the ball could be tailor-made to have the ideal young's modulus for a part serving the purpose of the ball. Increasing the quality of materials would also ensure that the physical comfort of the client is maximized, fulfilling one of the main design objectives.

Introduction

Relevant Background Information:

When working on this project, the main objective was to create a mechanical device for the client to assist them while painting. The client finds painting as one of their favourite ways of relaxing, so we decided to focus on helping the client paint. Our client is a painter that suffers from many difficulties such as lymphoedema, fibromyalgia, and spondylitis. The client's lymphoedema gives her difficulty using her fingers to grip a paintbrush as her fingers cramp up and swell when gripping it. The client also suffers from unpredictable tremors that negatively affect her ability to paint. When designing our solution, we also had to consider other factors, such as material to use (as the client's skin is sensitive to some material), and certain factors that she feels are comfortable.

When coming up with methods for building a device suitable for our client, the first thought that came to mind was the client's safety. When the client is painting, gardening, or completing any other daily task, her safety should be the main priority as there are numerous ways that the device can cause her pain [1]. According to research collected, the clients' lymphoedema has a significant effect on her ability to grip a paintbrush as she

cannot grip it for a long time due to swelling and other pain factors. Recent studies show that exercising the affected area will allow the area to handle the pain and complete tasks with reduced difficulty [2]. Exercising the affected area can also reduce the lymph of an affected area, as seen through other patients that faced the same issue [3]. This information led to the idea of implementing a way of lightly exercising the client's affected area while painting without an excessive amount of pain through our mechanical device.

Furthermore, the device made also had to take the client's fibromyalgia into account. Fibromyalgia leads to different forms of pain all around the body which causes a lack of concentration, sleep, and mood disorders [4]. These effects can affect the intricateness of the client's painting negatively and the goal of the device is to oppose that effect. Through research done, the best alternative method of treating fibromyalgia instead of prescription pain killers is "self-management" techniques such as muscle strengthening [4]. This aligns with our idea of implementing a way of lightly exercising the client's affected area while painting as it decreases the repercussions of lymphoedema and fibromyalgia. The device would also have to focus on the comfortability of to help with the client's Fibromyalgia [4]. One way to implement more comfortability is to use soft material for the device's components that come in contact with the skin. The device would also have to be lightweight to reduce the force of gravity put upon the client's wrist and arm.

Refined Problem Statement:

Create a mechanical device for those living with disabilities to use within the home or studio that would allow the user to be more comfortable while painting. This will be done by creating a device to stabilize the wrist, prevent excessive movement and encourage movement in the fingertips while painting.

Objectives and Constraints:

The first objective was the low production cost of the device. We wanted the device to be affordable for all so the client would not hesitate to buy the device. The idea of buying an expensive device would add more unnecessary stress and frustration to our client. The product made should be made of durable material that is at a reasonable cost so it can perform efficiently. Furthermore, the device should have a low maintenance cost to expand the product's lifeline rather than dispose it of due to the inability to repair it. This objective would be measured in dollars.

The second objective is to make the device physically comfortable. The product should not hurt or make the client uncomfortable in any way. When the client wears the device, it should not feel rough upon the client's body. Moreover, the device should be flexible, and the moving components should not require much effort to operate. This objective would be measured in a rating system for the device's comfortability from 1-10.

The third and final objective is to make the device easy to use for the client. The device should be accessible to a wide variety of individuals. The client mentioned that they are not technology-oriented, so the device should include electronics and intricate mechanisms. This would also correlate to minimizing the maintenance costs as it would allow the device to work for a long time period. The objective would be measured through a stress analysis test (stress response).

The one constraint that the device had was the weight of device. According to our client, the max weight she can lift is 5-10 lbs, so the mechanism had to be significantly lower than that in order for the client not to have any trouble lifting the device.

Existing Ideas/Solutions:

In the past, there was one commercial device and one patent that was made that influenced how our design was created in the end. One of the patents was a stress ball with a strap attached to it to be secure [5]. This product was used for rehabilitation for the client. The strap was mainly used for the stress ball to be secure in the buyer's hand. This idea impacted the thought process for the design as a strap can help the client secure the object as she may sometimes drop it. The idea of adding more straps to assist the client with her hand tremors was also integrated into the design as an extra component.

The patent device that influenced the design was called the paint can handle. This device consisted of a strap attached to the member for securing the object, a strap that is a band portion (for tensions), and a band lock [6]. This patent device allows a client to hold an object with wrist straps, steadily securing their hand using the force of tension [6]. This influenced the device made as the idea of wrist straps utilizing the force of tension to allow a user to hold an object with a minimal constraint of movement on the hand is beneficial to the client's tremors.

Conceptual Design

The conceptual design process used in the creation of the stabilizing gauntlet brush allowed for many different unique concept sketches and prototypes. Almost immediately after meeting the client, the group decided to veer in the direction of helping the client to paint more effectively and for longer periods of time. In the interest of staying open to as broad of a spectrum of design concepts as possible, functional analysis was performed using a morphological chart (Appendix B, Table 1). It was determined that the creative, more abstract nature of the morphological chart tends to allow for a broader range of concepts and ideas when compared to the alternative option, that being a decision matrix. A decision matrix requires that one has a more concrete idea for their design already in mind, whereas the morphological chart encourages thinking that leads to many of these concrete ideas. The four main functions dictated that the design must make it easier to produce intricate details while painting, encourage movement, be easy to hold and be able to stabilize the hand. A variety of means to accomplish these goals were conceived and each group member picked a combination of them to form two concept sketches.

Ideas from the magnetic squish brush (Appendix B, Figure 1), magnetic strap brush (Appendix B, Figure 2), the sponge strap brush (Appendix B, Figure 3), and the motion sensor-based hand stabilizer (Appendix B, Figure 4) concept sketches were carried forward in the design process to the initial prototyping stage. The initial prototyping stage led to one concept per group member which can be seen in appendix B, figures 6-9. In order to evaluate the devices, the decision matrix seen in tables 2 and 3 in the appendix B was used. The prototypes were evaluated based on how well they accomplished the criteria of lightweight, ease of assembly, ergonomic shape, durability, and tactile comfort. Every decision made in the design process to that point had first and foremost concerned the client's comfort. That means that the comparative decision matrix used had an emphasis on things that influence comfort, above all. For example, four out of six of the criteria used (tactile comfort, lightweight, adjustability, and ergonomic shape) all dealt directly with what the client would feel in her hand while she paints. Tactile comfort encompassed different things related to a sense of touch such as soft material and rounded edges. The lightweight criterion was exactly how it sounded in that it judged the concepts on whether they were light enough to be held for an extended period of time by the user. Adjustability concerned how well the device could adapt to the user depending on her situation as we know that she often suffers from swelling and other things that could alter the temporary structure of her hands. The final criterion relating directly to the client's comfort was the ergonomic shape. This judged the concept's ability to keep the user's hand in a sustainable position for extended periods of time. The other two criteria used were durability and ease of assembly. Ease of assembly was deemed the least important criterion simply because it did not affect the client in any way, but rather, the group's ability

to actualize the design. Durability was seen as an important criterion as the design needed to be something the client could use many years into the future. It was quite difficult to use any metrics other than a simple rating and comparison between the possible concepts when it came to the rankings. For example, for things like mass and softness of the chosen material, it would have been difficult to obtain an accurate measurement because the concepts put forth were only low-fidelity prototypes and did not fully reflect the nature of the real design vision. After these steps were taken to craft the perfect decision matrix, two designs prevailed. These designs being the ball brush with the strap and the motion sensor glove. The concepts were the two highest-scoring out of the four and since so much care was taken when designing the decision matrix, it was felt that the outcome of the scores to determine which designs would be taken further in the design process, was reliable.

Another large component of the project 4 design process was receiving feedback from peers, TAs, and science students (Appendix B, Table 4). Above all, the TAs and science students encouraged combining the two remaining prototypes into one final design. After this feedback, peers assisted with finding different ways to ensure that the combination of the two designs did not result in a prototype that was too stiff to support a wide array of movements. This was very important to consider as it would have greatly hindered the client's fine motor abilities while she was painting, essentially ensuring the opposite of one main objective for the design, that it would make it easier for her to paint. The result of this rigorous design process was a streamlined device that will make it easier for the client to paint for extended periods of time.

Final Proposed Design

Design Description and working:

The design consists of a ball handle with a back strap and a wrist strap (Appendix C, Figures 1-4). The ergonomically designed ball grip is held within the hand of our client while painting. It is made of synthetic rubber and can be squeezed. The squeezing of the ball supports hand dexterity as it accommodates small movements of her hands and any muscle spasms. There is a back strap attached to the ball that goes around the back of her hand so the hand can fit into it. The back strap allows the client to rest her hand and it prevents any sudden dropping of the ball.

The ball has a paintbrush socket positioned such that it stays between the index finger and the thumb while the client is holding it. Paintbrushes owned by the client can fit it. The socket is a small cylindrical attachment to the

ball and is made of PVC Coupler. The inner part of the socket is made of sponge as it has the ability to take any shape. The sponge can extend to a variety of diameters which allows the client to fit brushes of different shapes and sizes into it. While the brush is resting inside it, the spongy material applies pressure on it and keeps it secured at the position.

There is a wrist strap that is worn around the arm to keep it firm while painting. The wrist strap provides support to the client's hand and minimizes the effect of hand tremors. It is designed to wrap around the client's arm and give strength to it and keeps it firm for longer periods.

There is a small buckle present at the bottom side of the ball. The back strap also has two wide gaps. The wrist strap is connected to the ball through a wide Velcro strap at the front which goes through the buckle at the bottom part of the ball. There are two Velcro straps at the back coming out the wrist strap and roll through the gaps present on the backstrap of the ball brush to connect the wrist strap to the back strap. The Velcro straps are covered with a soft spongy material so that the Velcro does not make any contact with the body and the soft material which makes contact with the body accounts to provide tactile comfort. The Velcro is chosen because it is length adjustable, and the client can tighten or loosen it easily according to her comfort.

Objectives/constraints met:

The design aligns with our objectives and constraints. Our first objective was low production cost and low maintenance. The total cost of production we came up with required is \$37 (Appendix C, Table 1). This cost is affordable and includes all the materials that can be used in making the device. The device does not require any maintenance and since most of the components are non-rigid or soft such as the ball made of synthetic rubber or the elastic wrist brace, it does not crack or break on harsh treatment or accidental dropping. This removes any repair cost and makes the device very durable.

The second objective is to make the device physically comfortable. The ball has a round shape and does not have any corners or edges which makes it very easy for the client to hold it and does not feel rough in the hand. The device also ensures tactile comfort as we are using soft spongy covering over Velcro and the Velcro itself does not make any contact with the user's body preventing any abrasion. Further, the wrist brace is designed such that the user does not feel any tightness while wearing it and it is made of elastic which makes it feel comfortable on the skin. It is rated is 9/10 on a scale of comfortability. One point is lost as the Velcro can still cause abrasion on accidental rubbing with the skin.

The third and final objective is to make the device easy to use for the client. The ball supports hand dexterity as it has a wide grip and is a bit squeezable. The paintbrush socket is having spongy material on its inner side and so it can accommodate brushes of different sizes used by the client. The design accommodates the hand tremors and gives strength to the user's hand. The Velcro strap is length adjustable so the client can wear it according to the tightness desired by her. The device does not have any complex mechanism or small parts and its usage is easily understandable by any user. Since all the parts are flexible, they can bear weight and the device does not break if kept under some heavy object.

The device is lightweight. Since most of our materials are non-rigid and soft, the overall product weighs around 1.5 pounds. Hence, it aligns with the weight constraint as the client can lift 5 pounds so our device should not make the client feel any burden on her hand.

See (Appendix C, Table 1) for the **Bill of materials**.

Justification of Materials Used:

The ball is made of thermoplastic which is long-lasting and flexible [7]. The back and the wrist straps are made of strong elastic which is flexible and can bear high stretching [8]. A good quality Velcro can bear many cycles of operations and is best for tasks involving frequent opening and closing [9]. The Velcro is also has components covered with leather to prevent contact with the client's skin [10]. A soft spongy material is best in contact with the skin and does easy to wear even if the skin is swollen. The PVC coupling is best for making a small part that is durable as it is resistant to corrosion and will not cause abrasion [11]. The spongy material is also chosen to consider the effect of Lymphedema on the skin as it swells the skin and since a sponge can change its shape and size, it can be easy on contact with such skin [12]. We also used adhesive material (gorilla glue) to attach all the components together as it makes the device sturdy and durable [13]. Every material used was also of a reasonable cost so the device could be easily replaceable/reparable (Appendix C, Table 1). The prices for each material were found through research on how much each material cost through different retail stores. The cost/m² was found and then used to calculate how much each material would cost based on how much of the material we used.

Conclusions

The product designed by Fri-38 is called the stabilizing gauntlet paintbrush. The product is made up of a stress ball, elastic back and front straps, leather and Velcro connecting straps, a paintbrush socket made of PVC coupling and sponge, and miscellaneous material to attach everything together. If we had more time to develop our design, we would develop more advanced physical prototypes to gain a better sense of how our design would feel for the client while painting. We would test the prototype with a variety of paintbrush sizes and try to figure out ways to improve factors such as ease of use and physical accessibility. We learned a lot throughout 1P13's Design Project 4. One major lesson learned is the benefits of incorporating different ideas from different minds to progress towards an improved final design. Ansh's motion sensor glove sought to reduce the impact of hand tremors on the client's painting, so we found simpler ways to accomplish the same goal. This led to a design that would be much more helpful to the client. Whenever our team ran into disagreements, we learned to rationally determine the next course of action. We assessed our options and came to an agreement as a group as to how we would proceed. It is always best to deal with conflicts in a calm and rational manner. If we were to do this project over again, we would probably focus more on the practicality of acquiring the materials required to construct a fully functional prototype. This would allow us to gain a better sense of how the design would be constructed, along with the materials and costs involved. All in all, we are very satisfied with the project and what we learned from it.

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Appendix A

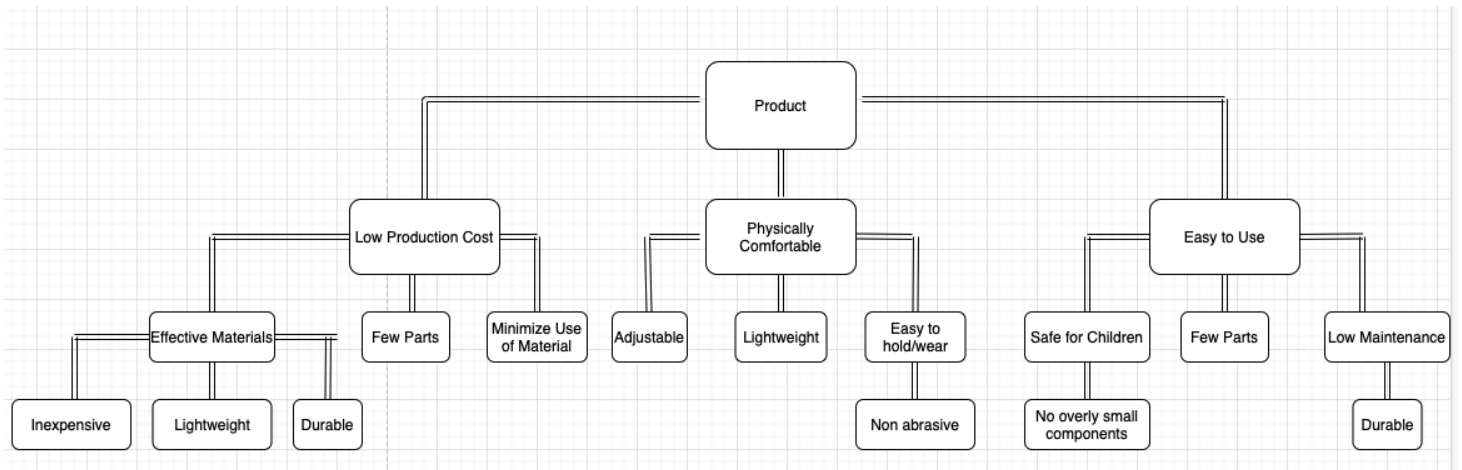


Figure 1. Objective Tree



Figure 2. Commercial Product #1

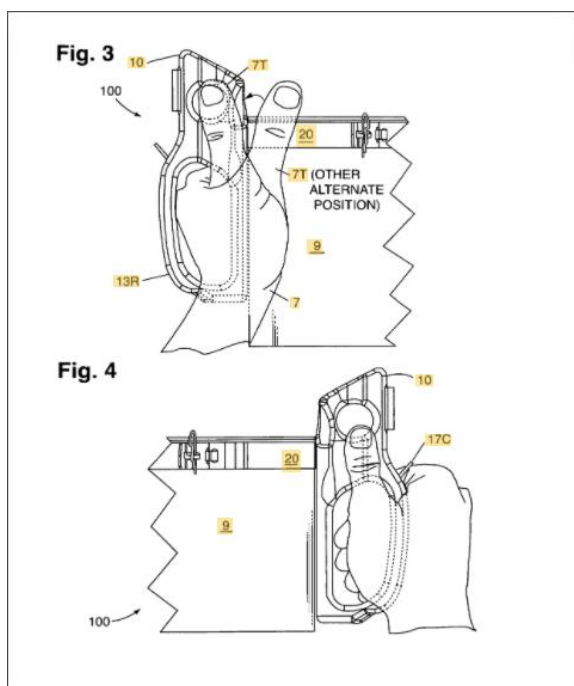


Figure 3. US9021662B1 (Paint can handle)

Table 1. Client Meeting Notes

Client Meeting Notes

- Her upper extremity is a strength for her
- Painting is her occupation
- She has Ankylosing Spondylitis is a medical condition that is episodic and chronic
- Exercises would help her according to physical therapists
- She hasn't tried holding the paintbrush in a different way, and she can adapt very easily to abstract work, but she does not envision adapting to detailed paintings
- Ankylosing Spondylitis primarily impacts the base of her spine, her hands are not currently impacted by this
- Pain in her hands are from other difficulties
- All her daily activities are more difficult compared to when she did not have any pain
- Bending at her waist is much more painful, doing squats would be better for her, but she can only do so much a day
- The largest painting she has done is about 10 feet x 10 feet
- The maximum load she can lift is about 5 to 10 pounds
- Client enjoys only painting in her studio
- She grows her plants from already planted ones from the store
- Built raised beds in a garden facility in Philadelphia
- Indoor plants and she had outdoor space that she has not planted
- She has grown vegetables, but does not have patience for it now
- She struggles more using smaller paint brushes

- She has limited range in motion, her hands start to freeze up when having muscle spasms, and she sometimes drops the paint brush. She can only grip the brush for short amount of times
- Prefers to paint on the floor, sits on meditation cushions as a seat, and she uses a stool to place her canvas on. If she places the canvas on the floor, she uses the floor to hold her own body up and paint, it feels easier for her to do this and she is able to paint longer. The closer she is to the ground, the less nausea she has (side-effects to her cancer treatment) because she feels like her body is stabilized. Holding the weight of her own body is exhausting in itself.
- While working with the Arthritis community, she finds repetitive movements painful rather than non-repetitive
- She cannot work with Paper Mache as she cannot work with gluten, she cannot work with some canvas' due to her allergies. She is cautious with chemical components
- Small wrists, right wrist (dominant) is 5 $\frac{3}{4}$ inches at the base and the left wrist (non-dominant) is the same. The width from the tip of her middle finger to her wrist is 6 $\frac{1}{2}$ inches and the crook of the thumb to the outer inch of the hand is 4 inches
- Works with a variety of brushes (sizes) on one piece
- Finger painting was tried (making fine adjustments with her paintings)
- When holding her paint brush, sometimes it affects her arms before the small joints on her fingers and vice versa, it is unpredictable of what will happen first
- Bearing the weight of her own arm is sometimes a lot of work also, she does just have lymphedema in her arms, it's in her torso, along the side, and in her back (specifically in her pectoralis muscle)
- The swelling is minimal as she catches it quickly
- She does not struggle to extend her fingers rather than it is to grasp things with her fingers. It is also easier for her to pull her arms downwards rather than lifting it up.
- A favourite activity that she likes and wants to do less effortlessly is painting as she has a need to leave the world a better place and the way she wants to do that is through painting
- Her wrist motions is similar to writing with a pen
- She does not enjoy fabric with sharp edges, Velcro, and other things that are not comfortable with the skin
- Any material that feels to strong on her will feel more comfortable
- It is more comfortable to hold something with a lighter grip for longer periods of time

Appendix B

Table 1. Morphological Chart

| | Mean 1 | Mean 2 | Mean 3 | Mean 4 |
|--|---------------------|------------------|----------|---------|
| Easier to produce intricate details while painting | Short handle length | Replaceable Tips | | |
| Encourages Movement | Squishy | Spring | Elastics | |
| Easy to Hold | Rounded/Ball shape | Wide Handled | Glove | Magnets |
| Stabilizes Hand | Brace | Strap | Gauntlet | |

Table 2. Decision Matrix Part I

| | Lightweight | Ease of Assembly | Ergonomic Shape | Durability | Tactile Comfort | Adjustability | Score |
|------------------|-------------|------------------|-----------------|------------|-----------------|---------------|-------|
| Lightweight | 1 | 1 | 1 | 1 | 0 | 1 | 5 |
| Ease of Assembly | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Ergonomic Shape | 0 | 1 | 1 | 0 | 0 | 0 | 2 |
| Durability | 0 | 1 | 1 | 1 | 0 | 0 | 3 |
| Tactile Comfort | 1 | 1 | 1 | 1 | 1 | 1 | 6 |
| Adjustability | 0 | 1 | 1 | 1 | 0 | 1 | 4 |

Table 3. Decision Matrix Part II

| | Weight | Ball with strap Brush | | Band with magnet attached to it | | Motion sensor based stability glove | | Ergonomic handle with strap and replaceable brush | |
|------------------|--------|-----------------------|-----------------|---------------------------------|-----------------|-------------------------------------|-----------------|---|-----------------|
| | | Rating | Weighted Rating | Rating | Weighted Rating | Rating | Weighted Rating | Rating | Weighted Rating |
| Lightweight | 5 | 4 | 20 | 2 | 10 | 1 | 5 | 3 | 15 |
| Ease of Assembly | 1 | 1 | 1 | 4 | 4 | 3 | 3 | 2 | 2 |
| Ergonomic Shape | 2 | 2 | 4 | 1 | 2 | 4 | 8 | 3 | 6 |
| Durability | 3 | 4 | 12 | 2 | 6 | 1 | 3 | 3 | 9 |
| Tactile Comfort | 6 | 2 | 12 | 3 | 18 | 4 | 24 | 1 | 6 |
| Adjustability | 4 | 3 | 12 | 1 | 4 | 4 | 16 | 2 | 8 |
| TOTAL | | | 61 | | 44 | | 59 | | 46 |

Table 4. Design Review Feedback

| |
|--|
| Initial Feedback |
| <p><i>Include feedback from peers in this row.</i></p> <ul style="list-style-type: none"> • sometimes she gets heat/cold flashes, and keep it in mind when choosing material and the ease of use/equipping • She has sensitive skin so is a glove a good decision and do you think the motion sensor would be accurate enough to allow her to paint while stabilizing her hands |
| <p><i>Include feedback from science students in this row.</i></p> <ul style="list-style-type: none"> • Flexing the glove will require a bit of power • The thrusters will require some gas • The 2 designs tackle different aspects of movement for the client • See which one of the movements is more important to the client • Make sure she can even hold the brush • Which type of movement should the design facilitate • It might affect the way she paints (harder to get fine details) • If there is a way to bring the bristle closer to her hand • Keep the ball idea but make the lengths of the brushes adjustable • Have a slot in the ball for the client to use her existing paintbrushes in • Combine the ideas possibly |
| Later Feedback |
| <p><i>Include feedback from peers in this row.</i></p> <ul style="list-style-type: none"> • How does she paint up and down? • Think of alternative to Velcro • Consider the variety of brushes she uses • Maybe use an imprint of her hand • Have a mechanism on the end of clasp for different brush sizes • Overall, make sure it can accommodate a bunch of different brushes • Make the connecting rod out of compression cable • Find a balance between elastic and rigid material for rods |
| <p><i>Include feedback from science students in this row.</i></p> <ul style="list-style-type: none"> • Like the brace to the arm • Softer, more flexible attachment from ball to brace • As a concept, merge motion sensor and counterbalance mechanism • Infeasible for the time period but cool concept • Length adjustment for brace |

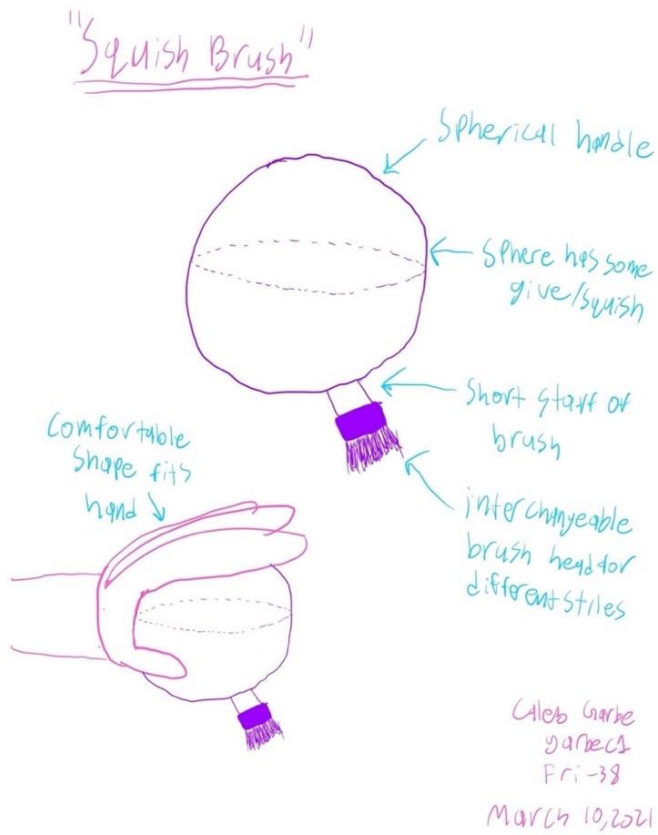


Figure 1. Squish Brush concept sketch

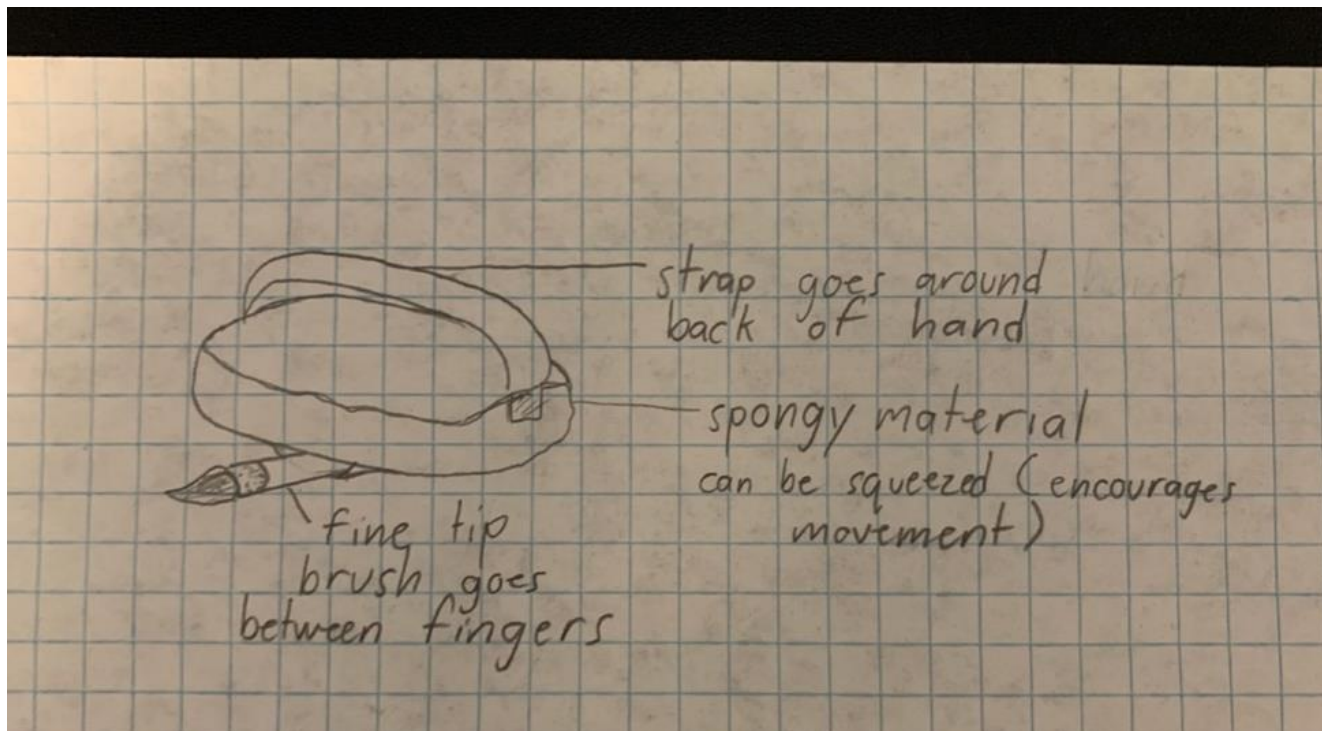


Figure 2. Sponge Strap Brush concept sketch

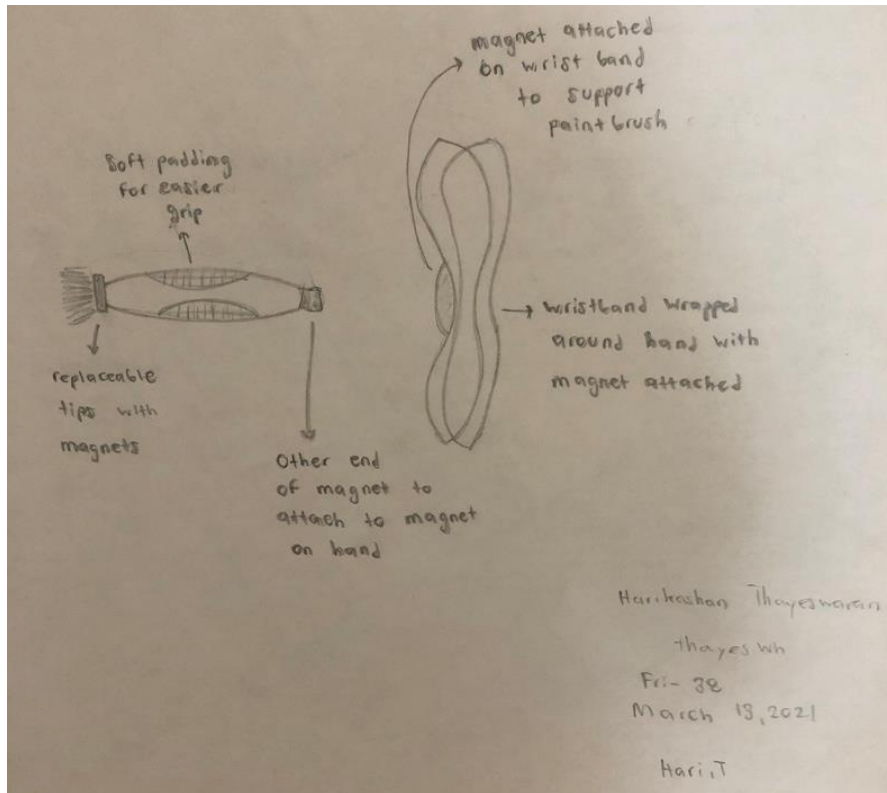


Figure 3. Magnetic Strap Brush concept sketch

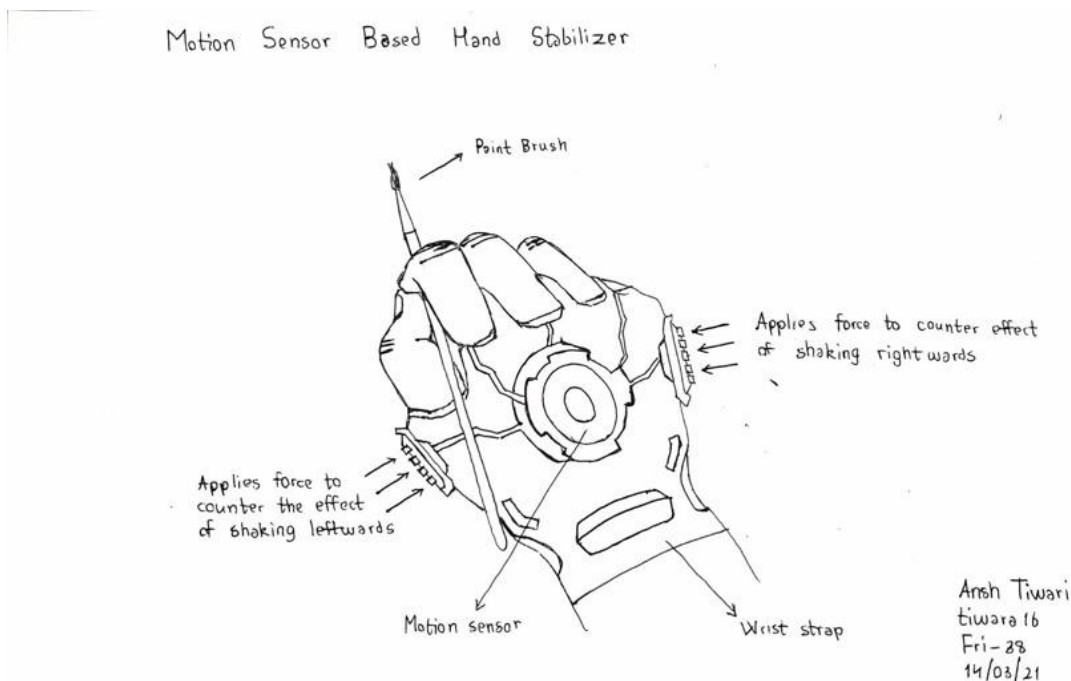


Figure 4. Motion Sensor Based Hand Stabilizer concept sketch



Figure 5. Band with magnet attached to it initial prototype

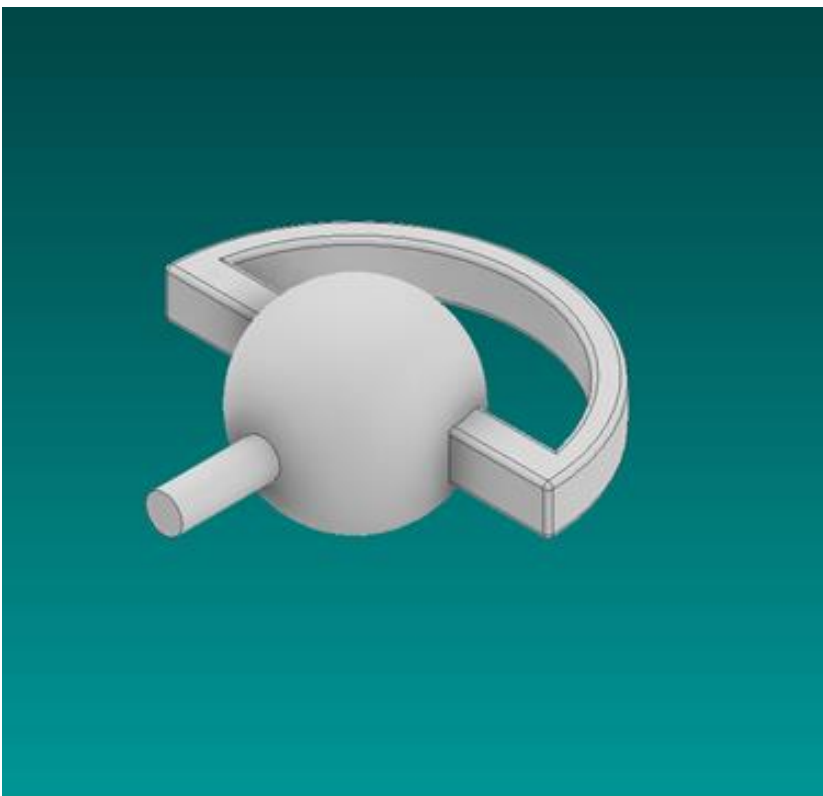


Figure 6. Ball with strap brush initial prototype



Figure 7. Motion sensor-based stability glove initial prototype



Figure 8. Ergonomic handle with strap and replaceable brush initial prototype

Appendix C

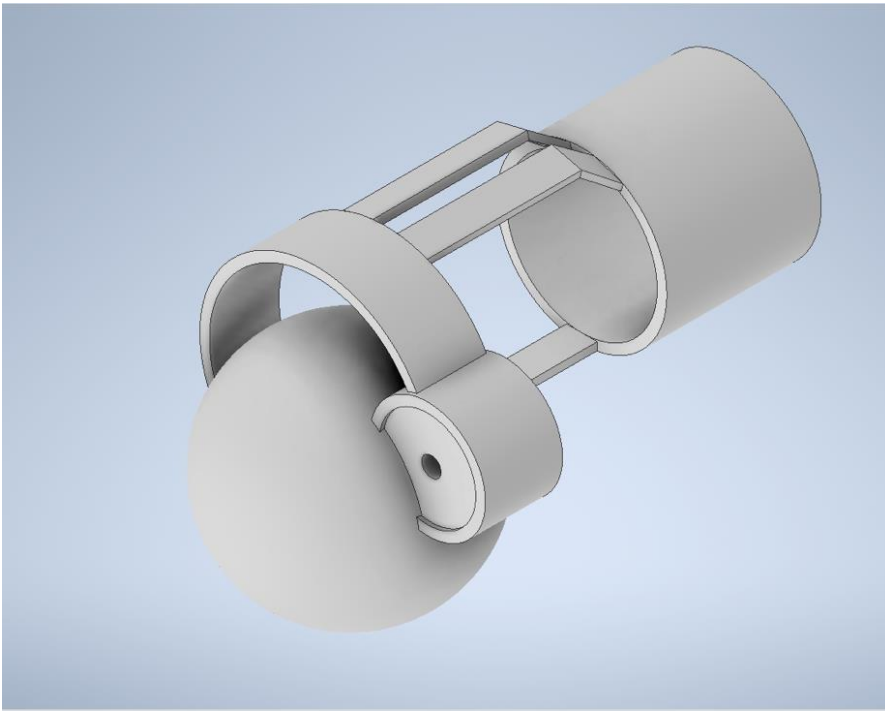


Figure 1. Final Prototype Model Front View



Figure 2. Final Prototype Model Back View

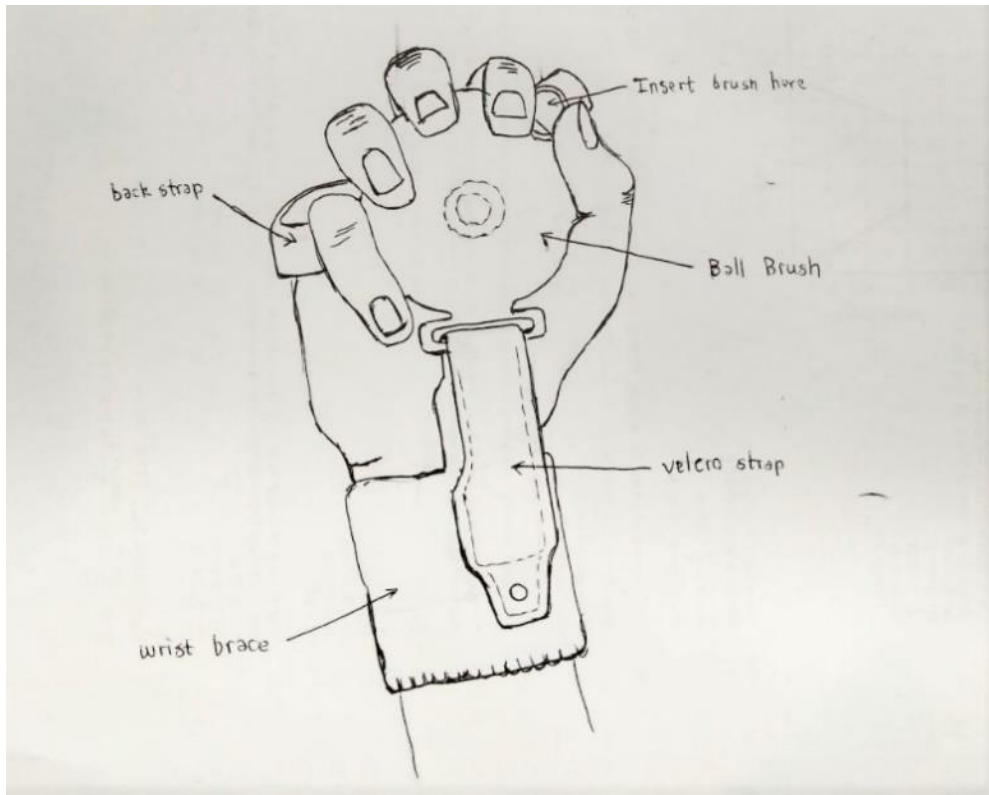


Figure 3. Final Prototype Sketch Bottom View

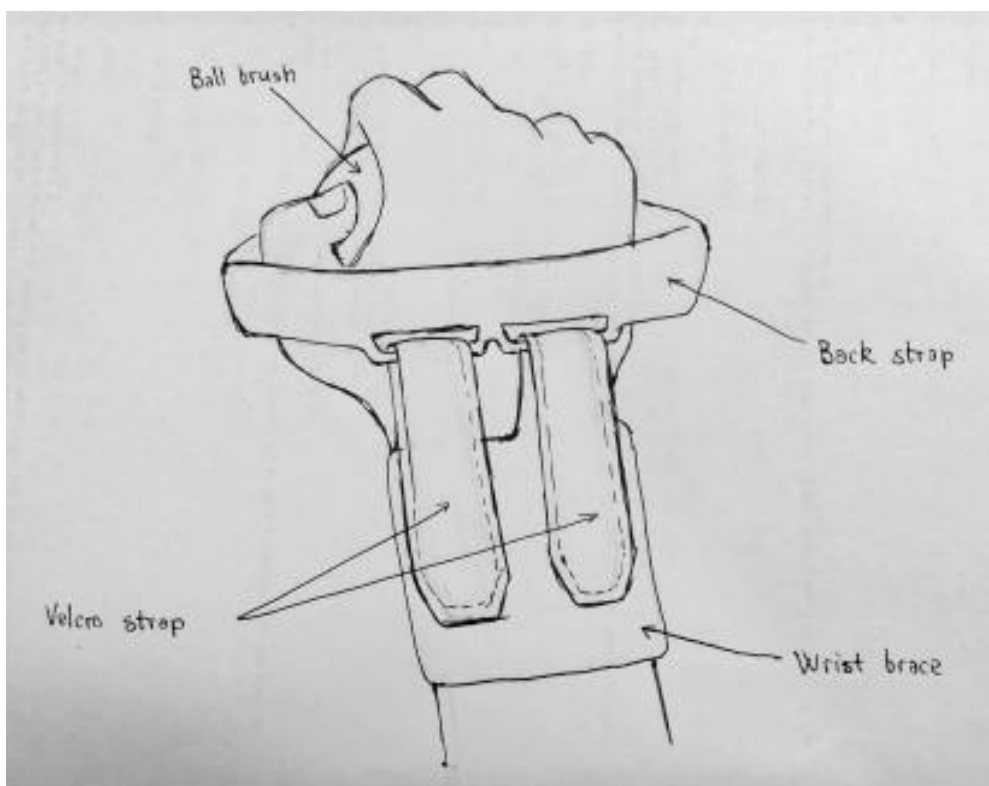


Figure 4. Final Prototype Sketch Top View

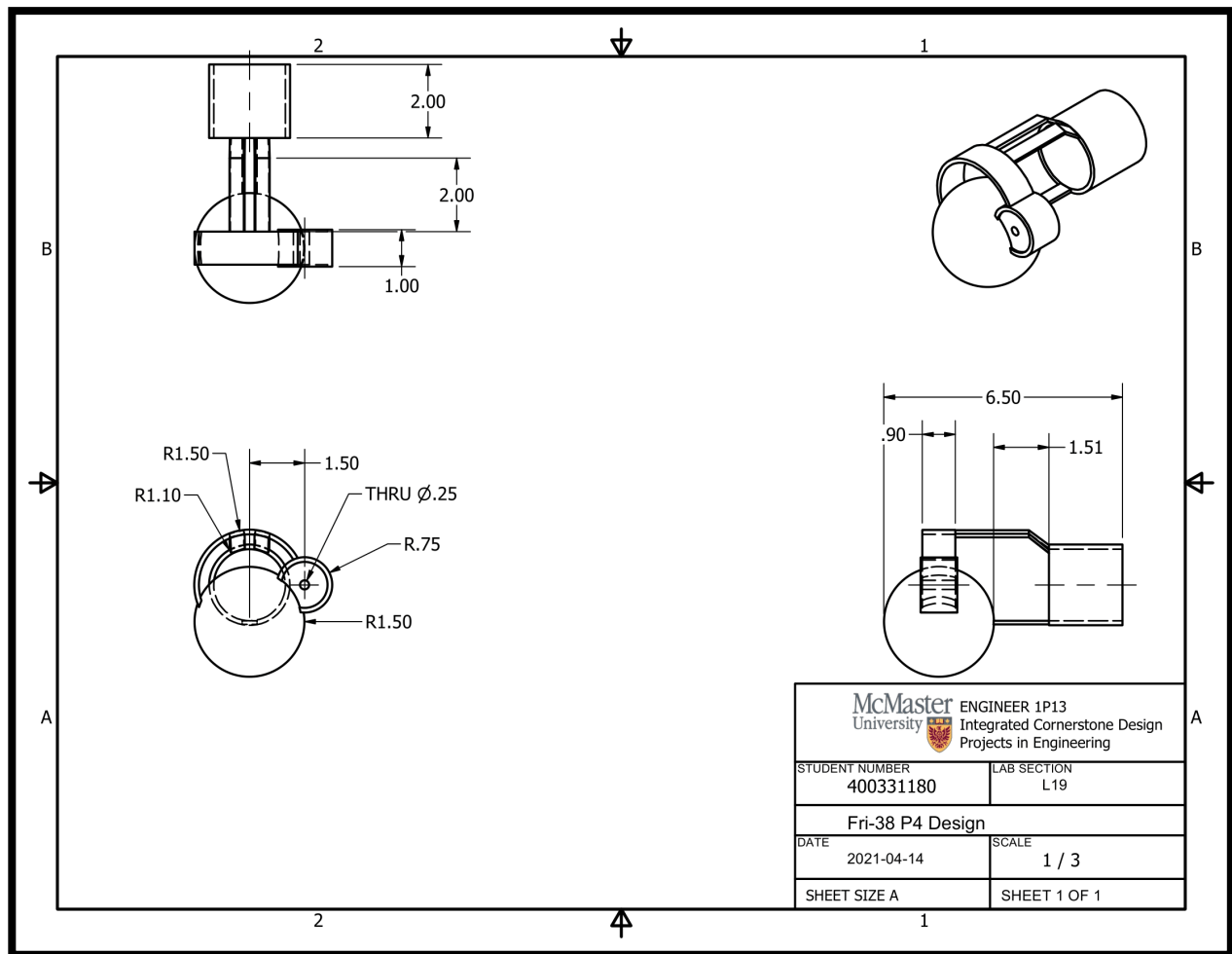


Figure 5. Dimensioned Engineering Drawing

Table 1. Bill of Materials

| Component | Material(s) | Quantity | Price | Approx. Cost |
|----------------------------|---|----------------------|--------------------------|--------------|
| Ball handle | Thermoplastic (synthetic rubber) [7] | 1 unit | \$9 | \$9 |
| Wrist Strap and Back Strap | Elastic [8] | 2 units | \$4 | \$8 |
| Connecting Straps | Velcro [9], Leather [10] | 2 units | \$6 | \$12 |
| Paintbrush Socket | Sponge [11], PVC coupling [12] | 1 coupling, 1 sponge | \$2 coupling, \$1 sponge | \$3 |

| | | | | |
|---------------------------|---------------|---------|-----|-----|
| Miscellaneous Material | Adhesive [13] | 2 units | \$5 | \$5 |
|---------------------------|---------------|---------|-----|-----|

Appendix D

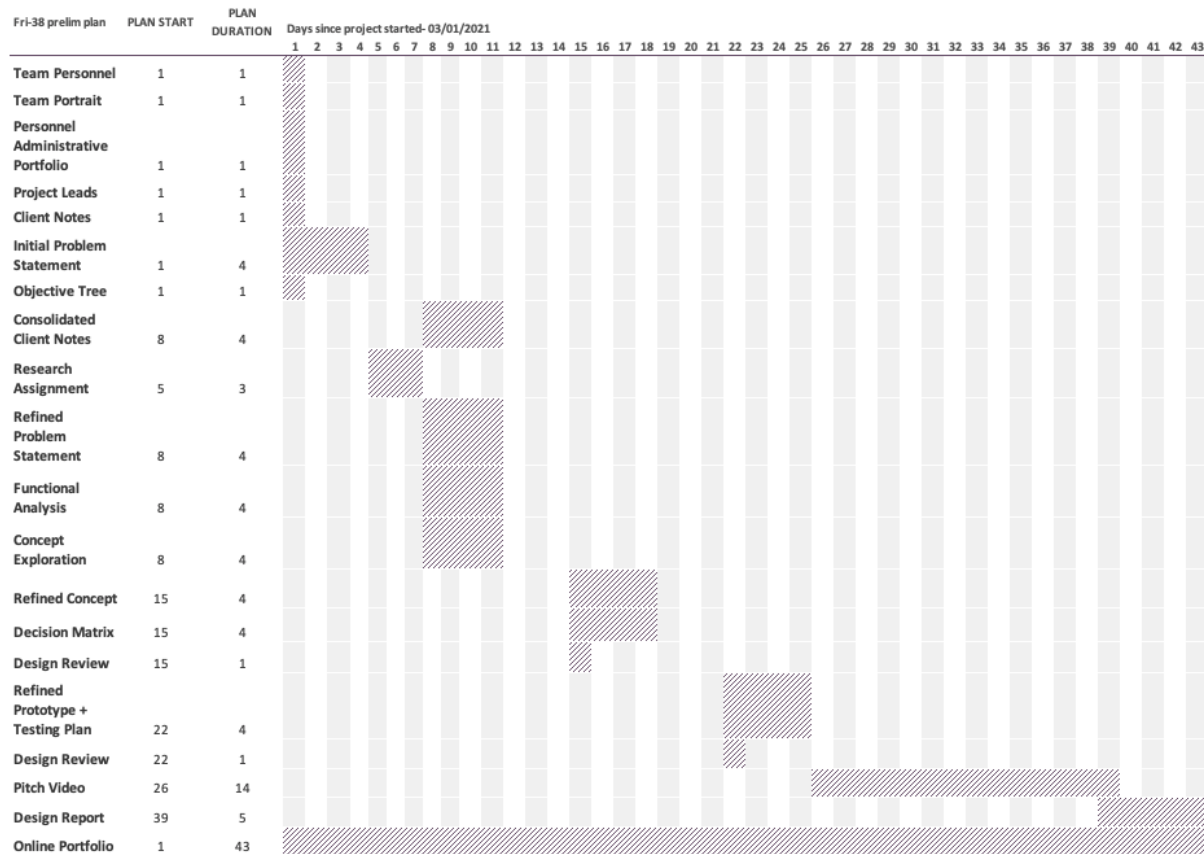


Figure 1. Preliminary Gantt Chart

Fri-38 Project 4 Final Gantt Chart

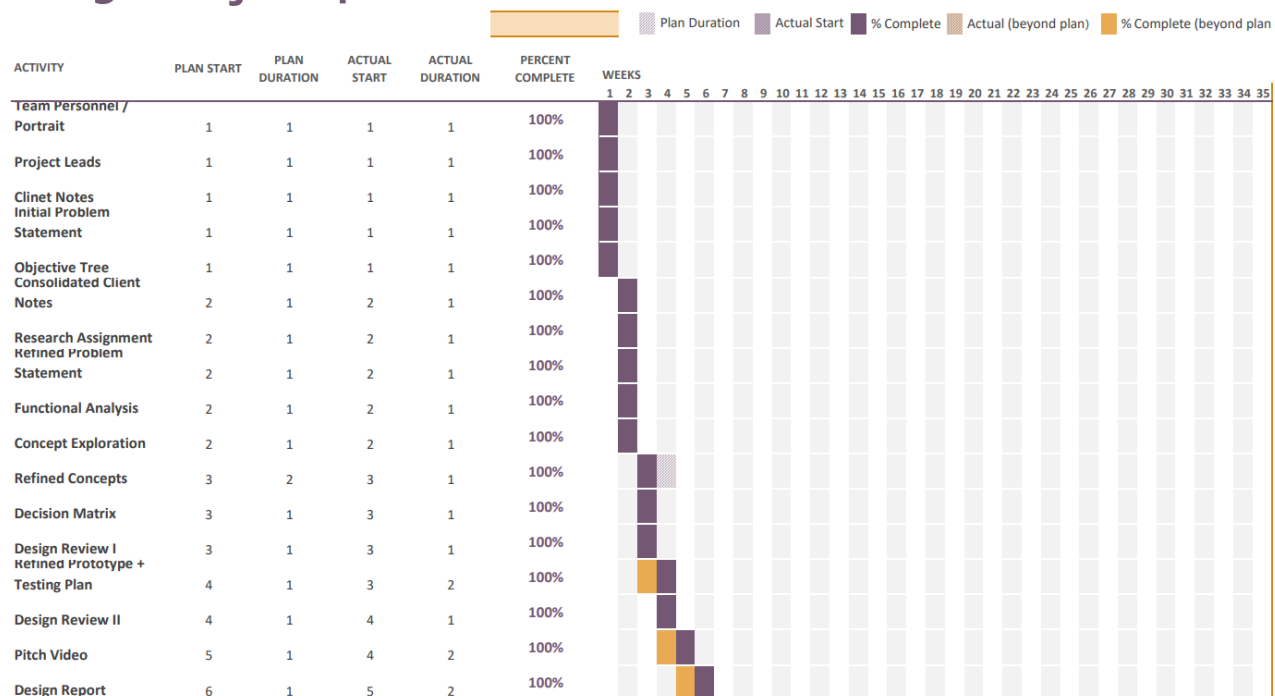


Figure 2. Final Gantt Chart

| Meeting No. | Meeting Date | Duration of meeting | Meeting Details |
|-------------|--------------|-----------------------|---|
| 1 | 18-03-2021 | 2 hours | Completed decision matrix and finalised our top two ideas |
| 2 | 19-03-2021 | 30 minutes | Discussion after design review and how can change our design |
| 3 | 25-03-2021 | 1 hour | Working further on the design |
| 4 | 26-03-2021 | 1 hour and 30 minutes | Incorporating further design review suggestions into our design |
| 5 | 08-04-2021 | 2 hours | Working on Final Prototype and Pitch video |
| 6 | 15-04-2021 | 4 hours | Working on Final Report |

Table 1. Logbook of Additional Meetings

Appendix E

| Source Materials Data Base | |
|--|---|
| <u>Milestone 1:</u> | |
| <ul style="list-style-type: none"> No sources used in Milestone 1 | |
| <u>Milestone 2:</u> | |
| [1] | CDC, “Fibromyalgia”, Arthritis [Online]. Available: https://www.cdc.gov/arthritis/basics/fibromyalgia.htm#:~:text=Fibromyalgia%20(fi%C2%B7bro%C2%B7my,often%20emotional%20and%20mental%20distress. [Accessed: March 7, 2021]. |
| [2] | Harvard Medical School, “The downside of taking pills to treat chronic pain”, Harvard Health Letter [Online]. Available: https://www.health.harvard.edu/pain/the-downside-of-taking-pills-to-treat-chronic-pain#:~:text=Prescription%20painkillers,-Opioid%20medications%2C%20such&text=They%20block%20messages%20of%20pain,%2C%20slowed%20breathing%2C%20and%20death. [Accessed: March 7, 2021]. |
| [3] | Zawn Villines, “How to relieve fibromyalgia pain”, Medical News Today [Online] Available: https://www.medicalnewstoday.com/articles/321534. [Accessed: March 7, 2021]. |
| [4]. | “The Benefits of Gardening for People with Disabilities - RISE Services Inc.” https://riseservicesinc.org/the-benefits-of-gardening-for-people-with-disabilities/ (accessed Mar. 11, 2021). |
| [5] | “Gardening with Disabilities Master Gardener Foundation of Grays Harbor and Pacific Counties.” https://pnwmg.org/garden-info/gardening-with-disabilities/ (accessed Mar. 11, 2021). |
| [6] | “Gardening for disabled people, Information for disabled gardeners, gardening tools for disabled people.” https://www.carryongardening.org.uk/top-tips-for-disabled-gardeners.aspx (accessed Mar. 11, 2021). |
| [7] | “Personal Stories - Canada Lymphedema Framework.” https://canadalymph.ca/personal-stories/ (accessed Mar. 8, 2021). |
| [8] | “Lymphedema&Exercise Breastcancer.org.” https://www.breastcancer.org/treatment/lymphedema/exercise (accessed Mar. 8, 2021). |
| [9] | M. R. Fu <i>et al.</i> , “Usability and feasibility of health IT interventions to enhance Self-Care for Lymphedema Symptom Management in breast cancer survivors,” <i>Internet Interventions</i> , vol. 5, pp. 56–64, Sep. 2016, doi: 10.1016/j.invent.2016.08.001. |

- [10] I. Strauch, D. F. Bruce, Q. Phillips, and K. Lee, "What Is Ankylosing Spondylitis? Statistics, Causes, Diagnosis, and More: Everyday Health," *EverydayHealth.com*. [Online]. Available: <https://www.everydayhealth.com/ankylosing-spondylitis/guide/>. [Accessed: 11-Mar-2021].
- [11] P. D. Ana Pena, "Spinal Mobility Problems Common, and Worsen Over Time, Swedish....," *Ankylosing Spondylitis News*, 06-Jun-2019. [Online]. Available: <https://ankylosingspondylitisnews.com/2019/06/06/spinal-mobility-problems-common-worsen-over-time-as-swedish-study-shows/>. [Accessed: 12-Mar-2021].
- [12] Ankylosing spondylitis," *Mayo Clinic*, 08-Nov-2019. [Online]. Available: <https://www.mayoclinic.org/diseases-conditions/ankylosing-spondylitis/symptoms-causes/syc-20354808>. [Accessed: 12-Mar-2021].
- [13] Ankylosing Spondylitis. [Online]. Available: <https://www.arthritis.org/diseases/ankylosing-spondylitis> [Accessed: 13-Mar-2021].
- [14] L. Gelman, D. Kemp, M. Wood, C. Maldonado, L. Green, R. Bawa, Ester, L. Mendez, Amy, V. Swales, Linda, and Sharon, "Common Ankylosing Spondylitis Signs and Symptoms," *CreakyJoints*, 12-Jul-2019. [Online]. Available: <https://creakyjoints.org/symptoms/ankylosing-spondylitis-symptoms/>. [Accessed: 13-Mar-2021].

Milestone 3:

- No sources used in Milestone 3

Milestone 4:

- No sources used in Milestone 4

Final Presentation:

- [1] "PurAthletics Hand Therapy Ball - WTE10303 at Walmart.ca | Walmart Canada." <https://www.walmart.ca/en/ip/purathletics-hand-therapy-ball-wte10303/6000084458101> (accessed Apr. 07, 2021).
- [2] "Nike Swoosh Wristbands | Sport Chek." https://www.sportchek.ca/product/nike-swoosh-wristbands-331232492.html?gclid=CjwKCAjw07qDBhBxEiwA6pPbHg3COV4y4oydyhzi8QdTsmKvxKuHkAapWzBahrFfdzOy5QLCzNljYhoC_yAQAvD_BwE&gclsrc=aw.ds#331232492=331232496 (accessed Apr. 07, 2021).
- [3] "VELCRO® Brand Heavy Duty Industrial Strength, 2 Sets | Walmart Canada." <https://www.walmart.ca/en/ip/velcro-brand-heavy-duty-industrial-strength-2-sets-white/6000114809865> (accessed Apr. 07, 2021).

- [4] “Leather Side Piece Veg Tan Split Medium Weight 12 X 12 Inches 1 Square Foot: Amazon.ca: Home & Kitchen.” <https://www.amazon.ca/Leather-Medium-Weight-Inches-Square/dp/B0045RTID4> (accessed Apr. 07, 2021).
- [5] “IPEX HomeRite Products PVC 1/2 inches x 10 ft SCHEDULE 40 PLAIN END PIPE | The Home Depot Canada.” <https://www.homedepot.ca/product/ipex-homerite-products-pvc-1-2-inches-x-10-ft-schedule-40-plain-end-pipe/1000100828> (accessed Apr. 07, 2021).
- [6] “Scotch-Brite® Heavy Duty Scrub Sponge | Walmart Canada.” <https://www.walmart.ca/en/ip/scotch-brite-heavy-duty-scrub-sponge/6000077045557> (accessed Apr. 07, 2021).
- [7] “Gorilla 2-3 g Super Glue Tubes | Walmart Canada.” <https://www.walmart.ca/en/ip/gorilla-2-3-g-super-glue-tubes-clear/6000196136769> (accessed Apr. 07, 2021).

Final Project Report:

- [1] “Gardening for disabled people, information for disabled gardeners, gardening tools for disabled people.” <https://www.carryongardening.org.uk/top-tips-for-disabled-gardeners.aspx> (accessed Mar. 11, 2021).
- [2] “Lymphedema&Exercise|Breastcancer.org.” <https://www.breastcancer.org/treatment/lymphedema/exercise> (accessed Mar. 8, 2021).
- [3] “Personal Stories - Canada Lymphedema Framework.” <https://canadalymph.ca/personal-stories/> (accessed Mar. 8, 2021).
- [4] CDC, “Fibromyalgia”, Arthritis [Online]. Available: [https://www.cdc.gov/arthritis/basics/fibromyalgia.htm#:~:text=Fibromyalgia%20\(fi%C2%B7bro%C2%B7my,often%20emotional%20and%20mental%20distress](https://www.cdc.gov/arthritis/basics/fibromyalgia.htm#:~:text=Fibromyalgia%20(fi%C2%B7bro%C2%B7my,often%20emotional%20and%20mental%20distress). [Accessed: March 7, 2021].
- [5] “Amazon.com: Secure Stress Balls on a String - for Stress Relief, Hand Exercise, Strengthening, Rehabilitation - Medium Stress Balls - No Falling or Rolling Away (12 Single Medium Squeeze Balls): Sports & Outdoors.” <https://www.amazon.com/StringyBall-Stress-Ball-String-Rehabilitation/dp/B07CP63TF4> (accessed Apr. 12, 2021).
- [6] “US9021662B1 - Paint can handle - Google Patents.” <https://patents.google.com/patent/US9021662B1/en?q=paint+brush+wrist+strap&oq=paint+brush+wit+h+wrist+strap> (accessed Apr. 12, 2021).
- [7] “PurAthletics Hand Therapy Ball - WTE10303 at Walmart.ca | Walmart Canada.” <https://www.walmart.ca/en/ip/purathletics-hand-therapy-ball-wte10303/6000084458101> (accessed Apr. 07, 2021).
- [8] “Nike Swoosh Wristbands | Sport Chek.” <https://www.sportchek.ca/product/nike-swoosh-wristbands-331232492.html?gclid=CjwKCAjw07qDBhBxEiwA6pPbHg3COV4y4oydyhzi8QdTSmKvxKuHkAap>

WzBahrFfdzOy5QLCzNljYhoC_yAQAvD_BwE&gclid=aw.ds#331232492=331232496 (accessed Apr. 07, 2021).

- [9] “VELCRO® Brand Heavy Duty Industrial Strength, 2 Sets | Walmart Canada.” <https://www.walmart.ca/en/ip/velcro-brand-heavy-duty-industrial-strength-2-sets-white/6000114809865> (accessed Apr. 07, 2021).
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- [13] “Gorilla 2-3 g Super Glue Tubes | Walmart Canada.” <https://www.walmart.ca/en/ip/gorilla-2-3-g-super-glue-tubes-clear/6000196136769> (accessed Apr. 07, 2021).